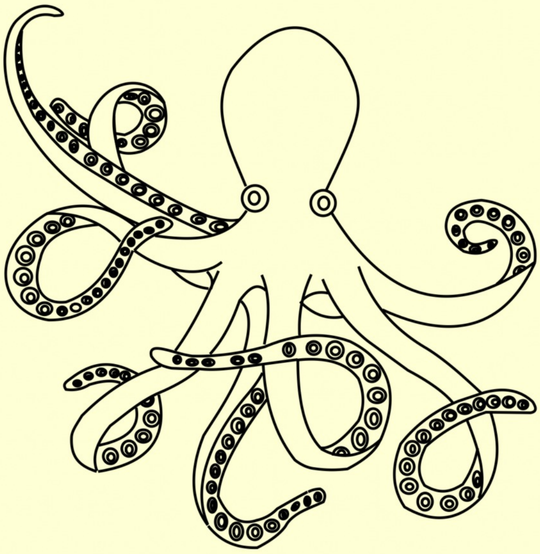

Diving & ROV specialists

Surface-Supplied Diving Handbook Series

Book #6

Prepare and manage the dives

June 2025

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This document is the sixth of eight books in the "Surface-Supplied Diving Handbooks Series", described below.

Book 1: Overview of surface-supplied diving operations and scope of this series
Book 2: Description and prevention of accidents associated to diving operations
Book 3: Legal aspects of project preparation
Book 4: Description and maintenance of surface supplied diving systems
Book 5: Managing Weather, Communications, Surface Supports & Underwater Vehicles
Book 6: Prepare and manage the dives
Book 7: Implement the MT 92 tables
Book 8: Implement the DCIEM tables

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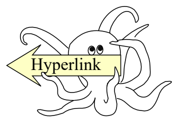

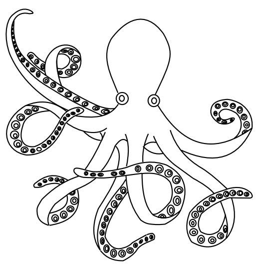

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1 - Gas management

1.1 - Gas transfer, and quality of gasses delivered

1.1.1 - Purpose

Gas transfer operations consist of connecting hoses and transferring gas from one gas container to another, or to a part of the diving system. If they are performed without precautions, these operations can cause injuries and fatalities such as:

- People injured or killed by an explosion or a fire due to oxygen quads improperly stored or operated, or the explosion of a gas container overfilled or not adequately maintained.
- People injured by the whipping of an unsecured open-ended hose under pressure.
- Personnel affected by blindness or deafness due to blast of high-pressure gas.
- Personnel affected by the loss of hearing due to regular exposure to the noise of venting gas.
- Divers affected, or killed by a wrong gas online.

Gas quality is also an important aspect, as suppliers' gasses may be polluted by other components, which may result in injuries to the respiratory system of the divers, loss of consciousness, and possibly death. For this reason, the gasses delivered to the system must be closely checked. Also, the gas quality may degrade due to improper maintenance of the system, pollutants introduced in it, the respiration and wastes of the divers, and if the filters and absorbents not changed on time.

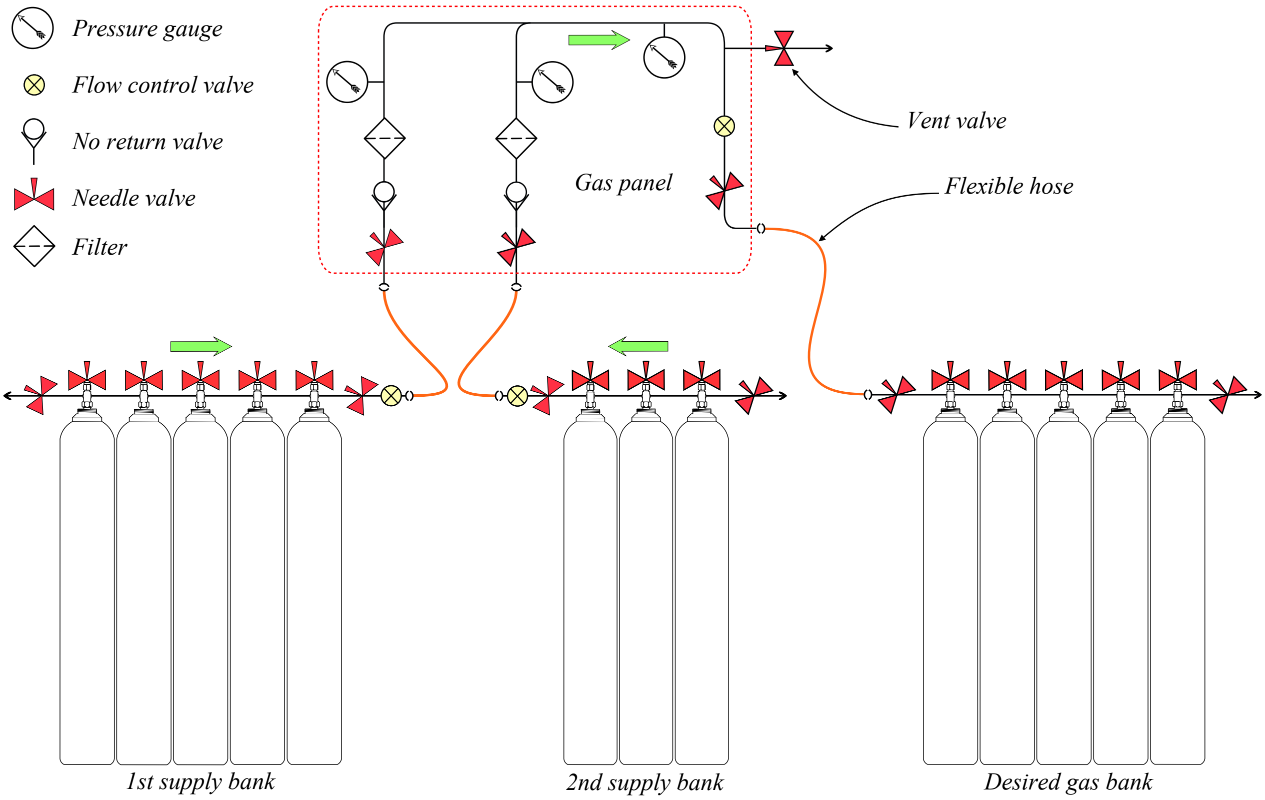
For these reasons, only personnel nominated should handle gas, and step by step procedures should be in place and followed at all times.

1.1.2 - Methods used for gas transfer, and precautions to be in place

Gas transfer operations are usually performed through flexible hoses. Two main methods are employed: Cascade and pumping.

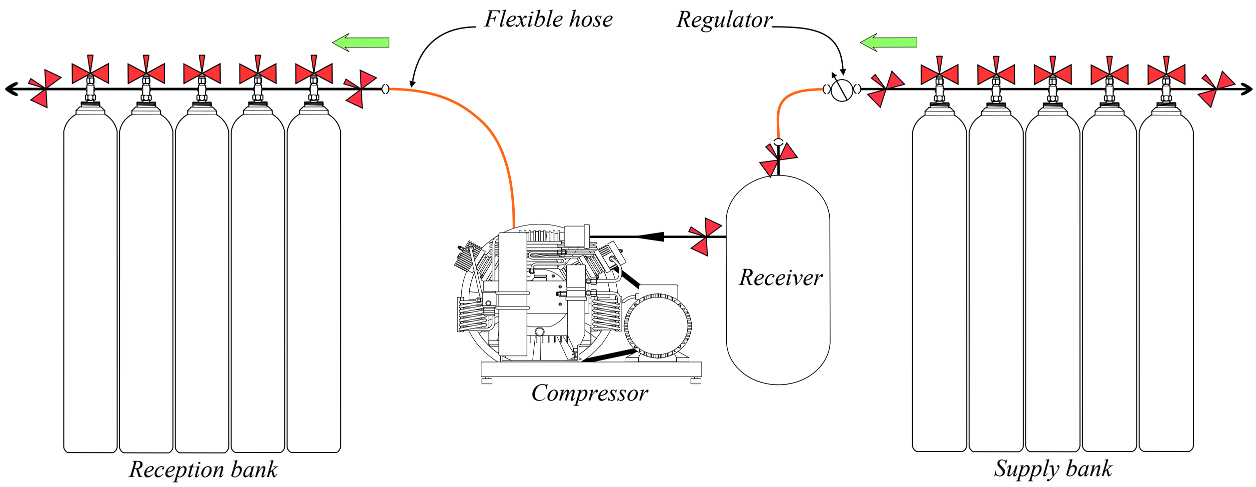
1.1.2.1 - Cascade filling

Cascade filling (also called decanting) is a procedure used to transfer compressed gas between storage cylinders or tubes by pressure difference from the more pressurized container to the less pressurized one.
This procedure, which IMCA recommends for the transfer of oxygen and high O2 percentage heliox mix offshore, has the inconvenience that the gas to transfer must always be at a higher pressure than the desired mix. The flow rate should be limited to 5 bar (70 psi) per minute to avoid igniting the rich mixture during the operation.



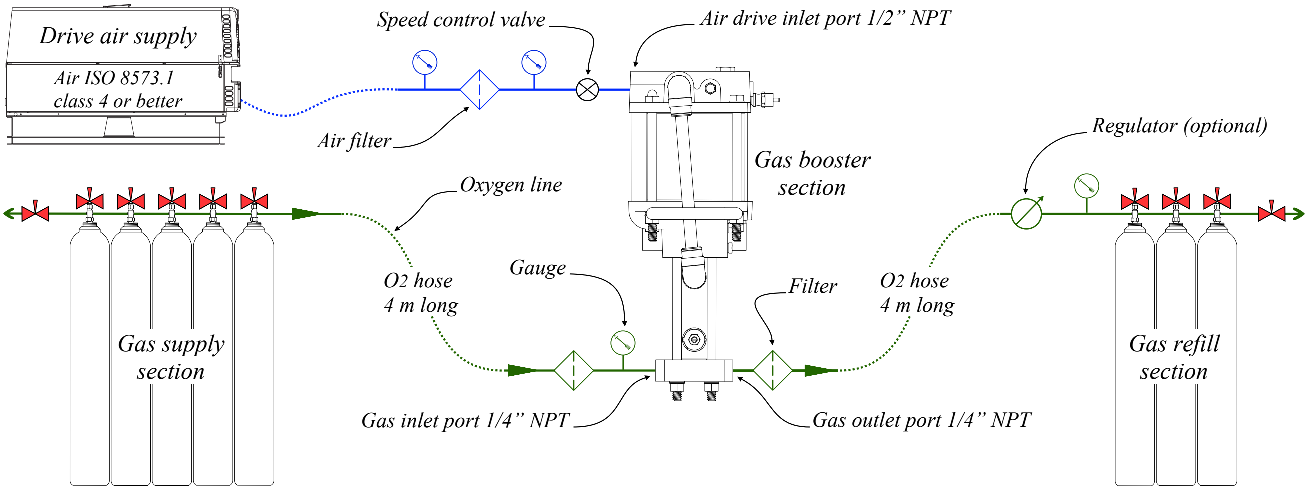
1.1.2.2 - Gas pumping

Pumping is used for transferring gas from quads or banks to other quads or banks and compensate for the inconveniences of cascade filling. It can be done using the piston compressors described in point 2.12.1 for gasses with less than 21% O2, and specific piston & membrane compressors such are those described in points 2.12.3 , 2.13, & 2.14 for mixes with more than 21% oxygen. With this method, the pressure of the gas to transfer from the quads or the tubes must be regulated down to the recommended inlet pressure of the compressor, which is usually a pressure inferior or equal to 8 bar. It is usually done through regulators that are installed before the compressor. The pressure inlet of the compressor can also be the pressure of the outlet of the nitrox or oxygen fabrication machine as indicated in points



A gas receiver is usually installed upstream the compressor inlet to reduce the pressure delivered by the gas cylinders to the recommended inlet pressure of the compressor and absorb the variations of pressure. Another procedure is to reduce the pressure of the gas to be transferred in a sealed gas bag, such as those used with reclaim systems.

Gas boosters such as Haskel pumps, which are described in point 2.12.5, are another system commonly use to transfer gasses. As a reminder, Haskel pumps are powered by compressed air provided by an industrial compressor or any compatible source. The compressed air moves a large piston that moves a smaller piston that compresses the gas to transfer in a separate cylinder. As explained before, such pumps are often used for oxygen transfer.



1.1.2.3 - Precautions for gas transfer

Gas transfer is usually performed in dedicated places that are accessible to only the appointed personnel. However, it often happens that these operations are performed in areas of the ship or the installation that are not dedicated to this purpose. It is the case when receiving new gas containers on deck and transferring their content to the system. It is also the case when verifying or blending gasses in temporary storage areas. In such cases, a work permit is usually needed for these activities. Also, for every gas transfer operation, the following precautions should be in place:

- The operator wears clean Personal Protective Equipment. It should be fireproof in case of oxygen transfer.
- A precise task plan that indicates the gas to transfer, where it will be stored and the means of transfer to be used must be provided to the operator. This task plan is confirmed by the diving supervisor or the appointed gas man before connecting hoses and operating the relevant valves. Note that gasses should not be put inline on the system as long as there is no confirmation of the person in charge.
- As already said, the gas to transfer must be analysed to ensure that it is the mix planned.
- Before connecting each hose, the operator must ensure that it is designed for the task (Its maximum safe working pressure should be visible, in addition to the gas it is designed for). He also ensures that the hose is of the recommended length, in perfect condition, and its fittings of the correct model. In addition, the container where the gas is transferred must be in optimal condition and designed to withstand the pressure it receives.
- Before being put under pressure, the hoses' end connections must be fastened to strong fixed points with ropes or whip checks to prevent whipping in the event of a fitting failure.
- Hoses should be routed so that they cannot cause injuries to personnel working at proximity in case of rupture. IMCA says that they should be fastened to supports every two metres. However, that would not stop them from whipping in the case of a rupture. For this reason, it is better to hold them at intervals less than 1 metre. The best policy is to secure them every 20 cm along ropes that can maintain them in one piece if they become cut.
- Valves for gas distribution are usually needle valves. They should be opened slowly at arm’s length so the operator is away from them. When the valve is fully open, the operator returns half a turn. That leaves the valve handle free to move and avoids blocking it in the open position. A small panel indicating that it is open should be installed on the opened valve.
- If the gasses connected are planned to be put online in the dive control, in addition to the analysis previously performed by the gasman before connecting the hose, the gasses must also be analyzed on the control panel before opening the final valves. Oxygen analysers with audio hi-lo alarms must always be online for each supply line. Also, remember that mixes with more that 22% oxygen must be regulated to 40 bar at the source.
- Note that every hose carrying gas to and from the dive control or the chamber control must be considered a “life line”.
- When the gas transfer is completed, the operator ensures not to over-tight the valves in the closed position, which may damage the seats and may result that the valve may be difficult to reopen. A needle valve should close with two fingers. If it is not the case, it must be changed or repaired.
- When venting gas, the operator should wear ear defenders to prevent long term damage to hearing.
- When simultaneous air or surface gas operations are performed, the gasses used for these activities must be separated from those used for saturation diving. As for saturation diving, the diving supervisor in charge of these operations must analyze the gasses planned to be online.

Low-Pressure (LP) gasses can be transferred or used to energize some diving system components, such as Haskel pumps. It must be remembered that Low-Pressure gas may have the same capacity to injure as High-Pressure gas, depending on the pressure, the size of the hose, and the volume of gas flowing through it. For this reason, it should not be underestimated and handled as High-Pressure gas.

1.1.2.4 - Additional precautions for oxygen transfer

Pure oxygen and gas mixes containing over 22% oxygen, have the potential to generate a serious fire or explosion, as almost all materials can ignite and rapidly burn in high-pressure oxygen.
As an example, when a supply valve is opened too quickly, the oxygen that flows from high to low pressure through an orifice reaches sonic velocity and compresses the oxygen downstream against an obstruction, such as the seat of the next closed valve or regulator. The gas temperature can reach the auto-ignition point of plastics, organic contaminants, and metals. The following values from the American Society for Testing and Materials (ASTM), demonstrate that, depending on the pressure ratios, materials submitted to an immediate rise of pressure can be destroyed:

Initial pressure	***Initial temperature***	***Final pressure***	***Pressure ratio Pf/Pi***	***Final temperature***	***Comments***
1.013 bar	20 Cº	34.47 bar	34	530 Cº	Final temperature above auto-ignition temperatures of non-metallic materials
1.013 bar	20 Cº	137.9 bar	136.1	920 Cº	Final temperature above the melting temperature of brass (900 Cº)
1.013 bar	20 Cº	275.79 bar	272.1	1181 Cº	Final temperature above the melting temperature of bronze (1020 Cº)

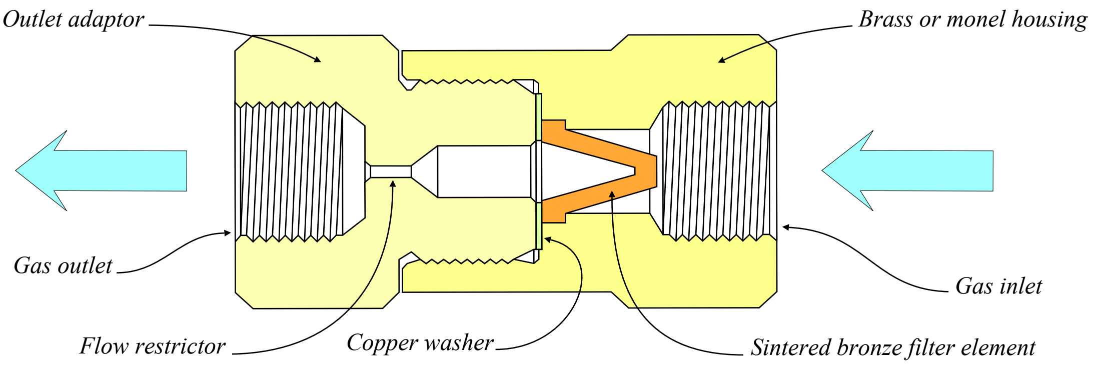
Note that fire ignition can also be the result of small particles carried by the flowing gas in the oxygen system that strike the surfaces of the system, such as piping intersections or valve seats, and creates heat at the point of impact.

To avoid such a problem the following procedures should be implemented:

- Any gas mixture containing more than 25% oxygen by volume should be handled like pure oxygen (Note that NORSOK standards U-100 consider gasses with more than 22 % as pure oxygen).
- Flexible hose should be kept to a minimum in oxygen systems and rigid pipework should be used as much as possible. Note that Haskel recommends flexible hoses of 4 m maximum.
- The oxygen circuit should be designed for oxygen, and checked compatible by a competent person according to the following guidelines or similar recommendations, but not limited to:
  - ASTM - G128 “Standard guide for control of hazards and risks in oxygen enriched systems”
  - ASTM - G88 “Standard guide for designing systems for oxygen service”
  - ASTM - G63 “Standard guide for evaluating nonmetallic materials for oxygen service”
  - ASTM - G94 “Standard guide for evaluating metals for oxygen service”
- Stainless steel pipe or fittings should not be used, or be oxygen compatible in accordance with the guidelines from ASTM - G94 “Standard Guide for Evaluating Metals for Oxygen Service”, and ASTM “Safe use of Oxygen and Oxygen systems”.
- Quarter turn valves are designed to allow a quick opening, which can create a condition for ignition of the oxygen, and thus, should not be used with pressures above 15 bar (8.6 bar with OSHA 29 CFR1910.430). For this reason, only needle valves should be employed with pressures above 15 bar. Note that ASTM recommends valves with a non-rotating stem. However, it is admitted that quarter-turn valves are in-line as emergency shut off valves. When used, they should be labeled as such and lightly taped open to prevent routine use.
- Also, when preparing the transfer line, sharp bends and numerous piping intersections should be avoided for the reasons highlighted above.
- The hoses should be labelled with their purpose in addition to the identification numbers. As for every hose dedicated for gas transfer, their maximum safe working pressure should be visible.
- All pipework, hoses, valves and other fittings used in the oxygen system must be cleaned for oxygen service. This topic is discussed in point 1.11.4 of this book.
- Using sealants is a standard procedure to reduce the risks of leaks at the connections. However, only oxygen compatible thread seal tape or oxygen compatible liquid sealants should be employed. The table below gives some recommendations regarding the selection of these materials.

Thread compound	Auto ignition temperature C°	Description
PTFE pipe tape *(Teflon tape)*	420 to 427	Polytetrafluoroethylene (PTFE) film, also called Teflon tape, can be used for sealing conic valve stem threads. Note that manufacturers use a colour code (white all industrial application, green Oxygen applications). When burning, PTFE pipe thread can emit toxic gases such as fluorocarbon alkene, and fluoride. Inhalation of gases from burning may result in irritation, irregular heartbeat, symptoms of drunkenness, suffocation, lung congestion. Long Term Exposure may result in kidney and liver damage. Threshold limit value of fluoride is 3 mg/m³
Epoxy cement	210 to 230	Epoxy cement are resins that can be used to seal and lock threads. Inhalation of gases from burning may cause allergy or asthma symptoms or respiratory difficulties if inhaled. Exposure to is limited to 150 mg/m³
Polyester thread sealant	140 to 150	Polyester sealant are very adhesive resins. However, their performances with oxygen are limited and they are not recommended for this purpose. Inhalation of gases from burning may result in cough, sneezing, nasal discharge, headache, hoarseness, and nose and throat pain. The threshold limit value of some gases they may emit is 5 mg/m³

- Flow restrictors, such as in the drawing below, which is based on a model from Oxycheck, should be installed at the source to prevent rapid pressurization and so adiabatic compression of the oxygen in the system. Note that such devices are recommended by the US Navy.



- In addition to the “flow restrictor”, a flow control valve should be used to ensure a precise fill rate and avoid ignition. Note that suitable “flow control valves” are proposed by several manufacturers, and that the valve of the gas container is not a real flow control valve.
- Oxygen and gas mixes containing more than 25% oxygen should be stored in a safe area on deck, or in a very well ventilated protected area, as a fire or an explosion could arise from oxygen leakages in a confined space.
- Greases, oil, and other materials which could ignite with oxygen should not be stored in the vicinity of oxygen and spare parts for oxygen service. Regular housekeeping should be carried out to ensure that the storage areas are clean. Also, tools with naked flame or emitting sparks should not be used in the proximity where oxygen is stored and transferred. Firefighting means must be provided and be ready for immediate use.
  Of course, the transfer of oxygen is to be performed only in such areas, or areas that are prepared accordingly
- In addition to the elements indicated above, the following precautions should be taken when handling oxygen:
  - The operator must ensure that the fittings are clean, so he should not touch the surfaces exposed to oxygen with dirty hands or contaminated objects.
  - It is common to open and closes a valve rapidly to remove particles of dirt before connecting a hose to air quads and cylinders. This procedure must not be used with oxygen as it can cause ignition. If cleaning is necessary, it is recommended to clean the valve with a suitable material and cleaning agent.
  - The first cylinder is to be opened slowly with the technician standing to the side of the quad and wait for the pressure to equalize slowly in the manifold. Then, he slowly opens the remaining cylinders to be opened. The same procedure is applied to fill the flexible hose connected to the gas container to fill and the control panel.
  - IMCA D 022 recommends that oxygen used for gas mixing is not pumped and slowly transferred by decanting at the lowest possible pressure. For this reason, oxygen is usually transferred first. The US Navy manual recommends nitrox and oxygen maximum fill rates of 5 bar (70 psi) per minute.
  - Vented oxygen can accumulate in clothing. For this reason, the operator should not smoke or go near someone who is smoking or near any naked flame immediately after completing oxygen transfer to avoid having his clothes ignite.

Note that when oxygen or mixes with 25% of O2 (22 % with NORSOK and European standards) are to be put online to supply several parts of the saturation system, the pressure must be reduced at the source to a maximum of 40 bar. Note that the regulator should be fitted with a filter that must be in good condition (generally it is a porous bronze filter): The function of this filter is to stop the impurities which may come from the cylinders or have been introduced in the circuit.

1.1.3 - Verification of the gasses delivered to the ship

1.1.3.1 - Condition of the gas containers delivered

Gasses are usually delivered in Multiple Elements Gas Containers (MEGCs) that should be checked for conformity before being transferred on-board the vessel.
In case suspicious points are detected on one or more gas containers, the units affected should not be accepted. For this reason, the person in charge should focus on the following:

- The cylinders and their piping should not be corroded, and a certificate of examination should be available in addition to the legal markings on their shoulders. Although full internal and external inspection of cylinders is performed every two years, corrosion can set up if the container is exposed to harsh conditions and not correctly maintained during the interval between these examinations, despite the six-monthly visual inspections. For these reasons, considering that it is impossible for the Life Surface Technician (LST) in charge of the reception to investigate the extent of a defect, the precaution principle should prevail, and he should reject every gas container that presents the following visible defaults:
  - Surface corrosion covering more than 20% of the external surface of the gas container
  - Local corrosion that seems affecting the wall thickness.
  - Corrosion forming a narrow longitudinal or circumferential line or strip, or isolated craters, or pits which are almost connected.
  - Corrosion forming isolated craters, or pits without significant alignment, but may affect the wall thickness.
  - Corrosion taking place in, or immediately around an aperture.
  - Visible deformation of the shapes such as swellings, depression.
  - Cuts and cracks on the body or around the neck.

  Note that the inspection of cylinders is explained in the diving study CCO ltd “Organize the maintenance of diving cylinders” (page 66) that can be downloaded for free at this address: http://www.ccoltd.co.th/index-b.htm
- Multiple gas container frames should be without corrosion, defects, or shocks that may affect their integrity. If corrosion is present, similar requirements as above should be used to evaluate the extent of the damages. The safe working load and manufacturing identification plate in conformity with the International Convention for Safe Containers (CSC) should be visible. Also, the lifting pad-eyes should conform to the specifications described in point 2.11.4. When the gas containers are fitted with lifting rigging, the relevant certificates must be provided.
- The valves should be easy to open and close, and the connectors should conform to those available onboard. Note that there are infinities of models of valve outlet connectors for gas cylinders and tubes, which usually are not compatible with each other, as a lot of countries continue using their national standards. This point is also explained in point 2.11.4. “Storage and distribution of the gasses” of this book.
- The pressure test and certifications should conform to what is also indicated in point 2.11.6 “maintenance” of the chapter “Gas storage and distribution”, which are based on IMCA D 018.
- The colour code and labelling should conform to what is indicated in point 2.11.3 “Identification of gasses in containers” of the chapter “Gas storage and distribution”.

1.1.3.2 - Verification of the contents of the gas containers delivered

Each breathing gas reservoir should be accompanied by an analysis certificate, that describes the gas it contains and the standards used for the analysis.
As already said, the gas of each container must be analysed for conformity before being transferred to the gas storage of the diving system.

The analysis of the gasses delivered is usually performed using portable analysers. The sampling of the gasses is done using a rubber bladder that is filled on each cylinder and then emptied through the analyser using an appropriate flow restrictor, or a regulator with a flow restrictor that optimise the gas flow for accurate sampling. The flow restrictor should be associated with a flow meter, which is a visual indicator of the flow rate that can be adjusted for a reliable pressure delivery to the gas sensors. Note that exposing analyser sensors to high flow and pressure would damage them.

The team in charge of the analysis should focus on the conformance of the content of the gas container with the gas analysis sheet attached to it. Note that the proportion of oxygen indicated in this document should comply with what is stated on the gas container (painted values on the cylinder or the frame).
The gas delivered should conform to a recognized standard of breathing gas purity. Such a standard may vary from one country to another. Nevertheless, international standards like the European Norm EN 12021, displayed on the next page, are adopted by professional and national organizations such as IMCA, NORSOK, and the official safety organizations of a lot of countries.
It must be considered that among the other national standards of breathing gas available, the US navy specifications of oxygen *(Military Specification MIL-PRF-27210G)*, are in force in some countries. Note that the US Navy manual does not provide specifications for heliox.
Also, nitrox mixes are usually made onboard the vessel by enriching compressed air with medical oxygen. In this case, the gasman should indicate the oxygen percentage on the cylinder and issue a document that states the nature of the gas, when it has been fabricated,and analysed, and by whom.

The tables below shows the requirements EN 12021 regarding the composition of compressed standard natural air.

EN 1221: Composition of breathing air

Component	*Concentration at 1 013 mbar and 20 °C*
Oxygen	21% (± 1%)
Carbon dioxide	≤ 500 ml m³ (ppm)
Carbon monoxide	≤ 5 ml m³ (ppm)
Oil	≤ 0,5 mg m³

Compressed breathing air must have a dew point sufficiently low to prevent condensation and freezing.

- *Where the apparatus is used and stored at a known temperature the pressure dew point should be at least 5 °C below the likely lowest temperature.*
- *Where the conditions of usage and storage of any compressed air supply is not known the pressure dew point must not exceed −11 °C.*

EN 1221: Water content of high pressure breathing air

Nominal maximum supply pressure in bar	*Maximum water content of air at atmospheric pressure and 20 °C mg m³*
40 to 200	≤ 50
> 200	≤ 35

EN 1221: Water content for supplied breathing air up to 40 bar

Nominal maximum supply pressure in bar	*Maximum water content of air at atmospheric pressure and 20 °C mg m³*
5	290
10	160
15	110
20	80
25	65
30	55
40	50

The table below shows the requirements EN 12021 regarding the composition of compressed oxygen compatible air.

EN 1221: Composition of oxygen compatible air

Component	*Concentration at 1 013 mbar and 20 °C*
Oxygen	21% (± 1%)
Water	≤ 25 mg m³
Carbon dioxide	≤ 500 ml m³ (ppm)
Carbon monoxide	≤ 5 ml m³ (ppm)
Oil	≤ 0,1 mg m³

The table below shows the requirements EN 12021 applicable for oxygen and nitrox mixes made with this oxygen and natural air. Note that this standard EN 12021 applies for depleted air and oxygen enriched air.

EN 1221: Composition of nitrogen depleted air and oxygen enriched air

Component	***Concentration at 1 013 mbar and 20 °C***
Oxygen	% as stated by the supplier ($\pm$ 1%)
Water	$\leq$ 25 mg m^3
Carbon dioxide	$\leq$ 500 ml m^3 (ppm)
Carbon monoxide	$\leq$ 5 ml m^3 (ppm)
Oil	$\leq$ 0,1 mg m^3

EN 1221: Composition of breathing oxygen

Component	***Concentration at 1 013 mbar and 20 °C***
Oxygen	> 99.5 %
Water	$\leq$ 15 mg m^3
Carbon dioxide	$\leq$ 5 ml m^3 (ppm)
Carbon monoxide	$\leq$ 1 ml m^3 (ppm)
Oil	$\leq$ 0,1 mg m^3
Total volatile non-substituted hydrocarbons (vapour or gas) as methane equivalent	$\leq$ 30 ml m^3 (ppm)
Total chlorofluorocarbons and halogenated hydrocarbons	$\leq$ 2 ml m^3 −3 (ppm)
Other non-toxic gases such as argon and all other noble gases	< 0,5 %

Air and nitrox can be fabricated using industrial nitrogen and oxygen. These gasses are usually called "synthetic air or Synthetic nitrox. The table below shows the requirements of EN 12021 regarding such gasses.

EN 1221: Composition of oxygen and nitrogen gas mixture

Component	***Concentration at 1 013 mbar and 20 °C***
Oxygen < 20 % by volume Oxygen $\geq$ 20 % by volume	Stated[a] $\pm$ 0.5 %* Stated[a] $\pm$ 1.0 %*
Nitrogen	Remainder
Water	$\leq$ 15 mg m^3
Carbon dioxide	$\leq$ 5 ml m^3 (ppm)
Carbon monoxide	$\leq$ 3 ml m^3 (ppm)
Oil	$\leq$ 0,1 mg m^3
Total volatile non-substituted hydrocarbons (vapour or gas) as methane equivalent	$\leq$ 30 ml m^3 (ppm)
Other non-toxic gases	< 1%
[a] Percentage as stated by the supplier. * Tolerance value is a percentage of the total gas mixture.	

En 1221 does not provide table for pure nitrogen. However, we can consider that the maximum levels of pollutants for nitrogen should be the same as those indicated in the table above.

As said previously, US Navy gas purity standards are in force in several countries, and It may happen that for logistical reasons, the gasses have to be renewed in such countries. For this reason, they cannot be ignored.

US Navy: Gaseous oxygen

Component	***Specification***
Oxygen	> 99.5 %
Carbon dioxide (by volume)	10 ppm *(max)*
Methane (CH4 by volume)	50 ppm *(max)*
Ethylene (C2H4)	0.4 ppm *(max)*
Ethane (C2H6 and other hydrocarbons)	6 ppm *(max)*
Nitrous Oxide (N2O by volume)	6 ppm *(max)*
Halogenated Compounds: Refrigerants	2 ppm *(max)*
Halogenated Compounds: Solvents	0.2 ppm *(max)*
Moisture (at dew point)	7 ppm , < -82 Fº *(max)*
Odor	Odor free *(max)*

US Navy: Breathing air

Component	***Specification***
Oxygen	20 - 22 %
Carbon Dioxide (ppm)	1,000 ppm (max)
Carbon Monoxide (ppm)	10 ppm (max)
Odor and taste	Not objectionable
Water (Notes 1,2) by dew point (degrees F at 1 ATM ABS) or by moisture content (ppm or mg/L)	-65°F 24 ppm or .019 mg/L (max)
Total Volatile Organic Compounds (in methane equivalents), ppm (Notes 3, 4, 5)	25 ppm (max)
Condensed Oil and other Particulates, mg/L	0.005 mg/L or 5 mg/m 3 (max)

Notes:

1. *The water content of compressed air can vary with the intended use from saturated to very dry. For breathing air used in conjunction with a U.S. Navy Diving Life Support System (DLSS) in a cold environment (<50°F), where moisture can condense and freeze causing system malfunction, the verification of the dew point is paramount and shall not exceed -65°F or 10°F lower than the coldest temperature expected in the area, whichever is lower.*
2. *Dew points of -40°F are acceptable for submarine diver life support systems, including the Dry Deck Shelter (DDS), the VA Class Lockout Trunk (LOT), and the SSGN Lockout Compartment (LOC).*
3. *Specification is 25 ppm in methane equivalents when measured by a laboratory-based flame ionization detector (FID) calibrated with methane and methane excluded.*
4. *Specification is 5 ppm in n-hexane equivalents when measured by a laboratory-based (FID) calibrated with n-hexane and methane excluded.*
5. *Specification is 10 ppm as measured by other portable photoionization detector (PID) containing a 10.6 electron volt lamp and calibrated with isobutylene (includes GEOTECH Dive Air 2 Portable Air Monitor).*

1.1.3.3 - Conformance with the purchase order

The conformance of the gasses delivered to the purchase order of the company is another important point.:
Life Surface Supervisors usually require certain quantities of gasses to be able to perform mixing for the project ongoing. Incorrect delivery in quantities or percentages may seriously impact the project.
For this reason, the person in charge of checking the gas containers should be provided with a list of the gasses that are planned to be delivered. A specific form should be used for this purpose and indicate:

- The company name
- The invoice reference number
- The reference number from the supplier
- The date
- The department
- The project
- The name of the person in charge of the inspection and his/her signature
- The description of the gas and equipment delivered
- The specifications or/and the reference number from the manufacturer
- The quantity
- Whether it conforms or not
- Comments

At the end of this process, the list is hierarchically transmitted to the department manager.

1.2 – Gas blending

1.2.1 - Units of measurement used for gas blending and transfer

1.2.1.1 - Metric and Imperial systems

Two systems of measurement are commonly used in diving:

- The metric system, also known as the MKS (Metre, Kilogram, Second) system or SI "Système International" which means "International System of Units", has been invented by the French at the end of the 19th century. It is very easy to use since all the units are based on a scale of 10. Note that European publications and those of the majority of countries are expressed in metric.
  It must be noted that because the metric system is recognised as the reference system by the whole scientific community; by today, every measurement should be expressed in metric.
- The Imperial or FPS (Foot, Pound, Second) system comes from a previous system of measure instituted as the official system by kings of England during the 15th century, and that have been continuously developed to become the Imperial system of measures in 1824. This system is still in use in countries which culture has been influenced by British such as the United States of America. It is also used in industries such as the petroleum and aviation industries. Note that there are slight variations between Imperial and US units on the FPS system.

1.2.1.2 - Distance, area, and volume

Gas blending involves volumes of gas, which cannot be calculated without the notion of distance and area. The official SI unit of distance is the metre.

- Distance:

Metric	Imperial
1 metre	3.28 feet (ft)
1 metre	39.37 inches (in)
1 centimetre	0.394 inches (in)
1 metre	1.094 yard (yd)
1 kilometre (km)	0.5399555 nautical miles (M)

Note: 1 m = 1000 mm 1 m = 100 cm

Imperial	Metric
1 foot	30.48 cm / 0.3048 m
1 inch	0.0254 metres
1 inch	2.54 cm
1 yard	0.914 metre
1 nautical mile (M)	1.852 kilometres

Note: 1 foot = 12 inches 1 inch = 0.08333 foot

- Area:

Metric	Imperial
1 square metre (m^2)	10.76 foot^2
1 square metre (m^2)	1550.003 inch^2
1 square centimetre (cm^2)	0.1550003 inch^2
1 square metre (m^2)	1.196 yard^2

Imperial	Metric
1 foot^2	929.0304 cm^2
1 inch^2	0.00064516 m^2
1 inch^2	6.4516 cm^2
1 yard^2	0.836 m^2

- Volume:

Metric	Imperial
1 cubic metre (m^3)	35.315 foot^3
1 cubic centimetre (cm^3)	0.06102374 inch^3
1 cubic metre (m^3)	1.307951 yard^3

Note: 1 m³ = 1000 litres 1 litre = 0.03531 foot^3

Imperial	Metric
1 foot^3	28316.85 cm^3
1 inch^3	16.38706 cm^3
1 yard^3	0.7645549 m^3

Note: 1 ft^3 = 28.31 litres

1.2.1.3 - Temperature

Kelvin is the official SI unit of temperature. Celsius, Fahrenheit, and Rankin are unofficial systems that are used because they were used before the Kelvin, or are more practical for some calculations.

- Convert Celsius to Kelvin: C° + 273.15 = K
- Convert Kelvin to Celsius: K - 273.15 = C°

- Convert Celsius to Fahrenheit: (Cº x 1.8) + 32 = Fº
- Convert Fahrenheit to Celsius: (Fº - 32) / 1.8 = Cº

- Convert Fahrenheit to Rankin: Fº + 460 = R°
- Convert Rankin to Fahrenheit: R° - 460 = Fº

1.2.1.4 - Pressure

Pascal is the official SI unit of pressure. However, depending on the units' system, bar, atmosphere, and psi are commonly used for the same reasons as those indicated above.

- 1 bar = 100 000 Pascal, or 0.987 atmospheres, or 750 mm hg

- 1 atmosphere = 760 mm of mercury (mm hg), or 1.01325 bar, or 29.52999 inches of mercury, or 760 Torr
- 1 bar = 14.5 Psi
- 1 atmosphere = 14.7 Psi
- 1 PSI (pound per square inch) = 0.0689 bar, or 0.068 atmospheres
- 1 millibar = 0.001 bar = 0.000987 atmosphere
- 1 metre of sea water (msw) = 0.1 bar = 3.26336 feet of sea water (fsw)
- 1 foot of sea water = 0.30643 msw
- 1 metre of fresh water = 0.0981 bar = 3.28084 feet of fresh water
- 1 foot of fresh water = 1.03 ATA = 15.132 PSI = 0.3048 metres of fresh water

1.2.1.5 - Mass

Kilogram is the official SI unit of mass.

- 1 kg = 2,204 pounds (Ibs)
- 1 pound = 0.4536 kg
- 1000 kg = 2204 Ibs (pounds)
- 1 ton GB (also called "long ton") = 2240 Ibs = 1016 kg
- 1 ton US (also called "short ton") = 2000 lbs = 907.2 kg
- 1 metric tonne = 1000 kg = 0.984 Ton GB
- 1 metric tonne = 1000 kg = 1.102 Ton US
- 1 metric tonne = 2204.62 pounds (lb)
- 1 ft^3 of fresh water = 62.5 lbs
- 1 ft^3 of sea water = 64.38 lbs
- 1 m^3 of fresh water = 1000 kg
- 1 m^3 of sea water = 1030 kg

1.2.1.6 - Amount of substance

The mole is the unit of measurement for amount of substance in the International System of Units (SI).
The mole is related to the mass of an element in the following way: one mole of carbon-12 atoms has 6.02214076 × 1023 atoms and a mass of 12 grams.
The units may be electrons, atoms, ions, or molecules, depending on the nature of the substance and the character of the reaction (if any)
Note that Avogadro (1776 - 1856) said that number of units in one mole equals to 6.02214076 × 1023.

1.2.1.7 - Molecular weight

Molecular weight is a measure of the sum of the atomic weight values of the atoms in a molecule.
Thus, molecular weight is mass per mole, which is written: m/n
Where the mass " m " is usually expressed in kilograms, and " n " is a measurement of the number moles.

1.2.1.8 - Molar volume

The molar volume (Vm) is the volume occupied divided by the amount of substance at a given temperature and pressure.
It is equal to the molar mass (M) divided by the mass density (ρ).
The Molar volume is directly proportional to molar mass and inversely proportional to density.

The formula of the molar volume is expressed as: *Vm= Molar mass / Density*
Where Vm is the volume of the substance.

1.2.2 - Physical laws involved in gas blending

Three laws are essential for diving and the calculation of gas mixes: Boyle- Mariotte, Charles, and Dalton. The other laws can be considered as complement and improvements of these three basic laws.

1.2.2.1 - Boyle-Mariotte law

This law was established in 1662 by R. Boyle, and independently in 1676 by E. Mariotte.

It is commonly employed in gas mixing and the calculation of pressures, and is considered a description of the process of ideal gas. It states that at constant temperature the volume of a given mass of a dry gas is inversely proportional to its pressure. Most gases behave like ideal gases at moderate pressures and temperatures.

It can be expressed by the equation: *Pressure 1 x Volume 1 = Pressure 2 x Volume 2*

1.2.2.2 - Charles' law

Jacques Charles (1746 - 1823) was a French scientist who established the physical principle that states that the volume of a gas equals a constant value multiplied by its temperature as measured on the Kelvin scale where zero Celsius degree = 273.15 Kelvin degrees (for convenience 273.15 is rounded to 273).

This law allows to estimate the volume of a gas according to the variation of the temperature. Combined with Boyle-Mariotte law, it provides the formula: *Pressure x Volume / Temperature = Constant*

As a result: $$\frac{\text{Pressure \#1 x Volume \#1}}{\text{Temperature \#1 (K°)}} = \frac{\text{Pressure \#2 x Volume \#2}}{\text{(Temperature \#2 (K°)}}$$

Example:

Find the final pressure at 19 Cº of a 12 litre cylinder filled to 250 bar which reached a temperature of 35 Cº immediately after the operation.

Temperature #1 = 273 + 35 = 308 kº

Temperature #2 = 273 + 19 = 292 kº

Applying the formula above:

$$250 \times 12 / 308 = ? \times 12 / 292 \longrightarrow 250 / 308 = ? / 292 \longrightarrow 250 \times 292 / 308 = 241.88 \text{ bars}$$

Based on the fact that compressing a gas results in heat, this law is to consider when filling a gas container or a chamber to calculate the final pressure after cooling. It can also be used to calculate the variation of depths in chambers exposed to weather conditions.

1.2.2.3 - Dalton's law

Dalton (1766-1844) published the law of partial pressures that states that the total pressure of a gas is equal to the sum of the partial pressures of the gasses that compose it.

It can be expressed with the following equation: *Pressure final = Pressure 1 + Pressure 2 + Pressure 3 …*

1.2.2.4 - Avogadro's Law

Avogadro (1776 - 1856) was an Italian scientist who published a law stating that the volume of a gas is directly proportional to the number of moles of gas when the temperature and pressure are held constant.

The mathematical expression of this law is: *V = k x n and V1/n1 = V2/n2*

Where "n" is the number of moles of gas and "k" is a constant.

Avogadro's law says that adding gas to a rigid container makes the pressure increase while adding gas to a flexible container makes its volume increase.

1.2.2.5. - Van der Waals equation

Van der Waals (1837 - 1023), a Dutch scientist, has provided an equation that states that the ideal gas law does not act ideally as expressed by Boyle-Mariotte law and deviates from assumptions at low temperatures or high pressures.

The equation is written as: $(P + an^2/V^2)(V - nb) = nRT$

Where, P, V, T, n are the pressure, volume, temperature and moles of the gas. 'a' and 'b' constants specific to each gas. This equation is used to calculate the compressibility of gasses.

1.2.2.6 - Compressibility factor " Z " of gasses

Linked to the Van der Waals equation discussed above, the compressibility factor " Z " is a thermodynamic property for modifying the ideal gas law to account for behavior of real gases.

For an ideal gas, Z always has a value of 1. For real gases, the value may deviate positively or negatively, depending on the effect of the intermolecular forces of the gas. The closer a real gas is to its critical point or to its saturation point, the larger are the deviations of the gas from ideal behavior.

The ideal gas law is commonly written as: *P1 x V1/T1 = P2 x V2/T2*

Scientist also define it as: $PV_m = RT$

Where P is the pressure; V_m The molar volume of the gas; R the universal gas constant; and T the temperature

The ideal gas law corrected for non-ideality is defined as: $PV_m = ZRT$ ⟶ Thus: $Z = PV_m / RT$

The compressibility factor may also be expressed as: $Z = V\ actual / V\ ideal$

Where P is the pressure; V_m The molar volume of the gas; R the universal gas constant; T the temperature; and Z the compressibility factor.

Note that gasses with a compressibility factor less than " 1 " can be more easily compressed than gases with values greater than " 1 ".

The compressibility factors of nitrogen and oxygen at temperatures between 15 and 20 degrees can be expressed as in the following table:

Pressure (bar)	***Oxygen***	***Nitrogen***	***Pressure (bar)***	***Oxygen***	***Nitrogen***	***Pressure (bar)***	***Oxygen***	***Nitrogen***
20	*0.99*	*0.996*	***120***	*0.94*	*1.008*	***220***	*0.95*	*1.068*
40	*0.97*	*0.994*	***140***	*0.94*	*1.015*	***240***	*0.96*	*1.084*
60	*0.96*	*0.994*	***160***	*0.94*	*1.026*	***260***	*0.97*	*1.102*
80	*0.95*	*0.996*	***180***	*0.94*	*1.039*	***280***	*0.97*	*1.121*
100	*0.95*	*1*	***200***	*0.95*	*1.051*	***300***	*0.97*	*1.14*

To calculate the pressure of a gas with the compressibility factor the formula is: P1 x V1 / Z1 = P2 x V2 / Z2

As an example, using the Boyle-Mariotte formula P1 x V1 = P2 x V2, 20 bar of oxygen added in a cylinder of 50 litres volume equals 1000 litres of oxygen (20 bar x 50 litres = 1000 litres) , so a percentage of 10% in the mix.
Using this formula taking the compressibility factor into account, the calculation becomes:
(20 bar x 50 litres) / 0.94 = 1063 litres, so a mix with 10.6% oxygen.

1.2.2.7 - Physical characteristics of the gasses used for diving

Three main gasses are used with diving procedures that have the following characteristics:

	Helium	***Oxygen***	***Nitrogen***
Symbol	*He*	*O_2*	*N_2*
Molecular weight	*4 g/mol*	*31.99 g/mol*	*28.01 g/mol*
Weight per litre (@ 0 °C)	*0.1875 gram*	*1.429 gram*	*1.251 gram*
Molar volume	*0.022424*	*0.011196*	*0.011197*
Thermal Conductivity (W/m°C)	*0.086 to 0.149*	*0.015 to 0.026*	*0.015 to 0.026*
Sound velocity in gas (m/s)	*1015*	*329*	*353*
Boiling point at 760 mm Hg	*-268.78 °C*	*- 182.97 °C*	*- 195 °C*
Flammability	*Not flammable*	*Oxidiser*	*Not flammable*

Helium is not used for air diving procedures except with medical tables such as Comex Cx30.

1.2.3 - Methods used for gas blending

The preferred method of gas mixing is the one explained in the document IMCA D 022 that remains the most used by teams working offshore. However, other methods exist that must not be ignored.

1.2.3.1 - Mixing by weight

Mixing by weight consists in calculating the proportions of the gases in the final mixture by their weight.
For this reason, it is necessary to know the receiver volume and weight, the final pressure, the temperature at which the receiver is to be filled, and the gaseous constituents of the mixture and their proportions. From these it is possible to calculate the weight of each gas to be added to the receiver.
That can be done using the molecular weights of the gasses to add:

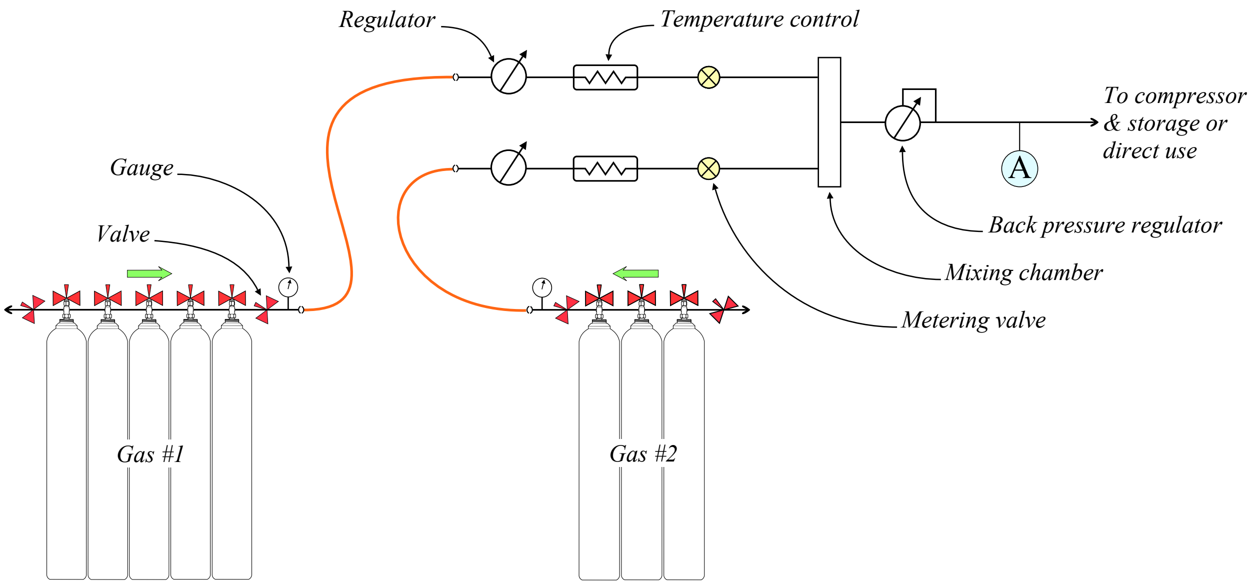
- Oxygen molecular weight : 31.99 g/mol
- Helium molecular weight: 4 g/mol
- Nitrogen molecular weight: 28.01 g/mol
- Air molecular weight: 28.96 g/mol

It can also be done by using the weight per litre of each gas:

- The weight of 1 litre of helium is 0.1875 gram at 0°C
- The weight of 1 litre of oxygen is 1.429 gram at 0°C
- The weight of 1 litre of nitrogen is 1.251 gram at 0°C
- The weight of 1 litre of air is 1.293 gram at 0°C

1.2.3.2 - Continuous flow gas mixing procedure

This procedure implies the use of a pre-calibrated system by which the flows of the gasses that compose the final mix are controlled as they are delivered to a mixing chamber where the blending process takes place. It is the process used by most gas mixers currently sold to fabricate nitrox, heliox, and trimix.
The gases that compose the mix are regulated to the same pressure and temperature before they are metered through precision micro-metering valves and nozzles. The valve settings are pre-calibrated and displayed on curves that correlate the settings with the desired mixture percentage.
The mixing system usually has feedback controls that adjust the valve settings automatically if abnormalities are observed in the gas percentage values.



Several methods are used to implement this procedure:

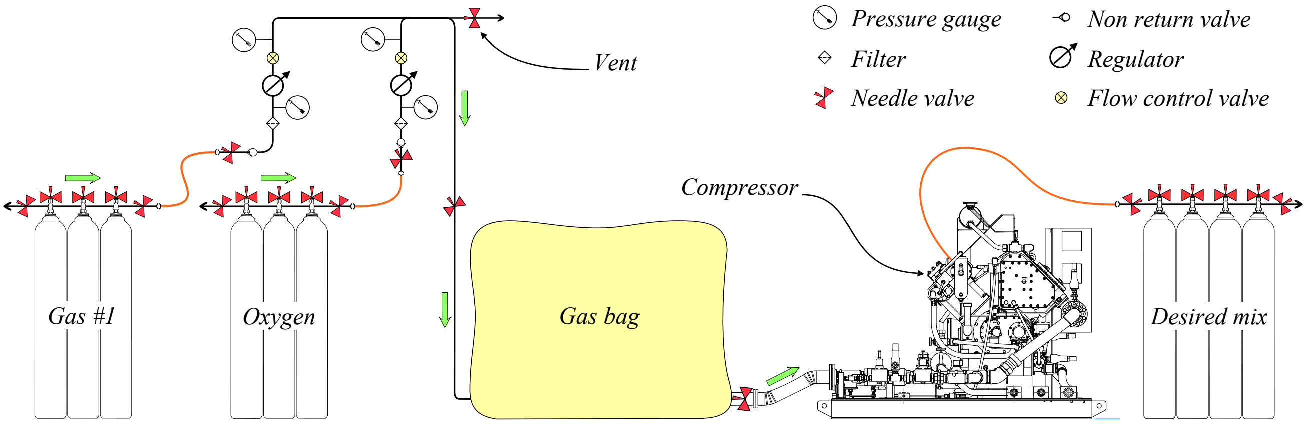
One is the use of one or more micrometer valves for flow modulation. The actual flow is calibrated using charts of settings for desired flow rates and mixtures. The gas is mixed in a chamber maintained under slight pressure by a back pressure regulator to avoid variations of flow.

A second method uses several subsonic and sonic nozzles that can be valved in and out of the flow circuit with solenoid valves in various combinations to provide variable flow rates.
The “ flow nozzle” are composed of a converging section where the flow accelerates, reaching its maximum speed at the throat, and a diverging section where the flow decelerates.
The difference between the sonic and the subsonic nozzles is that with a subsonic flow, the flow speed is below Mach 1, and any change of the pressure affects the differential pressure, which in turn affects the flow through the nozzle. Thus a back-pressure regulator is necessary to regulate the flow. It is not the case with a sonic nozzle where the reduced size of the throat and the gas speed reached, which is equal or above Mach 1, allow a more constant flow rate.

Note that the regulator installed before the valves reduces the cylinder's gas pressure to a pressure allowing regulated gas flow through the metering valves or the subsonic and sonic nozzles.

1.2.3.3 - Mixing by volume

This mixing procedure consists of regulating the gasses to be used in the mix that are usually stored in high-pressure tubes or cylinders to near atmospheric pressure and storing the planned volume of each gas in a gas reservoir at near-atmospheric pressure. This reservoir is usually an inflatable bag, which is similar to those used with reclaim systems, large enough to contain the total volume of gas required for the mix. This bag also acts as the mixing chamber. The final mixture is then compressed into high-pressure tubes or cylinders.
US Navy says that this procedure requires accurate gas meters for measuring the volume of each gas added and that the gasses being mixed should be at the same temperature unless the gas meters are temperature compensated. Another problem is that the size of the bag limits the volume of gas fabricated (50 litres @ 200 bar =10000 m³).



1.2.5.3 - Calculate a gas mix using equations (IMCA procedure)

The procedure explained in this point is also explained in the document IMCA D 022, and is based on Boyle-Mariotte and Dalton equations. This procedure is currently the most employed offshore.

The formula to apply is as follows:

$$\text{Pressure of high mix} = \text{final pressure} \times \frac{(\%\ \text{final mix} - \%\ \text{low mix})}{(\%\ \text{high mix} - \%\ \text{low mix})}$$

To mix two gases in an empty quad, mix #1 and mix #2 are mixed together to give the final mix. As a result, the percentage of the final mix is between the percentages of mix #1 and mix #2.

Mix 1 is the richer mix (the one with more oxygen). As a general rule, the richer mix should be introduced first. Also, there is a fire risk associated with high-pressure pumping with mixes containing over 21% oxygen. For this reason, IMCA D 022 chapter 9 - point 9.6 (page 161) recommends to decant oxygen at a rate of 5 to 7 bar per minute instead of pumping it. Note that this rate of decantation is also indicated in the US Navy manual.

Example 1:

To make 200 bar of 9% using 2% and 12%:

Final pressure = 200 bar

% final mix = 9

% mix #1 = 12

% mix #2 = 2

The formula is: $\text{Pressure mix 1} = \text{final pressure} \times \frac{(\%\ \text{final mix} - \%\ \text{mix \#2})}{(\%\ \text{mix \#1} - \%\ \text{mix \#2})}$

$$\text{Pressure of mix 1} = \frac{200 \times (9 - 2)}{(12 - 2)} \longrightarrow = \frac{200 \times 7}{10} \longrightarrow = 140 \text{ bar of } 12\ \%$$

To determine the pressure of the low mix: 200 bar - 140 bar = 60 bar of 2%

140 bar of 12% and 60 bar of 2% are needed to make 200 bar of 9%

Example 2:

To make 200 bar of 16% using 2% and 20%:

Final pressure = 200 bar

% final mix = 16

% mix #1 = 20

% mix #2 = 2

The formula is: $\text{Pressure mix 1} = \text{final pressure} \times \dfrac{(\%\ \text{final mix} - \%\ \text{mix \#2})}{(\%\ \text{mix \#1} - \%\ \text{mix \#2})}$

$$\text{Pressure of mix 1} = \frac{200 \times (16-2)}{(20-2)} \longrightarrow = \frac{200 \times 14}{18} \longrightarrow = 155.6 \text{ bar of } 16\ \%$$

To determine the pressure of the low mix: 200 bar - 155.6 bar = 44.4 bar of 2%

140 bar of 12% and 60 bar of 2% are needed to make 200 bar of 9%

The proof of the mix can be proved by adding the PPO_2:

$$PPO_2 = \frac{\%\ \times \text{press.}}{100}$$

The addition of the PPO_2 of the weak and rich mixes should equal the PPO_2 of the final mix

$$\text{Partial pressure final mix} = \frac{16 \times 200}{100} = 32 \text{ bar}$$

$$\left.\begin{array}{l} \text{Partial pressure rich mix (\#1)} = \dfrac{20 \times 155.6}{100} = 31.12 \text{ bar} \\ \text{Partial pressure low mix (\#2)} = \dfrac{2 \times 44.4}{100} = 0.888 \text{ bar} \end{array}\right\} 31.12 + 0.88 = 32 \text{ which is the } PPO_2 \text{ of final mix}$$

For some, the gas mixing, the triangle based formula, is easier to remember and to use. Using the 1st example:

To make 200 bar of 9% using 2% and 12%:

Final pressure = 200 bar

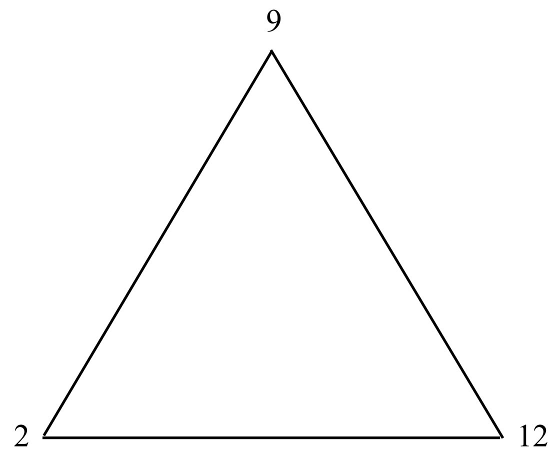
% final mix = 9

% mix #1 = 12

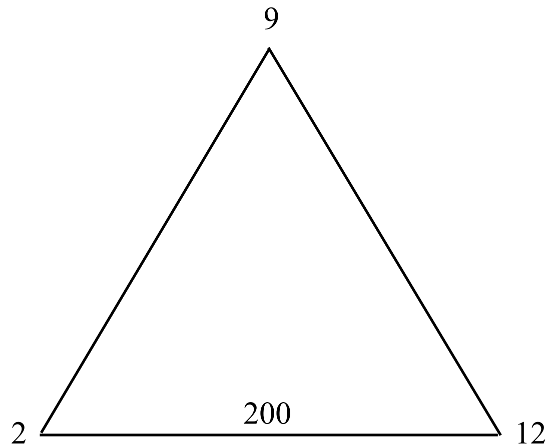
% mix #2 = 2

Draw a triangle and write the oxygen (O_2) percentages of the mix at each corner of this triangle.

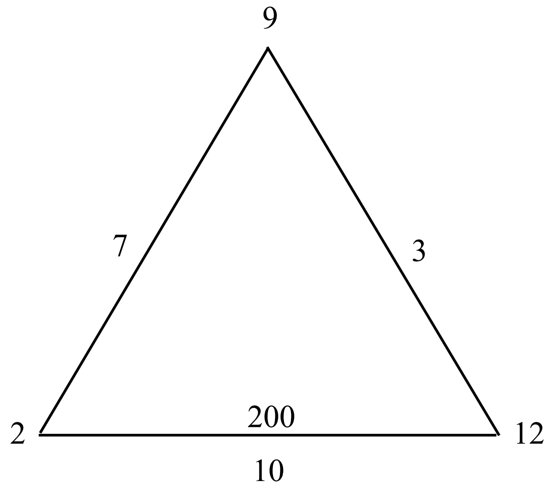
Always put the mix that you know the pressure of at the top.
In this case, it is 9%. It does not matter where the other mixes go: The important fact is that the pressure must remain with the percentage it refers to, i.e. 200 bar of 9%.



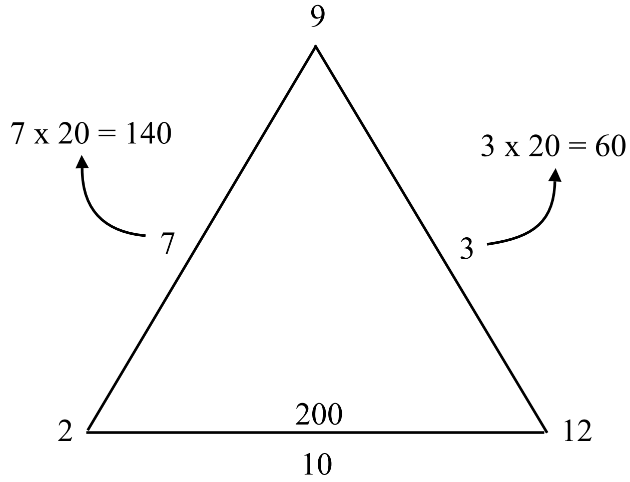
Write in the pressure that you know inside the triangle opposite to the mix with that pressure



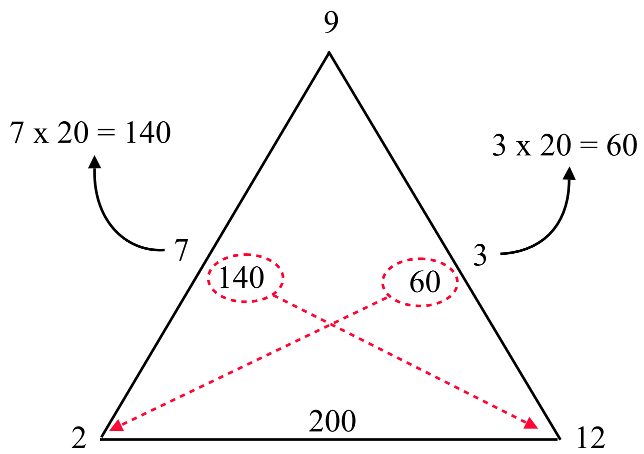
Subtract the small figure (%) from the larger figure (%) and write the answer between the same two percentages along each side of the triangle.



Divide the pressure by the figure underneath it. In this case, that is 200 divided by 10 which equals a factor of 20. Multiply the factor by the other two figures as shown.



Write 140 inside the triangle. Do the same on the other side of the triangle (i.e. insert 60). Reading the opposite corners shows that you need 140 bar of 12% and 60 bar of 2%. Remember, the percentage figure at the corner of the triangle goes with the figure on the opposite side.



The procedure above shows the principles of calculations. However, having to fill an empty quad is rare, and mixing usually involves transferring gas into a not empty quad or tube. In this case, the formula should be turned round to calculate the final pressure:

$$\textit{Final pressure} = \textit{pressure mix 1} \times \frac{(\%\ \textit{mix 1} - \%\ \textit{mix 2})}{(\%\ \textit{final mix} - \%\ \textit{mix 2})}$$

Example 1:

Determine the final pressure of a mix 10% O_2 made with a quad at 100 bar of 4% O_2 by pumping in a quad of 20% O_2:

The formula is: $\textit{final pressure} = \textit{Pressure mix 1} \times \frac{(\%\ \textit{mix 1} - \%\ \textit{mix 2})}{(\%\ \textit{final mix} - \%\ \textit{mix 2})}$

Pressure mix #1 = 100 bar

% mix #1 = 4

% mix #2 = 20

% final mix = 10

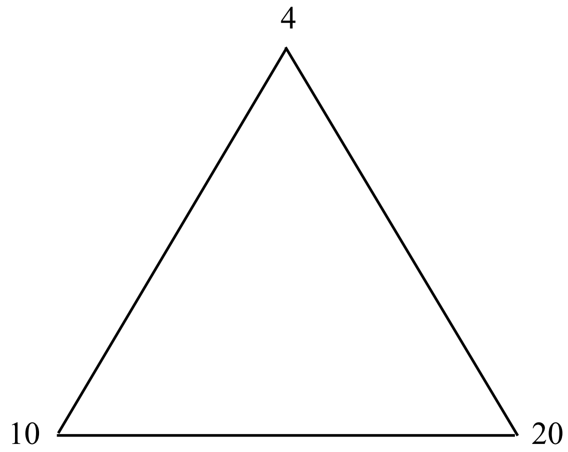
$$\text{Final pressure} = \frac{100 \times (4 - 20)}{(10 - 20)} \longrightarrow = \frac{100 \times -16}{10 - 20} \longrightarrow = \frac{100 \times -16}{-10} \longrightarrow = \frac{100 \times 16}{10} \longrightarrow = 160 \text{ bar of } 10\ \%$$

The final pressure is 160 bar.

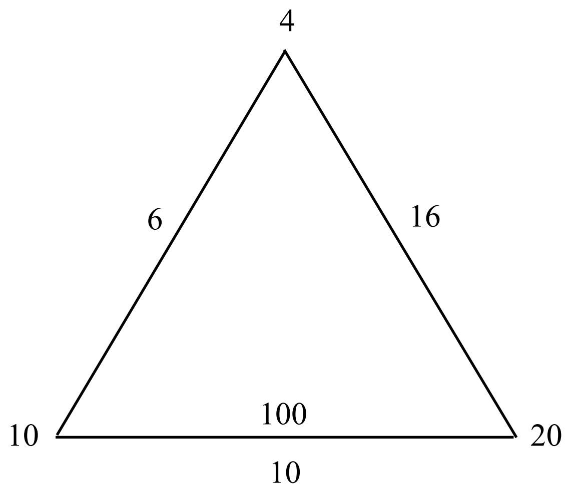
Mix #2 (20% O2) should be transferred until the pressure reaches 160 bar (or a little bit more to allow for cooling)

Using the triangle method:

As before, write the mix that you know the pressure of at the top. In this case it’s 4%. It does not matter where the other mixes go.

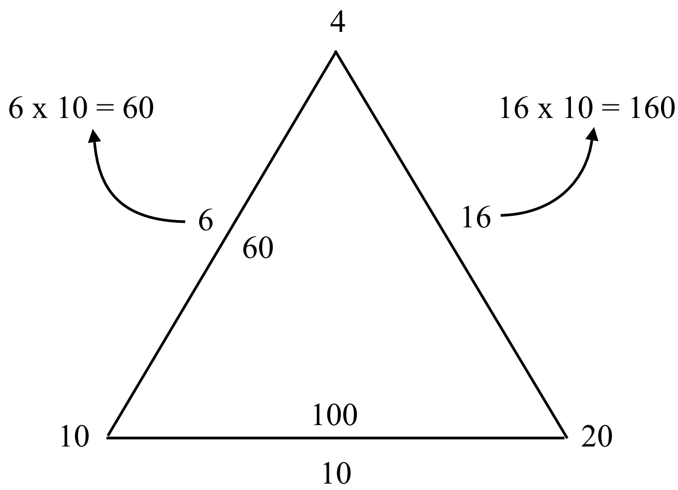


Write in the pressure that you know, inside the triangle opposite the mix.



Subtract the small figure (%) from the larger figure (%) and write the answer between the same two percentages along each side of the triangle. Divide the pressure by the figure underneath it. In this case that is 100 divided by 10 which equals a factor of 10. Multiply the factor by the other two figures as shown.

Write 60 inside the triangle. Do the same on the other side of the triangle. Reading the opposite corners shows that the pressure of 10% will be 160 bar. This is achieved by pumping 60 bar of 20% into the existing 4%



Important notes:

- The procedures used for transferring the desired mix components are cascade filling or gas pumping that are discussed in the previous points. Because gas compression generates heat, the desired gas's temperature stored in cylinders or tubes is increased. It thus generates a false indication of the real pressure in the gas storage

Container. Note that this phenomenon is valid with all gas mixing procedures where these gas transfer techniques are used. The real pressure in the container after cooling to the ambient temperature can be calculated using the Charles law's formula below:

$$\text{Final pressure} = \frac{\text{Initial pressure x final temperature (ºK)}}{\text{Initial temperature (ºK)}}$$

Celsius degrees (°C) are converted to Kelvin (°K) by adding 273 to the temperature in °C.
The formula used to convert Fahrenheit to Kelvin is: Temperature °K = (Temperature °F + 459.67) x 5/9.

- This gas mixing procedure does not take into account the variation of the compressibility of gasses previously discussed in point 2.2.2.6. That may result that the composition of the mix may not be exactly the one desired. Also, the gas may not be perfectly mixed, and an immediate analysis may result in an incorrect reading. For these reasons, it is recommended to stand the mix for at least six hours to permit the gases to mix homogeneously. Following this time, an analysis should be done to verify the percentages of the content, and adjustments to obtain the desired proportion should be performed using the formulas explained above.
  Note that many teams wait for the mix to homogeneous for 24 hours minimum, particularly when the desired gas mix is stored in large banks.

1.3 – Maintaining gas reserves

1.3.1 - IMCA D 050: Minimum quantity of gas required offshore

1.3.1.1 - Purpose

IMCA D 050 is a guideline that sets up the absolute minimum amount of emergency breathing medium (air or mixed gas) required to be kept at an offshore dive site before and during the dive.
However, this guideline also indicates that attempting to formalise these minimum levels is difficult as they are heavily dependent on individual circumstances such as:

- The breathing mixtures used;
- The decompression schedules;
- The depth planned for the dives;
- The work rate;
- The environmental conditions at the site.

This document is not perfect, as demonstrated in the "Diving management study CCO Ltd #7". However, it is today the reference in force that is the most used by the manufacturers to design systems with sufficient operational capabilities, and companies to calculate the necessary gas to be provisioned for a project. It provides the following recommendations, which are reinforced here according to the "Diving management study CCO Ltd #7" recommendations. Note that this guideline classifies the gasses into two categories:

- "Consumable gasses" are provided for ongoing use and will vary in quantity available on use and re-supply
- "Reserve gasses" must be provided and kept to solve emergencies. They are therapeutic gas, Built-In Breathing System (BIBS) gas, gas reserves to compress the chambers, and others.

Note that backup supplies must be immediately available. Also, a gas container at less than 20 or 30 bar pressure cannot be considered part of the reserve.

1.3.1.2 - Minimum gas provision for surface orientated air or nitrox diving

Gas purpose	*Classification IMCA D 050*	*Minimum requirement IMCA*	*Comments / Additional precautions CCO Ltd*
Operational in water gas + in-water decompression gas	Consumable	Sufficient gas should be provided for the bottom time and decompression, based on a breathing rate of 35 l/min at work & 25 I/min at rest.	Add a safety margin of an additional dive, or increase the consumption rates. For example, use 45l/min instead of 35 l/min.
Diver personal gas reserve (Bailout)	Reserve	10 m/min of umbilical deployed from the surface (basket) or the wet bell at emergency breathing rate.	Breathing rates from UK HSE report RR 1073 (50 to 75 l/min) should be promoted to the detriment of the IMCA rate of 40 l/min
Diver rescue air or nitrox	Reserve	2 dives of 30 min bottom time to the maximum intended diving depth at emergency breathing rate.	Emergency breathing rate of 62.5 litres /min instead of 40 litres (see above)
Wet bell / basket gas reserve	Reserve	It must be sufficient to recover the divers safely from the longest and deepest planned dive at emergency breathing rate.	Emergency breathing rate of 62.5 litres /min instead of 40 litres (see above)
Surface decompression gasses	Consumable	Sufficient gasses to compress both chamber's locks to the max. surface deco depth + three (3) surface decompression cycles per chamber	The surface decompression cycles include the full compression and decompression of the chamber + the gas used for flushing. Note that 20 - 25 l/min is the breathing rate.
Chamber scrubber		Not indicated in the guidance IMCA. Consumption: 0.25 kg/diver/hour	Soda lime and Purafil for 3 surface deco. dives + the longer therapeutic treatment planned + the same quantity as a reserve.
Therapeutic treatment gasses	Reserve	Sufficient gas to pressurize both locks of each DDC to the maximum possible treatment depth + 90 m³ Oxygen	The quantity of gas to pressurize the locks should be doubled Also, plan for sufficient gas for 3 decompression of medics and 3 compressions of the entry lock. If a heliox table such as COMEX 30 is used: add 90 m³ heliox 50/50 and 90 m³ heliox 20/80.
Calibration gasses (Analysers)	Consumable	No calibration gas required	Sufficient quantities for the calibration processes recommended by the manufacturer for the entire duration of the project + the same quantity as reserve

Surface orientated air or nitrox diving (continuation)

Gas purpose	Classification IMCA D 050	Minimum requirement IMCA	Comments / Additional precautions CCO Ltd
Dive crew evacuation air	Reserve	Allows to evacuate the area at emergency breathing rate	62.5 litres / minute instead of 40 litres (see above)
Diver transfer oxygen	Reserve	Allows to transfer the divers to the facility at emergency breathing rate	62.5 litres / minute instead of 40 litres (see above)

1.3.1.3 - Other gas provisions

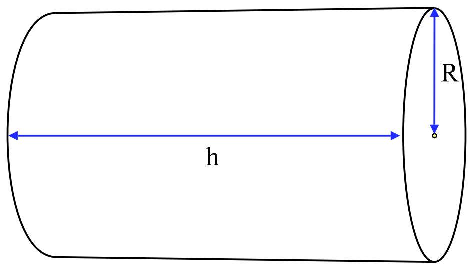
IMCA D 050 also provides guidelines regarding heliox surface supplied orientated diving and saturation diving. They are described in the study CCO Ltd No 7 "History and evaluation of IMCA D 050 rev. 1 - Minimum quantities of gas required offshore". These guidelines are not necessary for surface-supplied air and nitrox diving.

1.3.2 - Elements to consider for the calculation of the gas needs

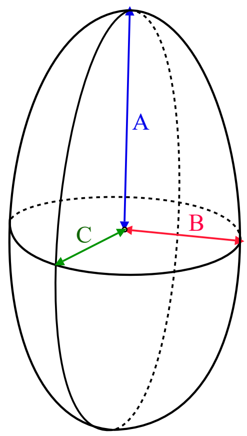
1.3.2.1 - Elements for the calculation of volumes

Every pressure vessel is normally fitted with an identification plate that, in addition to the information regarding its construction process, indicates its volume. The manufacturer is also required to indicate the volume of the elements that compose the dive system in a document that should be accessible to the people in charge. Thus, the Life Support Supervisor should have all information to calculate the volume of the system.
In the improbable case that the volume of a chamber or a lock has to be calculated, the following method and formulas can be used:

- For medical locks of pressure vessels with a similar shape, the formula to apply is the one for the calculation of the volume of a cylinder: Vol. = $\pi R^2 h$



- In the case of a chamber with rounded ends, which are today very rare, the volume of the item is equal to the volume of the cylinder + the volumes of the two half spheres at the extremities. As two half spheres equal a sphere, the formula for the calculation of the volume to be used is: Vol. = $4/3\ \pi R^3$, where R is the radius of the sphere.
- Most chambers are provided with oblate spheroid ends, which can be considered ellipsis. In this case, the following formula can be applied: Vol. = $4/3\ \pi \times A \times B \times C$ *(see A, B, C in the scheme below)*. This volume is to be added to the volume of the cylinder to give the volume of the chamber.
  Note that when A = B = C, the ellipsis is a sphere.



- To find the volume of the pipes, the formula for the volume of a cylinder can be applied.

1.3.2.2 - Elements to consider for the calculation of consumption.

The consumption of a diver at work is 35 litres per minute, and 62.5 litres in emergency. Note that IMCA continues to promote 40 litres/min, but as indicated in the study CCO Ltd #7, this value in incorrect and should not be used.

The average consumption of gas using the BIBS system is given to 20 litres (0.706 ft³)/minute per diver by IMCA (the divers are usually at rest). That is equal to 1200 litres per hour per diver (42.377 ft³). Note that depending on the persons and the conditions, it can raise to 25 litres.

Oxygen metabolic consumption is 0.5 litres/ minutes per diver . That corresponds to 30 litres per hours (1 .05 ft³). It also corresponds to 720 litres / day per diver (25.42 ft³). The production of CO_2 is proportional to the consumption of oxygen (0.5 litres per minute, and thus 30 litres per hour). Many chambers are equipped with a scrubber filled with soda sorb to absorb the CO2 in excess. The consumption of Soda lime is 0.25 kg/diver/hour (The weight of soda-lime is 0.75 kg/litre).

2 - Prepare the diving operations

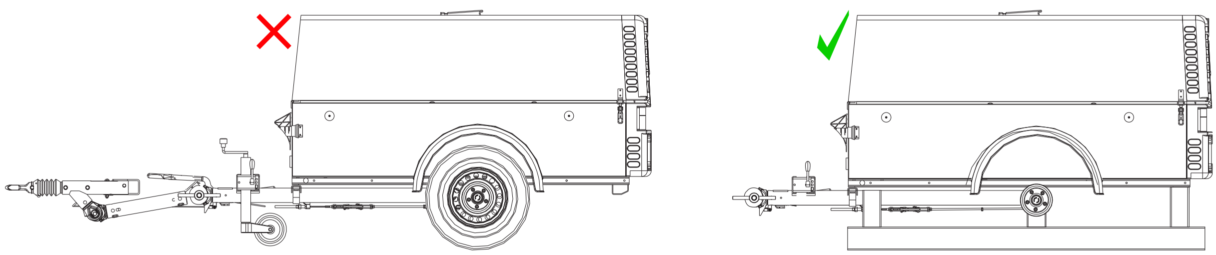
2.1 - Prepare the dive station

2.1.1 - Deck layout and sea fastening

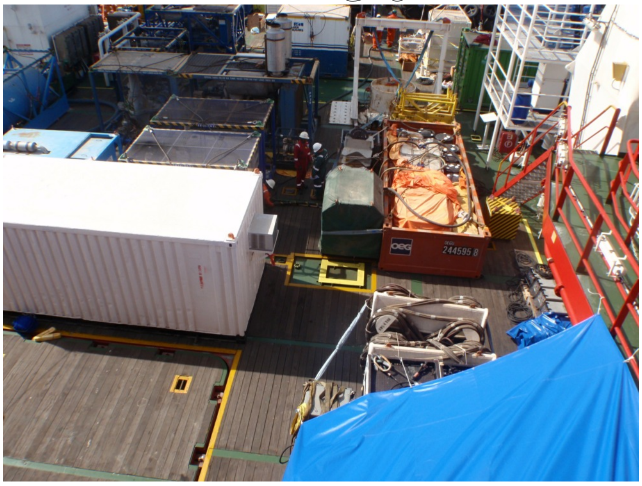
2.1.1.1 - Before and during the mobilization

Typical means of fastening the diving system's elements, such as the Launch and Recovery Systems (LARS), dive and chamber control containers, and workshop containers, are explained in the sections related to these items. Similar procedures are used to secure the various machines employed during the project to the deck. As for the elements of the dive system mentioned above, their sea fastening is calculated by specialized engineers according to the vessel characteristics, notably the vessel's deck and under-deck strength. Additional welded temporary connectors are usually installed for this purpose. These operations must be performed by appointed welders competent in the types of welding procedures used. Non-destructive testing (NDT) and load testing of critical connections (i.e., launch and recovery systems, etc.) should be carried out by competent third-party persons. The diving team is not directly responsible for these calculations and the installation of the connectors. However, the persons in charge of the team are responsible for ensuring that the elements of the diving system are adequately positioned to allow for safe and easy diving operations:

- The diving ladder should be installed according to the description in section #2.1 “ladders”.
- The LARS should be positioned according to what is said in section #2.2 “Launch and Recovery Systems using baskets”. If diving from a DP vessel, remember the position of the diver and standby diver baskets to allow for an optimum rescue intervention if needed.
- Containers of the elements that compose the dive system must be positioned according to what is mentioned in section #2.21.4, “Specifications of containers accommodating elements of portable diving systems”.
- Open and closed containers should be provided to store the elements planned to be installed and the specific tools needed for the scheduled installations to avoid forcing the team to store them in inadequate spaces. If the parts to install are too voluminous, they must be secured on deck using the pre-installed fastening points of the vessel or welded padeyes added for this purpose and slings. The slings must be designed for the shapes and mass of the object to secure, provided with relevant, up-to-date certificates, and be in optimum condition.
- The gas reserves should be in a protected deck area where restricted access can be implemented. If it is planned to fabricate mixes on board and pump oxygen, The area where these mixes are fabricated must be isolated from the vessel's dive station and other acclivities and provided with adequate firefighting systems as indicated in points 2.13.3 & 2.14.3. Removal fastenings should be used for quads that may have to be changed during the operations such as oxygen quads.
- The machines powered by a thermal engine should be positioned such that their exhaust fumes do not pollute the dive station and thus the air compressor inlets. On the other hand, they must be quickly accessible by the appointed team members. Remember that in case of work to be performed in an oilfield or in the proximity of a facility where explosive and flammable gases are likely, machines powered by thermal engines must be provided with “spark arrestors”. This device should be manufactured according to guidelines of the European directive ALTEX 94/9 EC and the norm EN 1834-2 /98/37/EC or similar (For example, the USA and Canada have their own, but very similar, standards). Note that a device that conforms to the directive ALTEX 94/9 EC should be marked with the logo “Ɛx” in addition to the name of the manufacturer and its traceability code.
- Remember that a minimum space (approximately 70 cm) should be provided to intervene on the mechanical and electronic parts of the various machines (Ensure that the access hoods and doors can be easily opened.
- Machines equipped with wheels should be appropriately wedged, their wheel removed, and the mechanical parts of the wheels protected from the ingress of salt water (reinforced plastic bags and other types of isolation).



- The cameras allowing to control what happens in the dive station must be adequately positioned and in sufficient numbers to avoid conflicts with the sunlight during sunrise and sunset. Conflict with the deck lights should also be monitored and avoided.
- Conflicts with other vessel activities, such as welding, cutting, and lifting, are also to be avoided. Remember that the area where the dive station is installed is to be classified “No go zone” to the crane operator and that “hot works” should not be performed in its proximity. Safe paths are to be provided to the dive team to go to and from the dive station safely.
- Containers of substances hazardous to health should not be stored in the direct proximity of the dive station. Radioactive elements should be isolated in a part of the deck with restricted access.
- Garbages should also be positioned far from the dive station and other activities on deck.

2.1.1.2 - During the diving operations

The sea-fastenings can be subjected to tremendous forces depending on the weather conditions and may break. For this reason, they must be regularly checked during the operations.

- The attachments of the Launch and Recovery Systems (LARS), should be visually inspected at the beginning of each working shift.
- The fastenings of the other parts of the diving system should be checked daily. This frequency can be longer if the vessel works within optimum weather conditions. Note that, if used, the tension of the slings must always be optimum. Also, they must be changed in case of apparent wear.

Temporary sea-fastenings create tripping hazards when they are not used, as they cannot be reinserted into the deck floor as those of the boat. For this reason, they must be removed when they become useless.

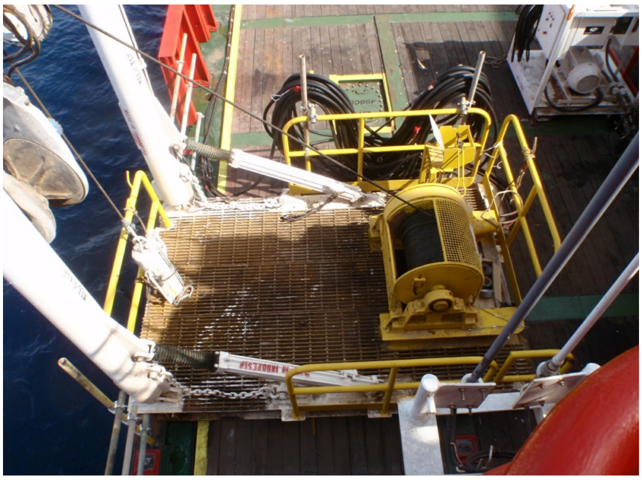
2.1.2 - Organization and housekeeping of the dive station

A lot of elements regarding this point are already indicated in section #2 “Description of the various parts of a surface supplied diving system”. However, they are mentioned for part of the system without considering the other elements for most of them. When all these elements are installed, the diving team must ensure that the dive station is organized such that the operations can be organized safely and that the safety protections already described for each system are organized to work with the others.

2.1.2.1 - Access and safe circulation

Access to any area in the dive station must be easy and secured: Tripping hazards must be removed, and those that cannot be must be highlighted with caution signs around (Broad yellow lines with or without red or black stripes are commonly used). Differences in level on deck must be indicated too. Low beams that may hurt people must be marked with caution signs and wrapped with absorbing shock materials such as neoprene, plastic foam, or similar. The deck must be cleaned with no slippery areas.

As for the additional LARS platform, additional working platforms and stairs must be fitted with handrails and/or barriers to prevent the personnel from falling down on deck or into the sea. Also, the winches and drums used to perform assistance tasks must be protected with guards in the same way as the winches used on the LARS.



Except for the operations planned only by day light, there must be sufficient lighting to erase shadow areas on deck during the night, and the light in the working areas must be sufficient to allow people to read documents and/or instrument’s gauges easily. Regarding this point, remember that NORSOK U 100 recommends a minimum of 300 Lux in all areas and a minimum of 500 Lux near control panels.

2.1.2.2 - Protection of/from pressure hoses and electrical wires

The temporary installation's hoses, electrical, and communication cables must be arranged to pass at least 2.2 m above the deck using one-inch (1") diameter ropes, metallic wires, rigid pipes, or cable trays as support and secured on these supports every 20 cm. IMCA requires every 2 m, but we consider it incorrect as hoses may be damaged at the supporting points. Also, this configuration would not prevent a ruptured hose under pressure from moving erratically and be the source of injuries. In addition to securing points, every 20 cm, a hose arrester must be installed between the pressure discharge fitting of machines or gas cylinders and the connecting hose and between hose-to-hose connections.

Hoses and cables running on deck without protection are prohibited. If, for an operational reason, the installation must be organized this way, the hoses must be fully enclosed, protected from shocks and not create a tripping hazard.

2.1.2.3 - Housekeeping

The hoses not in use must be properly coiled and stored in a protected area. Those carrying breathing medium and not in use must have the extremities hermetically closed to avoid pollution and damage. They must be stored away from potential sources of pollution. Additional precaution must be taken for oxygen hoses which must be separated from the other hoses to avoid confusion. The last date of oxygen cleaning must be indicated and visible on each hose.

Unused tools slings, cables, ropes, and other items must not be left on deck and be stored in proper places. As indicated in the previous point, dedicated containers must be provided for this purpose. To comply with the requirements of standards such as ISO 9001, access to the stores must be restricted and under the responsibility of nominated persons. There must be a document where the tools and consumables used during the diving operations are logged.

Chemicals must be segregated according to chemical compatibility and should be packaged in suitable, secure and chemically compatible containers.

Personal diver's tools and suits must be stored in a dedicated place. There must not be suits or tools stored on gas quads or in the chamber and dive control room(s). The machinery of the vessel is also not a suitable place for diving suits and personal gears. A dedicated area where the divers can wash their diving suits and dry them should be provided.

2.1.2.4 - Protection from weather conditions

The electrical panels and devices installed outside must be waterproof with dedicated sockets and connectors agreed for works in wet and salted environments.

In addition, to protect the people from electrical shocks, suitable breakers and safety trip devices like earth leakage circuit breakers must be installed to all the electrical installations. It should operate at less than 20 MS. These safety devices must be checked by a competent person. Explanation about electrical shocks are in the document"Diving accidents".

If the free-board of the surface support is less or equal to two (2) meters, containers, control rooms, stores, and electrical equipment should be installed on legs at least 40 cm high, allowing waves to pass freely underneath. Also, control rooms and electrical equipment should be provided with sealed doors (see in point 2.21.4, *" Specifications of containers accommodating elements of portable diving systems"*).

There must be a workshop with a dry atmosphere to maintain sensitive electrical and electronic systems, store the specific tools, and protect the spare parts and sensitive systems from the weather.

The standby diver must be ready to intervene quickly at any moment. There must be a well protected shelter with a chair on which he can sit comfortably fully dressed, and a screen with sound showing him what is happening on the bottom during the dive.

2.1.2.5 - Protection from falling into the sea

Sufficient work vest, and harness must be ready for use near the Launch And Recovery System (LARS) and any working station with an opening above the sea. Suitable rings to connect the safety lanyards/stop falls of the harness must be installed and easily reachable by those working to launch and recover the basket, or supplying tools to the divers.

There must be chain guards, doors or any suitable means to close the openings to sea when the diving operations are completed.

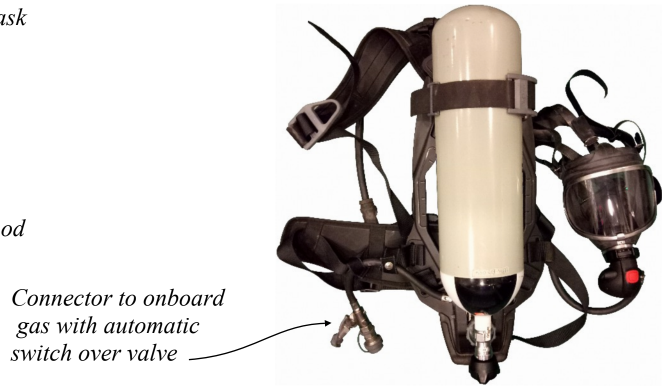
2*.1.2.6 - Gas detection, emergency escape, and fire fighting systems*

When working near facilities exploiting gas, or when H_2S is possible, suitable gas detectors must be installed on deck and near the air intakes of the diving compressors. These gas detectors must be fitted with audible and visual alarms. Personal gas detectors should also be worn by at least some key deck personnel.

In case of an emergency involving harmful or explosive gas on deck or fire, sufficient Breathing Apparatus (BA) sets must be on deck in the proximity of the LARS to allow the people in charge of the recovery of the diver(s) to continue their duty. These BA sets must be of the same model as those used in the dive control and thus designed to be connected to an onboard gas reserve and therefore use the bottle only to escape, in addition to communications to the dive control.

A sufficient number of escape respirators (at least one for each person on shift) must be provided and stored in an accessible place. In addition, an adequate number of life jackets must be kept near the escape respirators in case of an abandoned vessel.

Emergency escape breathing respirators



BA set with connector to onboard gas

Firefighting systems of the Launch and Recover Systems (LARS), dive control, chambers, compressor room, and workshops are already described in the sections related to these parts of the diving system. Remember that the various components of firefighting systems and how they must be installed are already explained in point #2.21.2, "Dive control and chamber control rooms".
In addition to what is explained in point #2.21.2, and for the various components of the system the diving team should ensure that the following precautions are in place on deck:

- Suitable extinguishers should be provided in strategic parts of the deck. Such extinguishers must be near, but not at direct proximity of the parts of the system that can trigger a fire to be reachable if the fire has started *(if the* *extinguisher is too close, it will be unreachable and/or damaged)*. Remember that the main categories of extinguishers are the following:

- Class A extinguishers are used to put out fires of materials such as paper, wood, cloth, and plastics.
- Class B extinguishers are suitable for fires that start from the combustion of flammable liquids and gasses.
- Class C extinguishers are designed for electrical fires
- Class D extinguishers are provided with an extinguishant agent for metal fires (Magnesium, sodium, aluminum, or titanium)
- Remember that dry chemical powder extinguishers are considered multipurpose extinguishing agents for at least fires class A, B, and C, which explains why they are usually the most used on the deck. Note that some powders are also suitable for class D fires. However, they are generally limited to electric fires below 1000 volts. The main inconvenience of this extinguishing agent is that it is very corrosive.

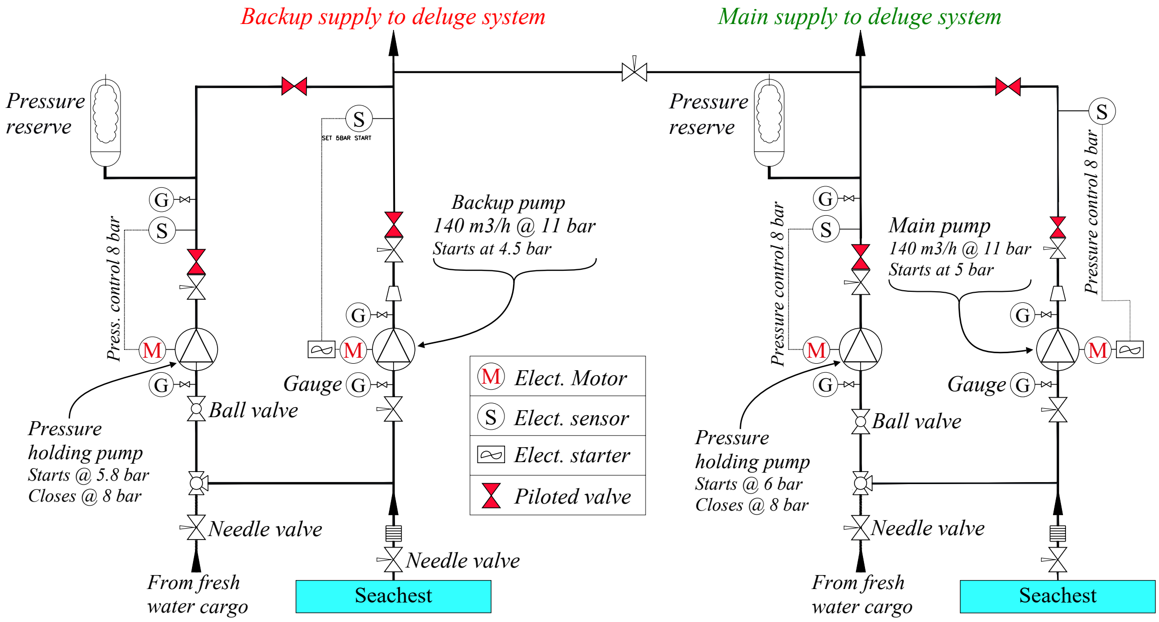
- Fire hydrants should be at the proximity of the dive station to be able to connect dedicated fire-fighting lances. A hydrant consists of a flanged metal casting fitted to the firewater pipe-work. It is equipped with a hand-wheel operated control valve, allowing the outlet to be opened or closed as required. The outlet should be fitted with a standard 2" coupling.
  A hose reel equipment, generally consists of a hose wound onto a drum, and connected to fire water pipe-work. It delivers water to a hose reel branch. Water lances are terminated with nozzles allowing to combat long-distance fires and enable fog mode for firefighters safety.

Water hydrant

Fire hose

Nozzle

- Deluge systems can be installed on sensitive parts of the diving station, such as the oxygen cylinders' storage place. They should be mandatory in case of gas mixing, so when oxygen transfers are to be performed on the work site. As already described, the systems consist of water supplied through canalizations and numerous spray nozzles. Manual activation/deactivation controls should be designed to prevent unintended activation. According to NFPA 99: Health Care Facilities Code (National Fire Protection Association [USA]), the water should be delivered from the sprinkler heads to provide reasonably uniform spray coverage with vertical, horizontal, or near horizontal jets. Average spray density at floor level should be not less than 80 litres per minute within 3 seconds of activation. There should be sufficient water available in the deluge to maintain the flow as specified for 1 minute. Regarding this point, the systems used on vessels other than those for hyperbaric systems can work for a longer time and as long as the pumps supplying them work. These pumps are organized as in the scheme below with a main pump and a backup unit. The pressure holding pumps and pressure reserves allow to start the system immediately. There should be sufficient stored pressure to operate for at least 15 seconds without electrical power.



- Smoke, heat, and flame detectors should be installed to trigger alarms and start the deluge system if this device is installed. Note that flame detectors are often selected to detect the presence of flame or fire caused by combustible gases and vapours. These devices use optical methods based on ultraviolet, infrared, multi-infrared, or a combination of the two systems to detect the presence of open fire or flames. Ultraviolet sensors work by measuring levels of radiation in the atmosphere, and infrared sensors utilize infrared patterns emitted by hot gasses.

2.1.2.7 - Installation and maintenance tasks requiring to work at height *(From diving management study #10 CCO Ltd)*

Works at height are usually performed during the mobilization of portable diving and ROV systems on vessels of opportunity. They should be planned with the mobilization plan.

- The deck plan that shows the various parts of the system to be installed should be studied.
    - The parts of the system that need to be installed at height should be identified.
    - The electrical supply lines and gas line to install at height should also be identified.
    - The possibility not to perform works at height should be evaluated and should be the preferred solution. That includes using extendable tools from ground level to remove the need to climb a ladder or installing cables at ground level if suitable protections are available.
- When the elements that need work at height to be installed are identified, the means of access should be selected.
    - A risk assessment should be done for each component to install that compares the means of access available with their advantage and inconvenience. That takes into account the space occupied by these devices, their ease of transportation and implementation, the stability of the vessel, and whether the mobilization is completed in port alongside the jetty or in the harbour where the ship is more exposed to bad weather conditions.
    - The risk assessment should consider the existing anchor points and those that are to be installed. When additional anchor points are to be installed, the procedure for how they can be safely installed should be considered.
    - When the means of access are identified, they should be listed for each element to install.
- The supply of the selected means of access should be then evaluated:
    - The phases of the mobilization plan should be scheduled to identify the devices that can be shared between teams and when these devices are to be provided.
    - Existing devices should be checked for their condition and conformance to the applied standards.
    - Incorrect devices should be removed from the worksite to avoid the teams the temptation of using them.
    - Missing equipment should be provided. The guidelines indicated in this study should be used to ensure that they conform to recommended standards.
- The teams in charge of the mobilization should be organized:
    - People authorized to work at height should be identified with the means of access they are allowed to use.
      Supervisors should be aware of the several phases of the mobilization plan and when the necessary means of access will be available.
    - Toolbox talks should be organized every day where the risk assessment for the planned tasks is discussed. The management of the change system should be in place.
    - The person in charge of the entire mobilization process should be identified. He must be aware of the various works at height and ensure that relevant procedures are in place.

When the mobilization is completed, the necessary devices for maintaining the various parts of the diving or ROV system situated at height must be kept or created. If the Diving and ROV systems are built-in, these means of access should be provided if they are not in place or damaged.

- As for the mobilization plan, the parts of the system that require interventions at height for their maintenance should be identified and logged.
- Elements that need to be frequently inspected and maintained should be provided with permanent means of access when it is possible. It is, for example, the case for winches and umbilicals' reels. Guards, welded ladders, horizontal lifelines, and stairs are commonly installed for this purpose.
- When permanent means of access cannot be installed to access the high parts of the system, devices such as ladders, small scaffolds, ascent ropes, lanyards, energy absorbers, harnesses, and others should be selected and provided. They should be chosen using the same procedures as for the mobilization. Also, they should be kept available at all times and adequately stored. In addition, permanent anchorage points should be installed on the system to secure them when they have to be used.
- Equipment for working at height should be logged in the store as the other tools and changed when damaged, or the date for replacement is reached.
- The maintenance of diving and ROV systems is a routine task that the technicians in charge perform. For this reason, they must be familiar with work-at-height procedures. The supervisors should ensure that the technicians under their responsibility are competent in using the work-at-height devices they implement.

2.1.2.8 - Chamber cleaning

Most treatments and decompression carried out in air chambers are of short duration. Nevertheless, long hyperbaric treatments may be carried out. As an example, the time of the USN table 7 is 36 hours, and the duration of a COMEX Cx 30 saturation is at least 48 hours, but it can be longer. These treatments must be considered saturation dives. Also, the patient to treat may be injured, thus being more sensitive to infection. For these reasons, a good practice is to follow recommendations given in DMAC 26 "Saturation diving chamber hygiene", and those in the document "Diving accidents" in this handbook:

- To limit microbial growth (particularly the predominant Gram-negative bacteria), and therefore, to protect against infection, chambers must be regularly cleaned.
  - Steam cleaning is often used and is effective.
  - Cleansing (with liquid anti-microbial) is started at the top of the chamber and is continued downwards. Cleanser in excess should be removed. Relays of fresh cloths/sponges should be used on each occasion and discarded carefully and appropriately after limited use.
  - Aerosol application of disinfectant agents must not be used. Almost all disinfectants turn out to be respiratory sensitisers, so the use of an aerosol in an enclosed chamber can cause problems for the users and is thus unwise.
- Before the diving operations, the entire chamber should be thoroughly cleansed and allowed to dry.
  - The parts of the chamber which will be in direct or indirect contact with the skin (e.g. shower-deck, tables and Built-in Breathing System masks) and other personal equipment should be disinfected using chamber cleanser, left for a minimum of 10 minutes, then rinsed and dried thoroughly.
  - If the chamber is equipped with water supply and toilets, shower-heads should be removed, cleansed, rinsed after 10 minutes, and dried. The toilet, sink and shower areas, service-locks and their immediate areas should be cleansed.
  - The chamber should be ventilated and clean bedding and towels provided.
- Cleaning should be continued during the diving project.
  - Built-in Breathing System (BIBS) masks should be cleaned after each decompression or every week if the chamber is not used.
  - Clean bedding and towels should be provided after each decompression, or changed every week if the chamber is not used.
  - The deck decompression chamber should be returned to surface to be cleaned and ventilated every week if not used, and twice weekly if intensively used (surface decompression). Chamber walls and bulkheads should be cleansed. Bilges or floor areas beneath deck plates should be cleaned and the cleanser in excess removed. If the chamber has been used for a medical treatment, it should be entirely cleaned following the treatment.
  - Portable toilets should be cleaned and disinfected immediately after use.
  - In the case that the chamber is equipped with toilets and water supply:
    - If intensively used, the toilet, sink and shower areas, service-locks and their immediate areas, and table surfaces should be cleansed daily. If not used, they should be cleansed every week.
    - If the shower is intensively used, the shower-heads should be removed for cleansing twice weekly. If the shower is not used, it should be done every week.
    - Shower areas should be drained quickly after showering and the floor retained dry.
- The prime requirements of the cleaning agents are that they should be very effective against the microbes known to flourish in the chamber environment and be non-toxic to man. Additionally, the cleansers should be odourless, non-volatile, and be free from irritant and sensitising properties.
  - Amphoteric surface active agents (e.g. Tego 2000) and potassium peroxymonosulfate (e.g. Virkon, Oxone) are often used. They combine good anti-microbial properties with relatively few disadvantages, e.g. they are odourless and less likely to be an irritant to the skin.
  - Various other products may also be suitable including dish-washing liquid solutions.
  - Dichlorophen (Panacide M) is now less used than previously because of its undesirable properties of strong odour and skin irritation.
- All chamber disinfectants should be used at the appropriate dilution. Skin contact should be minimised by the use of personal protective equipment, and they should be applied by cloth or sponge to avoid the formation of an airborne aerosol. During and after cleaning processes, all associated used materials should be removed from the chamber quickly. Hot water used for cleaning should not be less than 60°C.
- Safeguarding against infection within chambers involves control of humidity (which should be maintained at the dry end of the range of comfort).
- When the chamber is equipped with a water supply system, samples of the water supplied should be tested by a laboratory at regular intervals These tests must be included in the planned maintenance system.
  - Legionella contamination of fresh water systems on-board vessels may be a relevant parameter for monitoring. This is particularly applicable if the water source is bunkered water from onshore supplies.
  - Legionella is a fresh water bacterium. Production of fresh water from salt water by, for example, reverse osmosis or evaporation, can help to prevent introduction of Legionella into the onboard fresh water systems. However, once in the system, these bacteria are very difficult to get rid of. Similar to with P. Aeruginosa, there are only certain genotypes that will cause illness.
  - The use of appropriate disposable “point of use” medical grade water filters (e.g. Pall Medical filters) on the shower and tap supplies inside the chambers can significantly reduce the risk of introducing pathogenic bacteria into the system. Other relevant Legionella preventative measures in the water system include the
  - cleaning of water pipes, proper temperature of cold and hot water, adding chlorine dioxide, or using copper-silver ionisation.

- Focus should also be on food safety for the divers who are in the chamber, for example, the use of a hazard analysis and critical control point (HACCP) management system.
- Contamination from other sources should also be controlled.
    - Diving suits should not be introduced into the chamber. The diver(s) should wear clean cotton clothes.
    - Technicians performing maintenance or cleaning should wear clean clothes.
    - Shoes are not allowed in the chamber.

2.2 - Prepare the dive

2.2.1 - Remember the diving rules promoted for this handbook

The limitations provided in this section are those mentioned in point 2.3 of book #2 of this handbook

2.2.1.1 - Maximum depth, bottom times according to the means of deployment used

These limitations 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 at sea or 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.
- The oxygen partial pressure limits at work are those promoted by the DCIEM tables, that are similar to those of NOAA (National Oceanic and Atmospheric Administration - USA). However, the limit of 1.4 bar is highlighted for those who want to implement it. Note that IOGP members follow the recommendations of IMCA & DMAC , and limit the O_2 partial pressure to 1.4 bar. The in-water oxygen stops are limited to 1.6 bar (6 msw/20 fsw).
- 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.

Depth		*Bottom times limits*
Metres	***Feet***	***SD & In water***
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*

2.2.1.2 - Surface support used

Diving procedures have to be organized according to the surface support used. These following types of surface support and the procedures for diving from them are described in Book #2 of the handbook:

- Working from barges or moored vessels is explained in section 7 of chapter B.
- Diving from Dynamic Positioning (DP) vessels is discussed in section 8 of chapter B.
- Diving from facilities and self-elevating units is explained in section 9 of chapter B.

The elements from these guidelines should be integrated in the dive plans.

2.2.1.3 - Diving operations with ROVs

ROV's categories and the procedures for using them are explained in section 10 of chapter B of Book #2.
Remember that the following must be in place when ROVs are to be used in conjunction with divers:

- 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.
- 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.
- 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 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 if required.
- The procedures for the recovery of the ROV should be understood by the diving staff.
- 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)

2.2.1.4 - On-shift diving team and assistance personnel

Team size and responsibilities are explained in section 3 of chapter B of Book #2.
There must be sufficient divers and competent people to perform the dives and operate the components of the diving system in addition to the various working tools. Thus, the team's size is evaluated according to the tasks to be performed, the bottom times planned, and the number of daily dives planned to complete the project.
Remember that, in this handbook, the minimum size of a surface supplied diving team using air or nitrox is 6 people:

- 1 diving supervisor: He is in charge of the ongoing dive and the shift
- 1 diver at work: He works under the responsibility of the diving supervisor who manages his decompression.
- 1 diver's tender: He is responsible for dressing the diver and controlling his umbilical.
- 1 standby diver: He is responsible for rescuing the diver if required. He stands by on deck, ready to dive.
- 1 standby diver's tender: He is responsible for dressing the standby diver and controlling his umbilical.
- A dive system technician competent in performing everyday maintenance and on-site repairs.

Trainees:
The persons working in a position as trainees are allowed to operate under the close control of a competent person officially appointed to teach them this function. Thus, they cannot be employed in the position they work as a trainee without surveillance.

DMAC 11 & DMAC 17 say the following about diver medics and medical staff:

- All divers should be trained in the first aid management of those common illnesses and injuries to which they may be exposed. This training should include the use of common items of first aid equipment including oxygen administration systems. In most situations this will form a part of basic diver training *(DMAC 11)*.
- In diving operations where a recompression chamber is on site, sufficient divers should have received additional first aid training to ensure that one trained diver can accompany the injured diver during treatment inside the chamber. Their training should be at "diver medic level"*. Consideration should be given to provision of another outside the chamber, particularly to act as a communication link to remote medical advice. Alternatively this requirement can be met if there is an alternative medically trained person available to provide support at the chamber e.g. rig medic or nurse *(DMAC 11)*.

  Note*: *The function of Diver medic has been invented to compensate for the lack of medical personnel on vessels. A "diver medic" is a diver who has completed an emergency medical course, which corresponds to those provided to advanced first aiders, with additional parts for treating decompression accidents and barotraumas. The duration of this initial course is approximately 15 days. Thus, "diver medics" are not to be considered nurses, whose formation is about five years, and their responsibility is to be limited to the responsibility of a 1st aider only. They are not to be employed for other purposes than helping medics during emergencies and should work only under the directives of a diving doctor who can be on the barge or remote and be contacted by appropriate primary and backup means of communications. When the team works on a vessel where real nurses or doctors are present, it is preferable to ensure that these real medics have a formation in diving medicine and can operate in the chamber.*
- First aid knowledge and skills decline with time after training, particularly where practical use of knowledge and skills is infrequent. This is particularly relevant to decompression illness where an individual first aider's exposure to the illness is likely to be minimal. Personnel assigned specific first aid or diver medic duties must hold valid in date qualifications.
  First aid at work and diver medic qualifications should be valid for no more than three years. However, note that since 2013, IMCA diver medics are required to attempt a refresher training at two year intervals. Where refresher training is carried out less than three months before the expiry date of the current certificate, the start date of the new certificate may begin from the expiry date of the current certificate *(DMAC 11)*.

- A suitable diving qualification is not required to medical staff to enter a chamber. They should, however, be examined and certified “fit” before entering the chamber. *(DMAC 17)*

2.2.1.5 - Penalties and health condition of the divers

The divers must be physically and mentally fit for diving. Also, note that the IMCA organization, which previously prohibited repetitive dives for standard operations, has removed this restriction from its recent guidelines. However, it must be highlighted that some clients continue to adhere to the previous IMCA rule. Consequently, client-specific regulations regarding this matter must be taken into account. It is also important to remember that even if a client's policy prohibits these practices for standard operations, they should be available for an emergency dive if necessary. Additionally, it is recommended to ensure that the standby diver is free of any decompression penalties. This is because the duration of his intervention is unpredictable, and it is preferable to organize to be able to focus on the diver to rescue. The elements provided in the section "Factors Influencing the Likelihood of DCS" of the chapter "Decompression Accidents" in Book #1, which are based on scientific papers, must be taken into account to better understand the problems arising from such dives and decide whether organizing the work with such a procedure is desirable. Among the papers cited, the document *"Short and Repetitive Decompression in Air Diving: The Commercial Diving Experience"* by J.P. Imbert, X. Fructus, and S. Montbarbon mentions the rules derived from the analysis of the Comex databank, which are those of the MT 92 table. These include the limitation to only one repetitive dive. They also note that repetitive dives have been considered challenging to fit within a 12-hour shift, which is why undertaking a long dive is generally preferable. However, this should not be a strict rule, and it is sometimes appropriate to organize a first dive at the beginning of the shift followed by a second one at the end of the shift.

2.2.1.6 - Rules for tending, standby divers intervention, and divers umbilicals

These rules are based on those of the UK-HSE Diving at Work Regulations 1997. Approved Code of Practice and guidance, and also those mentioned in IMCA documents, which are the most practiced.

A. Tender:
   - For umbilicals or lifelines that are tended from the surface, at least one tender is required for each diver in the water.
   - For umbilicals tended from a basket or stage, one tender is required for every two divers in the water. In depths of less than 50 metres, a tender may not be required if an effective mechanical handling system for the umbilical is fitted to the bell or basket. Note that when diving from a DP vessel, it is common to provide a passive 2nd tending point through which the diver passes to enclose his umbilical.

B. Standby diver:
   - A standby diver should be ready to rescue the diver immediately. Thus, he must always be prepared to dive.
   - The standby diver should be dressed to enter the water but does not have to wear a mask or helmet. However, this equipment must be checked and supplied with the relevant gas so that the standby diver can be launched in less than 1 minute
   - There should be one standby diver for every two divers in the water. For surface-supplied diving operations, the standby diver remains on the surface.

C. Umbilical lengths:
   - The standby diver’s umbilical should be 2 metres (7 ft) longer than the diver’s umbilical to allow him to reach the diver in an emergency.
   - When diving from a Dynamic Positioning Vessel, the maximum distance of the diver from the closest part of the propeller is 5 metres. It is, however, not an obligation to be so close to the propeller. The rule for the standby diver is the same as above, so in case of an intervention, he will be 3 m from the closest part of the propeller.
   - The method for calculating these umbilical lengths is indicated in point 8.4.1, “Prepare the umbilicals”, in chapter B of Book #2. This calculation method is more stringent than the one promoted in the document IMCA D-010 as the following elements are considered, which is not the case with the guideline IMCA:
     - The position of the thrusters propellers (in 3D).
     - The ballasting of the vessel.
     - The reference points for checking the depth of the basket.
     - The angle of the basket depending on the current.
     - The position of the diver’s basket and the standby diver’s basket (If the stand by diver’s basket is badly positioned, he will not be able to rescue the diver under certain circumstances).

D. Clarification:

   From the points above, the following clarifications must be made for two divers in the water:
   - Two divers working together at depth: The umbilical length must be identical. In an emergency, things will be worse if the casualty has more umbilical length than his partner. That is why the standby diver must be launched, and the second diver must act as an assistant.
   - One of the divers acts as a bellman in the basket: He has an extension of 2 meters, but he must act only as a bellman and cannot leave the basket to work. Also, he cannot be considered a standby diver because it is

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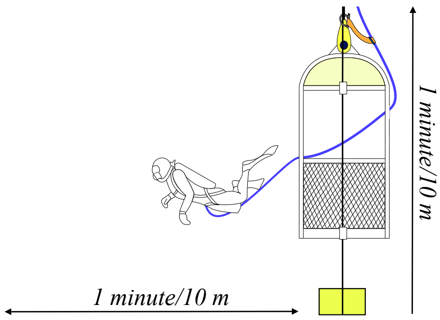
clearly stated that for surface supplied diving, “the standby diver should remain at the surface”. In case of an emergency, the standby diver must be launched, and the bellman and the standby diver assist each other under the direction of the diving supervisor to rescue the casualty as soon as possible.

2.2.1.7 - Bailout endurance and maximum umbilical length deployed

The calculation of the bailout endurance should be based on 1 minute for every 10 metres horizontal excursion plus 1 minute for every 10 metres of depth at a breathing rate between 50 & 75 litres/minute at the surface (62.5 l/min is usually selected). The maximum horizontal distance from the basket should be the one recommended by NORSOK U100. Thus, 45 metres.

Procedure to calculate the diving duration offered by a bailout:

1) *Find the pressure available:*
   Pressure bottle - absolute pressure bottom - working pressure regulator
2) *Find the volume of gas available:*
   Cylinder's floodable volume x Available pressure
3) *Find the breathing duration offered by the cylinder:*
   Available volume / (average consumption x absolute pressure)



2.2.1.8 - Chambers' availability

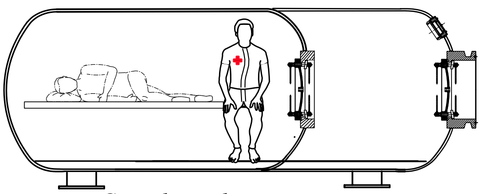
At least a two-compartment chamber designed to provide suitable therapeutic recompression treatment is mandatory.

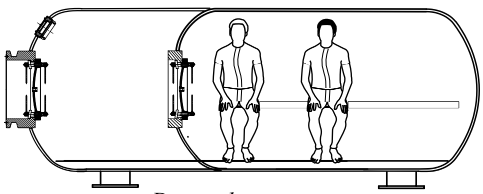
When carrying dives using “in water decompression” procedures, only one chamber is acceptable, because the divers are not using the chamber. In this case, the chamber is only for emergencies.

When carrying Surface O2 decompression procedures, one additional chamber should be mobilised because one chamber is regularly in use and one chamber must be available in case of decompression accident.

The procedure to organize continuous diving operations are detailed in the “Diving management study CCO Ltd #1”:

- The recommendation is to have two decompression chambers in the case that surface oxygen decompression is the method of decompression selected. The reasons that are agreed by most superintendents, diving managers, and diving medical specialists are that:
  - If only one chamber is on site, it will be intensively used for the decompressions and may not be immediately available for the casualty.
  - The casualty can be injured and on a stretcher. If the chamber is in use, the stretcher cannot be introduced into the chamber and the casualty cannot be properly transferred.
  - Note that, as indicated previously, the frequency of Type 2 decompression accidents is higher with surface decompression than in-water decompression and the chamber must be immediately available for the casualty and the diver medic.
  - Having a diver medic in the chamber is required, because the assessment and the assistance of the casualty must be performed by qualified people and a diver who has not this qualification cannot do it. The fact that one diver in decompression who is qualified could act as diver medic is not taken into account as it may not be the case when the accident happens, or the diver may not be in condition to act as diver medic.
  - The treatments for decompression accidents are long treatments, particularly in the case of Type 2 accidents, and the tender and the casualty must be comfortably installed: Small chambers are not originally designed to welcome more than 2 people.
  - If there is only one deck chamber available on the worksite, the rule is to stop the operations whenever the recompression chamber is no longer available.
  - If two chambers are used, in the case of any unplanned occurrence, the diving operations can continue using the second chamber as a back-up.


Casualty under treatment


Divers decompressing

- When carrying out in-water decompression, the recommendation is also to have two decompression chambers for most the reasons indicated above. Nevertheless, because the decompression of the divers is not carried out in the chamber, one decompression chamber can be considered acceptable if the diver at work can be recovered on free time (without decompression stops). This point has to be explained and accessed.

2.2.1.9 - Remembering the guidance “Diver attachment by means of weak link” (IMCA 058)

Divers often need to secure themselves to a structure in order to be able to carry out certain tasks using a safe and reliable weak link device which should break or release at a predetermined force. However, a lot of divers use incorrect devices, and the supervisor must be very attentive to this point. For this reason, procedures taking into account the guidelines of IMCA D 058 should be taken into account to establish safe procedures the divers are comfortable with. Note that this guide line was previously AODC 058.

Design requirements indicated in IMCA D 058

- Supporting a fully equipped working diver in water.
- Breaking/releasing reliably on application of an appropriate load, considered to be around 70 kg.
- Withstanding environmental conditions, e.g. mud, water, grease etc.
- Capable of manual release under tension by the diver.

Unsuitable options indicated by the guidance:

- "Carabino" or "Carabineer" clips

- Cordage

- Cable ties (Ty wraps)

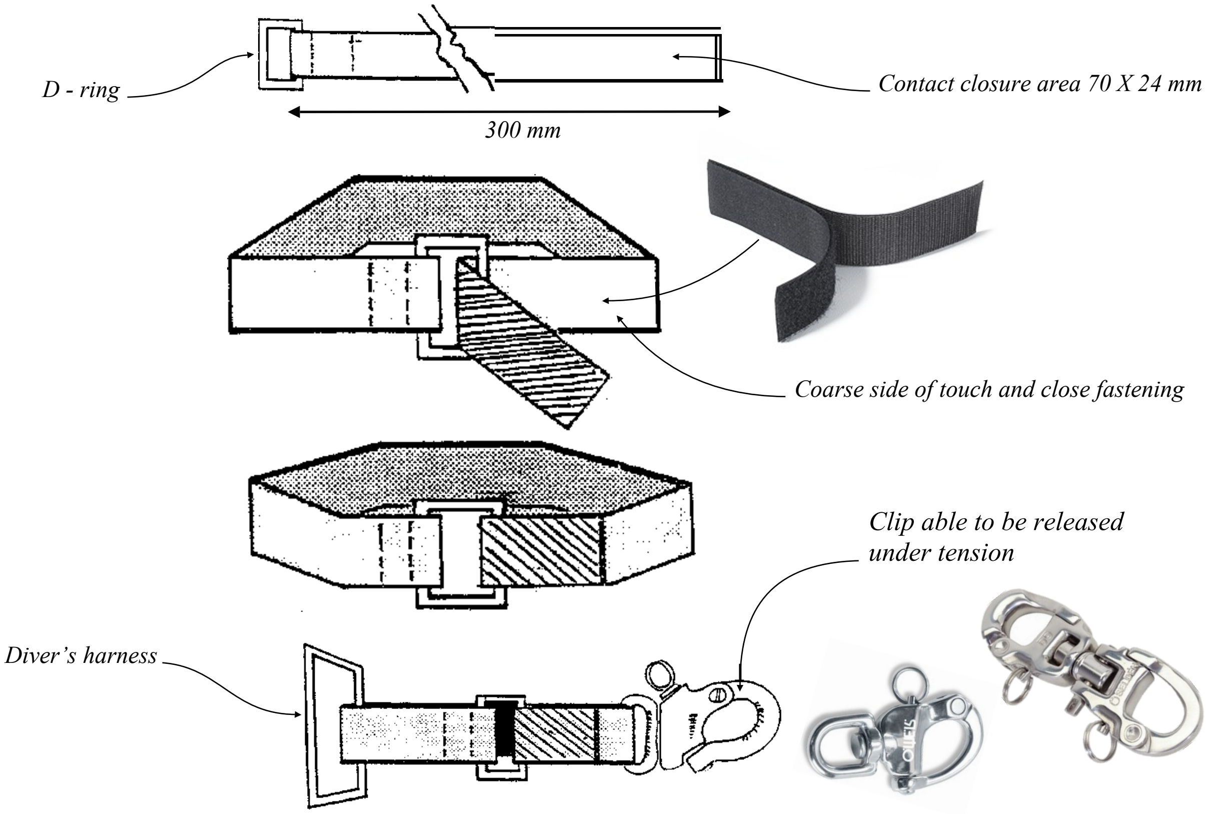
- Welding rods

- Ascenders or "Jumar" clips *(if used alone)*

- Safety hooks

Solution proposed by the guidance:

AODC (today, IMCA) tested a device constructed of "Cosmolon" (another brand is "Velcro"), which is a hook-and-loop fastener of width 24 mm, with a contact closure surface of length 70 mm as indicated below



Rules to apply:

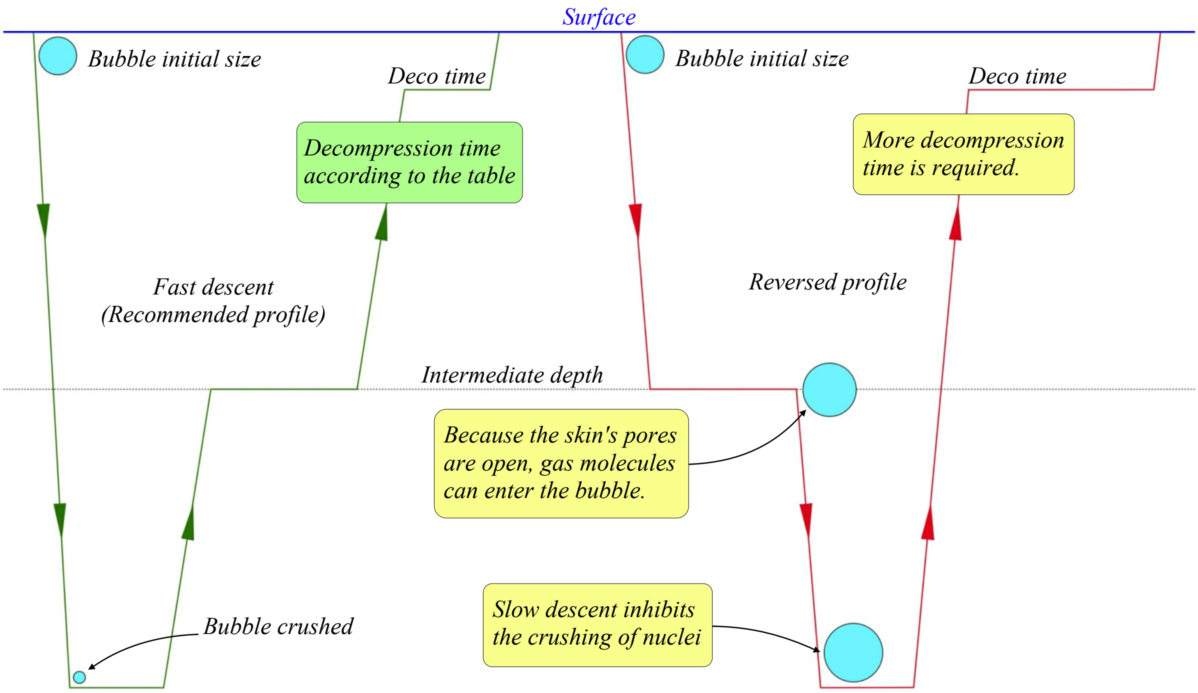
It is not an obligation to fabricate exactly the system proposed by the guidance IMCA D 058 (previously AODC 058). Still, the four rules indicated at the beginning of this topic should be implemented. For this reason, the systems selected must be rigorously tested to see whether they comply with these four requirements before approving them for use.

It must be highlighted to the divers that a sudden loss of position does not happen only to Dynamic Positioning vessels, and that a weakness of the mooring can trigger the same result to an anchored vessel. The effects resulting from a vessel losing its position should be sudden traction of at least several hundred tons for the diver. Because the umbilicals and the harnesses are calculated to withstand very high traction, if there is no proper weak link in place, the weak link will be the diver who will suffer from various traumas such as fractures of the ribs and crushing of organs.
Regarding magnets designed to keep a diver attached to smooth steel structures, they should be calculated to release as a result of traction of 70 kg.

2.2.1.10 - Dives profiles:

In the chapter "Decompression accidents" of Book #1 of this manual, explanations regarding procedures for using the MT92 and DCIEM tables state that *"In the case where work requires the diver to operate at different levels, it will be necessary to organize the dive so that work commences at the deepest level and repeated rises are avoided".*
It is also explained that there are several reasons for starting the work at the deepest depth, the most obvious being that it allows decompression to begin during the ascent to the next level, where the gas absorption process will be more reduced than at the deepest depth. In addition, it is mentioned that all multilevel procedures, including those of DCIEM, are based on this profile that should be the preferred one.

Another theory regarding dive profiles mentioned in Book #1 is based on the Varying Permeability Model from Doctors Yount et al., which suggests that a gas bubble is surrounded by a "skin" that comprises pores through which the gas molecules can pass. This skin becomes impermeable if the bubble is compressed by external pressure to a size where its pores are closed. The pressure at which this phenomenon occurs varies according to the bubble characteristics. To simplify, given that the bubble has an internal pressure, the dissolved gases in each tissue compartment will move across the skin into the bubble and increase its size as long as the tissue tension of the compartment exceeds its internal pressure. As a result, if the diver starts working at an intermediate depth and then finishes the dive at the planned maximum depth, more gas is absorbed by the existing bubbles and nucleus than if the diver goes first to the maximum planned depth, which is a pressure closer to those where the mentioned bubbles and nucleus are expected to become impermeable.
In a document called "Bubble Formation in Supersaturated Gelatin: A Further Investigation of Gas Cavitation Nuclei". Doctors Yount and Yeung concluded that a slow descent inhibits the crushing of nuclei and thus leads to enhanced bubble growth compared to rapid compressions. Therefore, the faster the diver descends, the less time the tissue tension in the faster compartments adjusts to ambient pressure.



Avoiding repeated rises refers to what is commonly called yo-yo dives.
Such dive profiles consist of descending and ascending several times during the dive. Remember that the initial procedures of DCIEM and MT 92 tables allow for one consecutive dive to be performed within a surface interval of less than 15 minutes, but no more. Additionally, repeated ascents and descents during the dive are considered a dangerous practice in many diving manuals. However, bounce dives with up to 10 ascents and descents are common among divers working in fish farms. This practice is supported by the *"Tasmanian Bounce Diving Tables," published in the study "Field Validation of Tasmania's Aquaculture Industry Bounce-Diving Schedules Using Doppler Analysis of Decompression Stress"*, published in 2014 by doctors David R. Smart, Corry Van den Broek, Ron Nishi, P. David Cooper, and David Eastman. This study and the Tasmanian bounce dive tables are also explained in Book #1, where the following restrictions regarding such specific procedures are also provided:

- Multiple ascents and descents result in a loss of working time. It is, therefore, more advantageous for teams involved in construction projects to organize a square profile with level changes during the final ascent.
- This procedure is considered valid in Australia, New Zealand, and perhaps Canada because some authors are Canadian, but nothing has been published in other countries. Therefore, it will be judicious to consult the

authorities of the country where the diving operations are planned to ensure that it can be implemented.

- This procedure has been validated for the DCIEM table only. Therefore, it should be limited to DCIEM tables only as long as similar validation processes are not implemented for the other tables.
- In a document titled "Yo-Yo Diving and Risk of Decompression Sickness in Trainee Military Divers", doctors Emmanuel Gempp and Christophe Peny indicate that the use of these types of profiles to train military divers has resulted in a significantly higher number of incidents than in the commercial diving industry. Therefore, we must keep in mind that, as mentioned in Book #1, the mechanisms that make a bubble pathogenic are not yet fully clarified and seem not only linked to the gas charge.

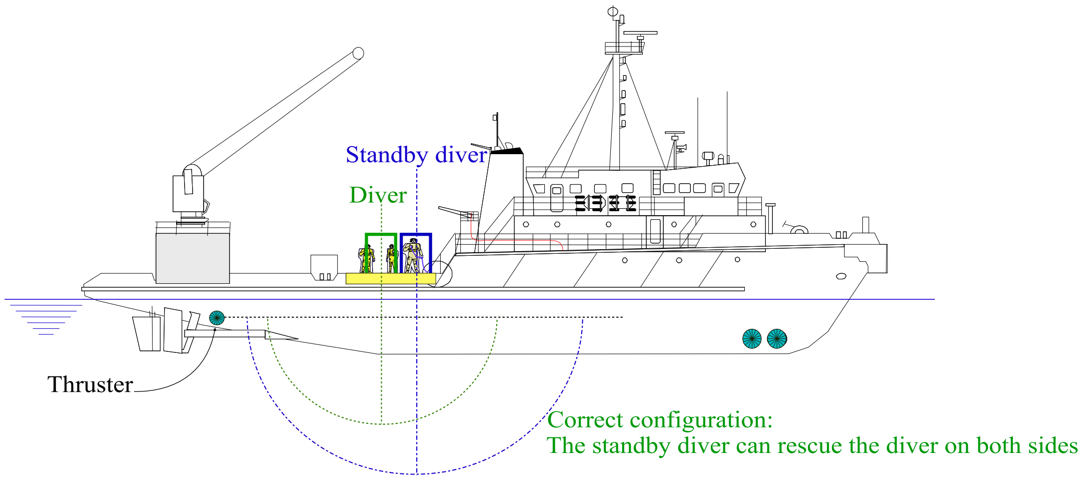
The problems linked to repetitive diving are also discussed in the chapter "Diving Accidents" in Book 1. Note that in their article *"Short and Repetitive Decompression in Air Diving: The Commercial Diving Experience"*, J.P. Imbert, X. Fructus, and S. Montbarbon explain why the MT 92 tables recommend only one repetitive dive. This article also explains that COMEX dive supervisors preferred to organize the work with one long dive per day rather than two short dives.

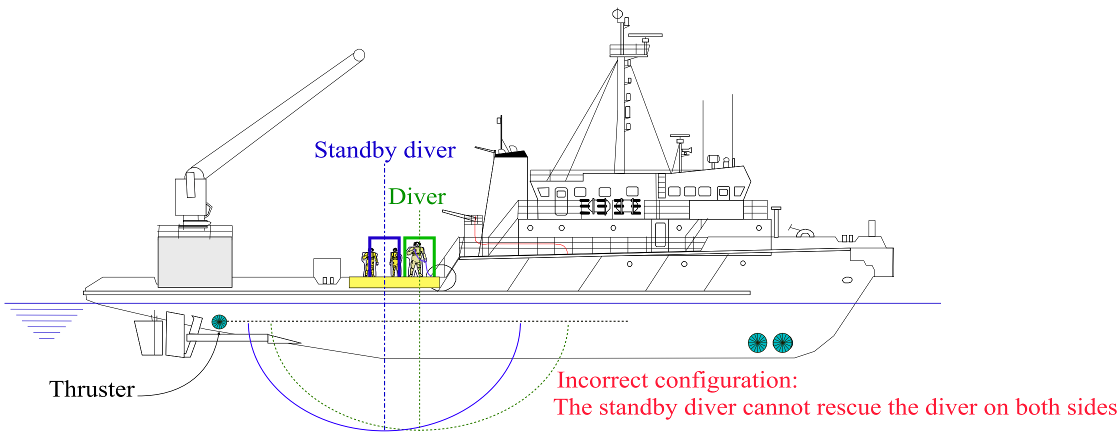
2.2.1.11 - Make sure that decompression dives can be performed safely

A suddenly degraded status may oblige to terminate the dive and recover the diver(s) as soon as possible. For this reason, the surface oxygen decompression table and the chamber should be ready, even though the method of decompression selected is in-water decompression (except if the diving conditions will never change, which is very rare).
As previously indicated in Book 4, regarding the description of the dives systems, the distance of the chamber from the launching station must be as close as possible. The time to reach it must be less than the "Surface interval" indicated by the table selected (7 minutes from leaving the stop at 9 m to the stop at 12 m into the chamber using the DCIEM table, and 4 minutes with the MT 92). Note that the time lost to undress the diver(s), unexpected delays, and the fact that the diver(s) must not run on deck have to be taken into account for the calculation. It is also essential to ensure that the chamber doors can be quickly closed and sealed.
Trip hazards should be removed where possible or highlighted to secure the path between the launching station and the chamber. During his transfer from the basket to the chamber, the diver must be accompanied by a tender who takes care of him. That is to avoid falls and injuries. Note that the diver must wear shoes during this transfer: Walking on deck barefoot is prohibited. If the conditions above cannot be fulfilled, dives with decompression cannot be undertaken.

2.2.1.12 - Remember the correct position of basket when operating from a DP vessel

In Section "Methods used to protect the divers from active propellers and sea-chests" of Book #5, it is said that 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.





Taking into account this rule, twin basket launch and recovery systems with a single A-frame and the baskets positioned sideway, such as the model described in point 2.2.2.2 of this book, comprise a large divers' basket and a small one limited to one person for the standby diver. This specific basket may be incorrectly placed if the set is installed on the wrong side of the ship. As a result, the umbilicals of the divers at work must be restricted to ensure that the standby diver can intervene in all scenarios.
Also, twin basket launch and recovery systems with a single A-frame with the divers' basket entering into the standby diver basket when recovered above the surface (like Russian dolls), also described in point 2.2.2.2, oblige the standby diver to pass through the divers' basket. He will lose time during this phase as he has to ensure that his umbilical will not be caught between the baskets and ensure he is secured during this phase. It must be considered that when diving from a DP vessel, the umbilical of the diver must always be connected to the basket, and never have the diver in the water with his umbilical unsecured to his deployment device.

2.2.1.13 - Rules when establishing a check list

Every equipment must be provided with a check list. The following safety rules to be remembered:

- The operator must not stand in front of devices under pressure (for example,medical lock, relief valves, etc.) when operating them, or in front of gauges (bourdon types or similar) when reading them: In case of failure, the pressure can build up inside, and the device may open or explode in the operator's face. This must be indicated in red on the check list.
- The check list must be organised to ensure that each element of the device checked is in perfect condition. Also, the check list must be organised according to a logical order to make sure that the operator can understand the function of each element checked, and how it can be isolated in case of a problem. A check list indicating only the position of some valves is incorrect.
- To perform a proper check list of the devices carrying gas under pressure such as diving panels, chambers and others, all the regulators must be set to zero and all the valves closed. The devices will be returned to pressure step by step according to the instructions given by the check list. Note that except the chamber, which must be activated 24/24 until the end of the bend watch, the devices used during the dive must be set to zero after the completion of diving operations.
- It is a common practise to secure the valves isolating safety devices like the relief valves in the open position using small cable ties or a similar means, but it often happens that the cable ties used are too strong and prevent the valves from closing in case of leak or malfunction. It must be integrated in the check list that these ties must break without effort when operating the valve. The function of these small ties is to serve as reminder that these valves must be kept open and must not be closed except in an emergency. The technician or the people checking the system must perform a function test to make sure that the size of ties selected is correct. It must be always remembered that in an emergency, these safety valves must be closed without delay.

Particularities of chambers:

- The chamber must be organised to be operated by the operator outside the chamber.
  Except for some elements like the medical lock, and BIB's supply and exhaust, the valves inside the chamber must be kept open.

Valve function	*Inside the chamber*	*Outside the chamber*	*Comments*
Relief valve	Opened	Opened	The function of the relief valve is to prevent any over pressurisation of the chamber. ¼ turn valves are installed to isolate it in case of failure.
Exhaust	Opened	Closed	Make sure that this valve will not be closed inadvertently inside the chamber. If badly situated, a guard must be installed.
Pressurisation (air inlets)	Opened	Closed	A lot of air chambers are still equipped with a ¼ turn valve in place of the normal no return valve recommended by IMCA (or sometimes in addition to). If this valve has been closed inadvertently, the operator will be obliged to use the secondary circuit or pressurise using the entry lock.
BIB's supply	Closed	Closed	They must be closed on both sides: Leakage of oxygen into the chamber could create fire hazard.
BIB's exhaust	Closed	Closed	They must be closed on both sides to avoid any leakage
Analysis	Opened	Opened	The function of these valves is to isolate in case of failure
Medical lock purge/Inlet	Closed	Closed / Surface	The medical lock must be kept at the surface with the door locked.

Valve function	Inside the chamber	Outside the chamber	Comments
Depth gauge	Opened	Open	The function of these valves is to isolate the in case of failure.
Equalising valve main chamber - Entry lock	Opened	Closed	Some chambers have 2 valves . In this case one is closed and one open on each side. When there is only 1 valve, it should be opened in the chamber and closed in the entry lock if the diver is not inside. When the diver is inside the chamber, the valve should be closed inside and opened in the entry lock.

- When the chamber is controlled by a separated panel, the valves on the hull must be kept opened. Thus, for each function of the panel, there must be an isolation valve on the hull.
- The entry lock must be kept at the surface. (The function of this lock is to transfer the personnel to and from the main chamber).

2.2.1.14 - Chamber management

Decompression chambers are described in point #2.20. Access to them is described in point #2.21.2.

Remember that:

- The chamber should be kept at a temperature below 29°C and the ideal temperature is 24°C .
- The alarms of the analysers should be set to ensure that the oxygen percentage in the chamber is between 21% and 23% maximum. The chamber's oxygen percentage should be 21% when it is not used.
- The carbon dioxide should be monitored with a carbon dioxide analyser. The maximum partial pressure is 5 millibar.
- If surface decompression is planned, the deck crew must be briefed on their duties and the procedures to ensure that the divers can enter the chamber as rapidly as possible. It is usual to have the main chamber already pressurised and blow the divers down in the outer lock. The outer lock should then be brought back to surface in case it is required for an emergency.
- Opposite to when surface decompression procedures are used, and the belief of many divers, when the chamber is not used for diving operations using surface decompression, it must be kept at the surface, ready to transfer a casualty on a stretcher. The reason is that with most chambers, it takes approximately 10 minutes to recover the main lock from 12 m to the surface, and it takes about one minute to pressurize it to 12 m. In conclusion, 10 minutes of waiting is too long for an injured diver who needs to be quickly recompressed in the chamber to avoid an additional accident to the one already affecting him. On the opposite, the chamber operator has sufficient time to pressurize the main lock to 12 m if, for emergency reasons, the diver's routine decompression in the water must be performed in the chamber.

Except with a few chambers described in point 2.20.2.3, medical locks are usually a component of the chamber with doors closed against pressure. For this reason, warnings and operating procedures should be displayed near them.

- Safety principle
  - When they are not in use, the locks should remain at the surface with the internal and outer doors closed and clamped.
  - Nobody starts any operation on a lock without informing the other side via the intercom.
  - There must always be someone on each lock side whenever it is operated.
  - The users should try and group items to be transferred to reduce the number of lock manoeuvres.
  - The operators should never stand in front of the door during the operation.
  - Sealed plastic containers may explode in the lock, and the debris can plug the vent pipe. The water and food containers should be opened or have a "vent" hole to equalize during the phases of compressions /decompression.
  - The locks are opening to the external environment, and can be a source of contamination. For this reason, they must be always clean.
  - The chamber operator or his assistant should always check the status of the door after use.
- Locking out operation
  - The diver medic who is inside the chamber calls the chamber operator.
  - If the medical lock is not in the same room than the chamber control, the chamber operator assistant (Lock operator) goes to the lock outside the chamber and signals his presence (port hole, knocks, intercoms). If the lock is in the same room as the chamber operator, the chamber operator informs the diver medic who is inside the chamber that the lock operator is ready.
  - If empty, the lock is pressurised from inside (the lock operator checks for leaks and watches the gauge).
  - The inner door is opened and the material passed into the lock. Note that this time must be minimized.
  - The inner door is closed and so is the inner valve.
  - The chamber operator is informed.

- The lock operator purges the lock a few metres and checks the gauge to confirm the seal has been established.
- The purge is completed, and the valve is left open.
- The door is opened and the equipment removed.
- The door is closed.
- The valve is closed and the interlock is « on ».
- The chamber operator is informed.
- The chamber operator readjusts chamber pressure if necessary.

- Locking in operation
  - The chamber operator informs the divers in the chamber and the lock operator goes to the lock.
  - The diver medic stands by near the lock inside the chamber.
  - The lock operator checks the gauge and opens the purge valve (regardless if the gauge shows any pressure or not).
  - The lock operator leaves the valve open and removes any «locked out » material that may be present.
  - The lock operator passes in whatever was intended and closes the door.
  - The lock operator closes the valve and signals « ready » (intercom, port hole, knocking signal, or all three)
  - The lock operator pressurises to 5 - 10 fsw and stops to check if a seal is obtained (no pressure drop on the gauge).
  - The lock operator resumes pressurisation to about (or just below) chamber pressure, closes the valve and reports to the chamber operator.
  - The diver inside the chamber opens the valve and allows the pressure to equalise.
  - The diver inside the chamber opens the door and gets access to whatever has been transferred.
  - The chamber operator readjusts chamber pressure if necessary.
  - The material that may have been « waiting » for the next lock operation is then passed.
  - The inner door is closed.
  - The inner valve is closed.
  - The chamber operator is informed.
  - The lock operator purges 5 - 10 fsw and checks if a seal is obtained.
  - To be continued according to whatever is necessary…

2.2.2 - Check the working documents

2.2.2.1 - Task plan

The task plan is one of the most important documents and it must be closely reviewed by the supervisor before starting the diving operations. In cases of elements missing or unclear, the problems must be resolved before starting the dives:

- The task plan is an official document and must be agreed by the client.
- The task plan is the referential working document of the diving team based on the technical studies and relevant safety practises: The working phases, safety precautions and recovery measures to be implemented will be based on it.
- The task plan is the means of control of the progress of the operations.
- The task plan is designed to help the supervisor to focus on his tasks: Control the safety, help and manage the diver, and make sure that the job is done according to what is planned, etc.
- The task plan must be agreed and signed by the supervisor.

The task plan is normally built in 7 parts :

- Presentation
- Description of the task
- Risk assessment
- Preparation of the task
- Dive plan
- Management of changes
- Post dive / next task

For any part read, the supervisor must ensure that the key elements are present and comprehensive:

1. Presentation:
   The dive plan is an official document that must be recorded. The following elements should be indicated:
   - The name of the client.
   - The name of the contractors (The team may operate as subcontractor and it must be indicated).
   - The date of issue.
   - The revision and reference numbers (They may be grouped in one reference number).
   - The elements which have been modified if there were one or several previous revisions.
   - The name and the company of the issuer (the task plan may have been issued by a subcontractor).
   - The name and the signature of the company managers who have agreed the dive plan.
   - The name and signature of the client representatives who have checked and agreed the task plan for the client.
   - The date of agreement of the task plan by the client.
2. Description of the task:
   The team must have an idea of the entire project to which their task is linked. For this reason, this section describes what to do, where to do it, why, and how to do it. The following information should be provided:
   - A description of the whole project (what to do)
   - The reason for the task within the scope of the project (why to do it)
   - Maps indicating where the job is planned (where to do it)
   - A study of the weather conditions with the prevailing winds, currents, and records of the tides.
   - The job site description with precise drawings of the facility where the intervention is planned to take place, the means of access, and the hazards such as:
     - Pipelines, risers (and what they carry)
     - Impressed current system, electrical's
     - Water intakes and discharge
     - Scaffoldings
     - Every item which can trouble the access and the safety of the divers.
   - The surface support to be used and the procedure of divers deployment. There must be:
     - A technical description with precise drawings
     - The study of positioning of the surface support along the facility
   - The task plan is often part of an ensemble of operations. For this reason, there must be:
     - A description of the previous task.
     - Status of how things should be on the job site after completing the previous task.
   - The step by step procedure. This part must be precise because the dive plan is built on it. There must be:
     - The description and precise drawings of the elements to be installed if any.
     - The important calculations for the installation (traction force needed, apparent and real weight, etc.)
     - The simultaneous tasks linked to the task plan (for example lifting…)
     - The lift plan and rigging plan if the crane has to be used.
     - The step by step sequences of installation or inspection, using drawings and precise descriptions.

- The technical information about particular materials to be used.
- The technical references from professional organizations, client operating procedures, and international and local rules on which the sequences of installation and the safety must be based.

3. Risk assessment

The process of a risk assessment is:

- Identify the hazards
- Assess the risks
- Identify the suitable measures
- Record
- Implement the control measures
- Ensure that the residual risks are as low as reasonably practical

This document must be as compact as possible and cover precisely only the task to be performed. Generally the clients request to have the risk assessment under their company format for internal reasons, and in this case, the official document must be under this format. Nevertheless, for the diver's toolbox talk, the risk assessment can be under the format they are used to having if that helps them to have an easier evaluation. The risk assessment must cover (but is not limited to) the following phases:

- Access to the diving station. In case of crossing of the deck where other people are working, it must indicate:
  - The dangerous areas.
  - The path to follow to reach the dive station.
- Preparation of the task:
  - Diving system function test
  - Filling the bail-outs and banks
  - Preparation of the LARS
  - Prepare the pieces to be sent to the bottom
  - Move to some parts of the deck
  - Any additional task which may be necessary to prepare the dive…
- Launching the dives / diver deployment
  - LARS deployment
  - Transfer the diver
  - Lower the basket (descent speed)
  - Descent to storage depth
- Access to the job site
  - Distance basket/bell to job site
  - Strong underwater currents
  - Swell / waves
  - Job site access
  - Job site protection removal
  - Impressed current, electrical wires, pipes, intakes…(all these should be secured and highlighted)
  - Down line installation
- Risks linked to diving
  - Technical break downs (regulators, helmet , gauges…)
  - Loss of communication
  - Narcosis
  - Diving profiles (yo-yo, inverse…)
  - Umbilical stuck or entangled
  - Misunderstanding
  - Dangerous marine life
  - DP alerts, mooring failure, or risk of collision…
  - Fishing lines
- Risks linked to the task
  - Simultaneous operation (lifting…)
  - Use of particular tools (welding, burning, cutting, lever hoists ….)
  - Risks linked to the several phases of the task (load transfers, use of lift bags, matching…)
- Diver recovery
  - Umbilical recovery
  - Contingencies due to technical problems of the LARS
  - Ascent speed
  - Transfer to deck
  - Leaving the basket
  - Transfer to chamber (surface decompression)
- Leaving the dive station
  - Securing the dive system & transfer to accommodations.

4. Preparation of the task:
   This part lists the elements that should be in place before launching the dive.
   - List of Tools needed: The tools are those identified in the “step by step procedure”, but not limited to:
     - Spanners, pliers, hammers, lump hammers, chisels…
     - Impact wrenches + sockets, Tensioners, saws…
     - Air lift, water jets, HP water jets…
     - Down lines, carabineers, basket tools …
     - Particular tools planned…
     - Inspection tools if the job is inspection (CP meter, UT, ACFM…)
   - List of rigging for the pieces to be installed if any (It must strictly conform to the rigging and lifting plans).
     - Wire slings (certificate number indicated)
     - Soft sling (certificate number indicated)
     - shackles (ref. number indicated)
     - Jaw winches, chain blocks, lever hoist…
     - Lift bags (certificate number indicated)
   - Communications (Note that the chain of communication may change from one task to another).
     - Chain of communications for the execution of the task with channels and/or interphone numbers
     - Chain of communications in case of emergency with channels and phone numbers
   - List of documents to be in place before starting.
     - List of consignation certificates
     - List of conflicting activities & simultaneous jobs
     - List of permit to work (with some clients there may be more than one, particularly when cold and hot works are planned)
     - Dive permit: The form to be used (client or internal) must be specified
   - List of work site protection
     - Barriers, segregations, etc.
     - Conflicting activities to be stopped during the dive.
     - Maritime signalization.
     - External boat management procedures.
   - List of extra deck personnel (names and function).
5. Dive plan:
   It is based on the “step by step procedure” indicated in the description of the task. However the steps must be detailed more precisely. Take care of the following:
   - The depth indicated must be to those indicated in the description
   - The range of the tides should be specified
   - The preferred diving method must be indicated.
   - The decompression reinforcement procedure to apply must be indicated for remembering
   - The number of divers planned for the task must be specified
   - Each step must be indicated by a reference number
   - The action of each step must be clearly explained
   - There must be a column to “tick” when the action is completed
   - When the dive plan involves a particular action from the surface, it must be indicated
   - The hazards must be integrated in the dive plan and highlighted
   - Check the dive profiles planned *(see in point 5.2.1.9 - Dives profiles)*
   - Ensure that the duration and depth planned conform to the maximum bottom times approved in the company procedure *(Normally the recommendations of doctors Shields and Lee)*
6. Management of changes plan:
   It is part of the bridging documents and must be agreed by the client.
   On occasions, site conditions of equipment, resources, timing, schedule or sequence may mean that an approved procedure cannot be followed. In this case, it is essential that a management of change process is considered to examine and identify risks associated with change and ensuring that the risks are controlled “As Low As Reasonably Practicable”.
   The plan must define clearly the process of change:
   - Which form to use (company form or client form)
   - The procedure to present the change request. A change request should provide the following:
     - What to change and what are the risks
     - How the change is implemented.
     - How the appropriate risk reducing measures are implemented.
   - The level of authorities for approval.
7. Post task:
   It must indicate the following:
   - The situation on the job site at completion of the task, and next task planned.

- The safety procedures to be in place to protect the divers.
  - The behaviour of the divers after their dive.
  - The minimum interval before the next dive.

2.2.2.2 - Check the emergency response plan

The emergency response plan is part of the bridging documents and must be agreed by the client.
The diving superintendent/supervisor must ensure that this plan is comprehensive, easy to implement, and that the information provided is reliable. In case of missing or incorrect information, the problems seen must be solved before starting the dives.

- Check the document
  - The name of the client is indicated.
  - The name of the contractor is indicated.
  - If the company is operating as subcontractor, the name of the main contractor is indicated.
  - Date of issue.
  - Number of revision.
  - If there were one or several previous revisions, what have been modified.
  - The name of the issuer.
  - The names and the signatures of the company representatives who have agreed to the emergency response plan.
  - The names and signatures of the client representatives who have checked and agreed to the emergency response plan for the client.
  - The date of agreement of the emergency response plan by the client.
  - There must be a chart indicating the chain of command and means of contacts.
  - The procedure for MEDEVAC (Medical Evacuation) must be properly explained (chart) and simple.
  - At least two diving medical specialist are indicated.
  - The diving emergency procedures are listed and clearly explained.
  - The procedures in case of fire and abandon barge are properly explained and simple.
- Some important elements of the document must be checked:
  - The diving medical specialists agreed for the project must be called using the satellite phone in the chamber room.
  - The persons indicated in the chain of command and supposed to be in direct contact with the supervisor are still in the position indicated and their contact details are valid.

2.2.2.3 - Check the permits to work and the isolation certificates

Note that even though they are based on the same principle, clients' permit to work systems have variations that must be taken into account for a correct reading. These permit to work systems are often imposed by the client in place of the company system.

- Cold work & hot work permits are in force in most systems.
- Some clients may have additional permits like:
  - Equipment disjointing.
  - Electrical intervention.
  - Diving operation.

The application of the permit is usually done by the person in charge of the task for the company. It may be the diving supervisor or the diving superintendent. Many clients request the applicants to pass their module "permit to work" before being authorised to do so.
In most systems, the permit to work application must be submitted at least 24 hrs before the start of the project. The duration of validity are from a few hours to several weeks depending on the client's systems.
When the permit to work returns to the dive station, it is signed by the authorising authority (usually the Offshore Installation Manager for the offshore facilities) and the chain of command identified in the permit to work system (the area authority and the performing authority).
The task indicated in the permit should conform to what is planned, but experiences have shown that mistakes can happen. In this case, the operation cannot start until the problems are resolved.

A. Cheek the permit to work form:
   At reception of the permit to work, the diving supervisor/superintendent must ensure that:
   - The work description conforms to what is indicated in the task / dive plan.
   - The work description corresponds to the permit to work selected.
   - The hazard identification corresponds to what is indicated in the risk assessment.
   - The control measures corresponds to what is indicated in the risk assessment.
   - The necessary protective equipment conforms to the control measures indicated in the risk assessment.
   - The document is signed by the authorising authority and the appointed chain of command.

- The permit system, and the dates of validity are indicated in the dedicated slots.

B. Check the supporting documents and isolation certificates
The isolation certification is part of the client's permit to work system. As with the main form, the diving supervisor /superintendent must ensure that:
   - The supporting documents and isolation certificates attached to the permit to work conform to what is indicated.
   - The isolation certificates are fully completed, signed, and dated, with duration of the isolation conforming to what is indicated on the permit to work.
   - The supporting documents and isolation certificates also conform to the list indicated in the task plan.

2.2.2.4 - About the ADCI "Delta-P diving checklist"

The documents listed above should have been done using risk assessments, taking into account all dangerous areas. Thus, the effects of suction on divers should be part of the process, and protective measures should be evaluated, and as indicated in the above list, be in place before diving.
Equipment and worksite configurations where differential pressures are likely to happen and create high suctions are known to create situations where the divers can be sucked and be deeply injured or killed.
To ensure that the protection measures regarding these elements are in place, the ADCI Delta-p checklist should be used when writing the various task and dive plans.
This checklist has been created at the request of the US Occupational Safety and Health Administration (OSHA) after a series of accidents linked to defective isolations of elements capable of creating suctions in power generation facilities and other work sites. It provides step-by-step safety measures to be in place when preparing the dive plan, before, during, and after the dive.
When checking the task plans and isolation certificates, the diving supervisor should ensure that at least the guidelines from this checklist are present and eventually add other protections.
In case of doubt regarding the process of isolation in place regarding pressure differential, and this document is not mentioned among the references, it can be downloaded from our website through this address:
https://diving-rov-specialists.com/index_htm_files/docs-41-delta-p-diving-checklist.pdf
It can also be downloaded from this address:
https://www.naylornetwork.com/adc-advisory/pdf/Delta-P_Diving_Checklist.01.28.22.FINAL.pdf

2.2.2.5 - About the document AODC 055 - "Protection of water intake points for diver safety"

This document, that can be linked to the document discussed above, was published in 1991 by AODC, today IMCA, in response to a safety notice emitted by the UK government (DEn Safety Notice 10/89) that required that *"inlets to fire pumps should be suitably guarded in order to minimise or even preclude the necessity for having pumps in non automatic start mode for reasons of diver safety"* (note that this document is no longer available on the internet).
It provides guidelines for the calculation of suction, and the evaluation of protections to be installed to avoid the diver to be harmed by the differential pressure arising from these sea chests.
This guideline is based on a maximum water current of one knot (about 0.5 m/sec) in the immediate vicinity of the water intake point to, according to its authors, *"allow a diver to manoeuvre without spending too large a proportion of his energy fighting the effect of the current, and avoid the possibility of him impacting with the structure with the consequent potential for injury"*
The calculations for construction of protective structures provided by this guideline are based on the following formula of the minimum surface area to restrict the average velocity to no more than 0.5 m/sec at the surface of the structure :

$$\frac{Fcu.\ m/sec}{0.5\ m/sec} = Area\ A\ sq.\ m$$

Where:
F = maximum flow rate of the pump
Area A sq.m   = total area of the protective structure, less the area of the material forming the protective structure , and less the area presented by 2 divers and their equipment (assumed to be 2 sq.m.)

In addition to this formula, the guidance says:
- The maximum mesh size, or the maximum size of any opening if not a mesh-type construction, should not exceed an area equivalent to a square of 20 x 20 cm, or if rectangular in shape, 28 x 14 cm, i.e. 400 sq. cm. In the case of a non mesh-type construction the openings should be spread over the whole area of the protective structure.
- Where the protective device is being designed for an existing water intake, the design must ensure that there is no restriction of velocity at the actual point of intake.

Most boats are provided with intake protections. For this reason, the following formula is provided to assess whether their suction is equal to or less than 0.5 m/sec (1 knot):

$$\frac{\text{F cu. m/sec}}{\text{Area A sq. m}} = \text{Current in m/sec}$$

The authors also say that the presence of marine growth results in increased water velocity, so will affect the principles

and calculations on which this guidance is based. For this reason, they recommend regular inspections and cleaning of the sea chests considered.
The authors also recommend installing protection on all water intakes and not only those of fire pumps.

Note that this guideline can be used to calculate the suction of water inlets on the job site. Thus, it can be considered a valuable complement to the checklist provided by ADCI. However, it also has its limitations:

- The calculation is based on a mathematical formula and thus remains theoretical.
- An additional protection placed over a sea chest may increase the vessel's dragging or catch undesirable debris such as plastic bags.
- A miscalculation is possible.

For the reasons above, it is preferable to involve the boat manufacturer in such design and for providing the relevant proof of conformity to existing protections.

2.2.3 - Ensure the diving system is ready and the weather conditions suitable

2.2.3.1 - Ensure the checklists of the dive system have been appropriately done

The safety rules for establishing a checklist are indicated in Book #4. Note that each element of the diving system must be provided with a suitable checklist. Thus, using documents from another dive system is incorrect. Also, the list of necessary verifications should include housekeeping and the organization of the dive station.
The diving supervisor may delegate some verifications to experienced divers, but he is responsible for the checks of the diving system. He must:
Ensure that the people who are performing the check list are competent and understand how important it is to do it properly. The following text from IMCA D 022 should be kept in mind: *"After a period of time,when the team has become completely familiar with procedures, there is sometimes a tendency to become casual. This is typically seen in the use of check lists. Items are ticked off without being properly checked. It is at this stage that accidents may happen"*.

- Ensure that all the checklists have been performed.
- Ensure that all the points of the check lists have been properly covered.
- Ensure that each checklist is signed with the date and time indicated.
- Organise corrective action to close up the defects which could have been reported (dive tech).
- Delay, or abort the dive if the defects seen cannot be solved immediately.
- Inform the Offshore Construction Manager of every defect which could delay the starting of the operation or abort it.
- Start the dive only if the system is in optimal condition.
- Log any defect found during the checks, even trivial, for further evaluation.

2.2.3.2 - Ensure the weather conditions are suitable

Weather and currents are explained in section #5 of chapter B of Book #2. The weather forecasts should be available in the dive control. The diving supervisor should ensure that:

- The observation of the sky conforms to what is indicated in the weather forecast, and no sign of imminent degradation is visible.
- The waves are suitable for diving
- The current conforms to the prevision and is suitable for diving.
- The vessel is not affected by the weather conditions.

2.2.4 - Toolbox talk

Toolbox talks are means of discussion between the supervisor and the diving team. They allow the persons in charge of the team to monitor the diving team's health and spirit. Several topics, not only the task to perform during the shift, must be discussed during this meeting.

2.2.4.1 - Health / temporary unfitness to dive

The divers are responsible for their own safety and the safety of others who may be affected by their actions. It must be remembered that a dive performed by people not in good health, under medical treatment, under stress or excessive fatigue, constitute a hazard for the diver himself, but also the other divers. That is why the divers must indicate any health problem or stress they are suffering to the diving supervisor. On his side the diving supervisor must implement all the necessary precautions to be sure that the divers sent underwater are in condition to dive safely.

- Any disease, ear infection or inability to equilibrate the ears must be indicated to the diving medical specialist.
- A diver under medical treatment must be agreed to dive by the diving medical specialist.
- Emotional distress must be reported to the management and the medic. In this case, the person must not be allowed to dive without evaluation and green light from the medic. Support and evacuation from the job site may have to be implemented.
- Note that the symptoms of diseases linked to diving are listed and explained in the manual “Air diving accident”.
- Particular problems which may be posed by divers under alcohol or drugs: The common offshore safety policies have clearly stated the consumption of alcohol and drugs as a breach to the safety rules. The divers who may be under the influence of these substances must not dive and should be evacuated from the worksite. The identification of drugs and management procedures to avoid having people under drug abuse on the worksite is explained in the Diving management study CCO Ltd #3 “Implement a drug and alcohol abuse policy”.

2.2.4.2 - Task & dive plan

To have efficient and positive discussion, the written task plan should be transmitted to the divers at least 1 day before the toolbox talk to let them understand and think about what is planned. The superintendent / supervisor must remember that people discovering a work procedure will not ask good questions because they have to understand what to do first.

- The organisation of the team and the function of every team member is clarified during the discussion of the task plan.
- The risk assessment must be reviewed by the team and additional precautions can be implemented.
- This is the last stage of the risk assessment. Because the divers may be exposed to potential risks, and they are responsible for their safety, they must have their say. They can request more precautions if they consider the preventive measures insufficient.
- At the end of the discussion, the divers must be able to explain to the supervisor what they have to do.

2.2.4.3 - Site rules

Each work site has particular rules linked to the procedures applied by the client. These particular rules must be explained to the members of the team.

2.2.4.4 - Safety and onboard life

The safety directly linked to the task to be performed must be discussed during the discussion of the task plan (and the risk assessment). Nevertheless, it is important to discuss all other aspects of the safety onboard the vessel.

- The safety observation cards emitted by the members of the team and the onboard personnel are exposed and discussed.
- Some safety flashes can be discussed.
- The safety recommendations from the management and the clients are explained and discussed.
- Some safety procedures like emergency alarms must be remembered.
- Diver rescue procedures must be remembered and discussed.
- Drills must be organised regularly and discussed.
- Various subjects like living conditions on board, crew changes, etc., must be discussed.

2.2.5 - Last pre-dive checks

The permit to dive is an official document indicating that all the pre-dive checks have been completed and the dive can be performed safely.
When the client does not have a permit to dive system in place, the document to issue will be the form from the company.
Before signing this document, the diving supervisor must ensure that the last precautions and documents are in place.

2.2.5.1 - Work site inspection

In most of the permit to work systems the area authority must ensure that the worksite conforms to the safety requirement prior to signing the permit to work, but when the diving supervisor has access to the facility where the conflicting activities are performed, it is better to ensure that the things are secured as requested by himself/herself.
Normally, this inspection has to be performed with the client representative.

2.2.5.2 - Pieces to install

The pieces to install must be checked by the dive team.

- The rigging must conform to what is indicated in the dive plan.
- The certification of the slings must be those indicated.

2.2.5.3 - Communications to the deck and to the clients

Communications with the diving team:

- The radio communication to the lead diver must be checked.
- The radio communication to the diving technician must be checked.
- Wired communications to the dive station (2 way loudspeaker) must be tested.
- If the chamber is separated from the dive station, the audio and video communications must be checked.
- If the supervisor has no direct vision of the dive station, the video installed is working.

Communications to the client representatives:

- The radios are working.
- The phone to the client office is working.

If an ROV is planned to be used simultaneously:

- The main communications (hands free) with the ROV pilot are checked.
- The backup communications with the ROV are checked.
- The screen indicating the positions of the diver(s) and of the ROV is working.

If the dive is planned with crane operations:

- The direct communications to the crane operator are working.
- Communications to the deck foreman and the banksman are working.

If the dive is planned with external machines: (for example, grouting…)

- The communications to the operators are working.

2.2.5.4 - Surface support pre-dive checks

The vessel check list is the responsibility of the master and must be done prior to starting the dive. It is however the responsibility of the diving supervisor to ensure that this check list has been done. The following elements should be verified and be included in the permit to dive.

Anchored vessels

- The mooring must be checked, particularly at the sensitive points.
- The tension of the mooring must conform to the anchoring plan.
- The distance from the work site conforms to what is planned.
- The signalization of the vessel is in place.
    - By day light: The alpha flag must be on the mast and visible and the signal buoys “Ball-Diamond-Ball” must be in position.
    - By night time the lights “Red-White-Red” must be in place and visible.
- The surrounding vessels must be warned to keep outside the 500 m radius around the job site.
- The weather forecast is confirmed suitable for diving by the master.
- Main and backup communications have been tested.
- The OIM and the area authority are informed that the diving operation is going to start.
- An announcement warning the people on deck that the diving operation is going to start has been performed.
- The supervisor opens the warning light above the dive station. This light is the complement of the the other warnings.

Dynamic positioning vessels:

- The vessel must be designed as explained in section "Diving from DP vessels" in chapter B of Book #2.
- Before moving in location and starting the "location set up check list" the DP pre-dive check list must have been completed
- The drift test should have been completed and conform to the previsions: At the end of the drift test, the vessel must be at the place indicated in the calculation submitted before (a margin of few metres is acceptable).
- The emergency lights (green, yellow, red, and blue) and audio alarms must have been tested. At the end of the test, the lights are kept open, and the alarm status must be on Red.
- The main priority (hands free) communication between the DP officer and the dive control must have been tested.
- The backup communication has been tested.
- The position of the vessel and the worksite is visible on the screen in the dive control.
- The position of the vessel above or along side the worksite conforms to what was planned.
- The reference systems conform to what is planned. For remembering:
  - Three references should be on line and at least two should be of a different type. If the work is in water depths of less than 60 m, the scope 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. Also, one of the 3 reference systems should be a radio or surface position reference.
  - Two wind sensors in different locations, with separate supplies and cable routes, should be provided.
  - Two vertical reference sensors should be provided.
  - Three gyro compasses should be provided.
- The signalization of the vessel is in place.
  - By day light: The alpha flag must be on the mast and visible and the signal buoys "Ball-Diamond-Ball" must be in position
  - By night time the lights "Red-White-Red" must be in place and visible.
- The surrounding vessels must be warned to keep outside the 500 m radius around the job site.
- The weather forecast is confirmed suitable for diving by the master.
- The OIM and the area authority are informed that the diving operation is going to start.
- An announcement warning the people on deck that the diving operations are going to start has been performed.
- At the end of the check list the diving supervisor opens the warning light above the dive station. This light is the complement of the announcement of the bridge informing the people on deck that diving operations are in progress.
- At the end of the checks, the DP operator gives the "30 minute pre-dive notice" to the supervisor. During this time, the DP crew complete the check lists and the monitoring of the vessel in working position. The supervisor uses these 30 minutes to dress the divers.
- At the end of the "30 min notice", the DP officer switches the alarm status lights from red to green and inform verbally the diving supervisor that the dive can start. The document from the bridge is sent to the supervisor this time.

Static surface supports

- The signalization of the diving work is in place:
  - By day light: The alpha flag must be on the mast and visible and the signal buoys "ball-Diamond-Ball" must be in position.
  - By night time, the lights "Red -White-Red" must be in place, visible and the work station illuminated.
- The surrounding vessels must be warned to keep outside the 500 m radius around the job site.
- The weather forecast is confirmed suitable for diving by the facility control.
- Main and backup communications have been tested.
- The Offshore Installation Manager (OIM) and the Area authority are informed that the diving operation is going to start.
- An announcement warning the people on the facility that the diving operation is going to start has been performed.
- The supervisor opens the warning light above the dive station. This light is the complement of the announcement of the bridge informing the people on the facility that diving operations are in progress.

2.2.5.5 - Oxygen supply pre-dive checks

Pure oxygen delivered to the diver at depth could result of quasi immediate acute oxygen crisis. To avoid such problem the supervisor must:

- Ensure that the oxygen supply is either disconnected from the diving panel or isolated.
- Ensure that the lines have been flushed with air.
- Ensure that the analysers indicate 21% oxygen.

2.2.5.6 - Divers pre-dive checks

Check that the divers know what they have to do and how the work site is organised.
Some time can have elapsed between the time the diver is going to intervene and the toolbox talk. The work site may have been changed, and the diver(s), occupied by other tasks on deck may have forgotten some important elements.
Before dressing the diver it is important to ensure that the diver(s) know(s):

- Where is the work site (depth, level if on a jacket…)?
- How to reach the work site (situation of the swim line on the jobsite…)?
- What are the potential dangers to avoid such water intakes, electrical systems, pipe lines, risers, etc., and where these dangers are situated?
- If working from a DP vessel and using taut wire, where is the taut wire?
- Where is the down line, the surface reference tugger if used? Note that there may be also several down lines.
- Where are the tools (basket tool or dedicated places)?
- What has been done on the bottom?
- What will be his/her task?
- What are the difficulties he/they may have to face, and what are the risks and the precautions to implement?

2.2.5.7 - Check the tenders

Before opening the guards and overboard the baskets the team must ensure that:

- The tenders have safety harnesses, and work vests in good condition.
- The stop falls are secured to the dedicated rings.

5.2.5.8 - Overboard the baskets

Before completing the dressing of the divers, the LARS must be deployed and the baskets ready to welcome the diver(s).

- The clump weight are at depth, except on DP vessel where they must be kept at the surface until the green light to dive.
- The baskets are stable (slightly resting on deck), secured, and ready for a smooth and safe transfer.

2.2.5.9 - Check the standby diver

Most safety and governmental organizations say that these checks must be appropriately documented. For this reason, in addition to the signed checklist, most teams record the communications between the diver in charge of the verification and the diving supervisor.
Note that it is a relevant practice to start with communications. Also, the “black box” should be started at this moment. This practice has been in force for a long time with most organizations. As an example, IMCA D 022 point 5.4 / chapter 5 communications says: *“Record all voice communications, starting with the pre-dive checks. 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”.*

- The communications are clear, and the black box is confirmed on “record”
- The bail-out is checked and reported in good condition with a valid inspection stamp.
- The bail-out content (pressure x volume) conforms with the maximum excursion limits calculation.
- The full face mask is in good condition.
- The spider is in good condition.
- The light installed on the full face mask or the helmet is working.
- The camera is working (if installed).
- The no-return valve has been tested and is confirmed in good condition.
- The supply from the bail-out has been tested, and the regulator works appropriately with this supply.
- The bail-out is open and closed on the mask (or helmet).
- After completing the bail-out checks, the mask is supplied with the appropriate breathing gas (main supply).
- The regulator and free flow work appropriately using the main supply.
- The depth gauge (‘pneumo’) has been tested and works appropriately.
- The diver has a harness in good condition, in service for less than five years, and less than ten years old.
- The umbilical is secured to the harness.
- The umbilical length is adjusted as requested by the supervisor.
- The diver has a knife.
- The diver has fins.
- The diver has a proper diving suit to maintain his thermal balance in the waters where the operation is planned.
- The diver has gloves.
- The diver has a rescue lanyard.
- The standby diver has no decompression penalty and is fit to dive.
- The diver reports he is ready to go if requested.

2.2.5.10 - Check the diver(s)

Of course, the elements that apply to the standby diver apply to the divers. Thus their checklist is similar, except that some points linked to their function are added or changed.

- The communications are clear.
- The bail-out is checked and reported in good condition with a valid inspection stamp.
- The bail-out content (pressure x volume) conforms with the maximum excursion limits calculation.
- The helmet is in good condition.
- The neck dam is in good condition.
- The light works appropriately.
- The camera works appropriately.
- The no-return valve has been tested and is confirmed in good condition.
- The supply from the bail-out has been tested, and the regulator works appropriately with this supply.
- The bail-out is open and closed on the helmet.
- After completing the bail-out checks, the helmet is supplied with the appropriate breathing gas (main supply).
- The regulator and free flow work appropriately using the main supply.
- The depth gauge (‘pneumo’) has been tested and works appropriately.
- The neck dam is properly adjusted.
- The helmet is secured and cannot be lost.
- The diver has a proper diving suit to maintain his thermal balance in the waters where the operation is planned.
- The diver has a harness in good condition, in service for less than five years, and less than ten years old.
- The umbilical is secured to the harness.
- The umbilical length is adjusted as requested by the supervisor.
- The diver has a knife.
- The diver has fins (if the diver is not wearing them, they must be in the basket).
- The diver has his tools.
- The diver has a weak link conforming to IMCA 58.
- The diver has gloves.
- The diver has no penalty and is fit to dive.
- The diver reports that he is ready to go.

3 - Diving operations

3.1 - Launching the dive

3.1.1 - Launching using basket

The following elements should be in place:

- The umbilicals are ready to be deployed.
- The vessel is stable, and there is no excessive rolling, pitching, or other movements which may jeopardize the safety of the personnel.
- If the standby diver is launched using a basket, the wave's height is less than 1.5 m, and there is no excessive “splashing” at the surface.
- The wave's height is less than 1 m if the standby diver is launched using a ladder.
- The 2 supplies of the Launch and Recovery system are started allowing the operator to switch the backup immediately if necessary.
- If available, the ROV is launched to monitor the adjustment of the clump weight.
- The clump weight is lowered to depth and adjusted using the information from the ROV. If the ROV is unavailable, the clump weight is stopped 5 - 10 m above the work site and adjusted later with the divers.
- The divers hold the handles and are secured in the middle of the basket. There is no hand that could be crushed during the descent. They are secured by lanyards (mandatory with DP vessels).
- The chain guards (or another system) of the deployment device are in place.
- The basket is controlled by the tenders to avoid any swinging when moving out. The winch operator must check whether the basket is controllable before moving it out.
- The distance from the basket to the hull is sufficient to avoid any shock to the hull.
- The descent to the water is slow and under control. The operator is ready to operate the brake if necessary.
- The basket is stopped 0.5 m below the surface to allow the divers to perform their helmet leak test safely.
- When the leak test is performed, and the divers confirm they are “ready to go”, the dive can be launched.
- The maximum descent speed indicated by DCIEM is 18 m/ minute (Same as for the ascent).
- On Dynamic positioning vessels, the descent may be periodically stopped to allow the tenders to install whips securing the umbilicals to the wires of the basket (main or guide wire).
- The divers are in contact with the supervisor during the descent. The winch operator is also in direct contact with the supervisor, ready to stop the descent at any moment.
- The divers must request to stop the descent if necessary (ears, problems with equipment…).
- The divers must stay in the basket during the descent.
- The descent is considered completed when the basket is stopped at its planned storage depth.
- The divers must not leave the basket without the consent of the supervisor.

Possible undesirable events *(but not limited to)*

Events	*Potential consequences*	*Action diver*	*Action surface*
Uncontrollable basket movements During 1st lift	- Injuries to personnel - Falls to deck or at sea - Damage to equipment	- Inform the supervisor, stay in the middle of the basket and hold the handles	- Stop the action and return the basket to the initial position - Dive to be cancelled
Too many waves in the splash zone	- Divers thrown to parts of the basket or ejected and thrown to the hull with injuries and potential fatalities as the consequences - The standby diver cannot be launched - leak test impossible	- Request aborting and pulling out immediately - Stay in the middle of the basket and hold the handles	- Recover the basket immediately - Dive aborted
Loss of control during the descent	- Divers injured (ears) - Umbilicals not following (potential injuries) - Narcosis (below 30 m) - Basket deeper than the planned storage	- Request to stop the descent immediately - Self check and request to abort if injuries occur	- Stop the descent (breaks) - Status diver - Abort the dive if injuries occur (even minor) - Check the reason of the loss of control and implement corrective action - Dive aborted if the reason is technical
Too strong current	- Fatigue - Hypercapnia - Intervention of the standby diver dangerous or impossible	- Send the information to the supervisor as soon as detected	- Stop the descent - Assess the situation with the divers - Abort the dive if too much current

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3.1.2 - Launching using ladder

Remember that ladders cannot be used with DP vessels.

The following elements should be in place:

- The umbilicals are ready to be deployed.
- The vessel is stable, and there is no excessive rolling, pitching, or other movements which may jeopardize the safety of the personnel.
- The wave's height is less than 1 m, and there is no excessive "splashing" at the surface.
- The ladder is secured and conforms to the description provided in point #2.1 "Ladders".
- Jumping in the water is strictly forbidden: The descent is done prudently on the ladder.
- When they are in the water, the divers must perform their helmet 0.5 m below the surface before coming down.
- When the leak test is completed, and the divers report that they are "ready to go", the dive can be launched.
- The maximum descent speed indicated by DCIEM is 18 m/minutes (Same as for the ascent).
- The divers are in contact with the supervisor during the descent.
- When arrived at the planned depth, the divers move directly to the job site.

Possible undesirable events

Events	*Potential consequences*	*Action diver*	*Action surface*
Too many waves in the splash zone Or too much ladder movements	- Diver thrown onto the hull with injuries and potential fatality as consequences - The diver can be injured by the ladder - The standby diver cannot be launched - Leak test impossible	- Request aborting and climb back immediately	- Recover the diver immediately - Dive aborted
Diver too fast during the descent	- Diver injured (ears) - Narcosis (below 30 m) - Diver deeper than the working depth planned	- Stop the descent immediately and correct according the normal speed	- Stop the descent (hold the umbilical) - Status diver - Abort the dive if injuries (even minors) - Implement control measures (slowing down using the umbilical/ self control by the diver)
Too strong current detected	- Fatigue - Hypercapnia - Intervention of the standby diver dangerous or impossible	- Send the information to the supervisor as soon as detected	- Stop the descent - Assess the situation with the divers - Abort the dive if too much current

3.2 - Divers at work

The divers are usually considered at work when they are arrived at the direct proximity of the work site.

When deploying the divers to the work site, the following actions should be performed:

- During the descent, the divers inform the supervisor of the physical condition and whether they can see the work site and the clump weight.
- The basket should be stopped 1 - 2 metres above the clump weight. That can be monitored by the divers and, if available, the ROV. If there is no ROV and the clump weight has to be adjusted, that has to be done and monitored by the divers. A mark is then made on the winch's cable to avoid losing time each dive. However, remember the possible variation of height due to the tides. A solution to manage the tides is to adjust the clump weight sufficiently high not to be trapped whatever the tide and close enough to reduce the distance of the divers from the work site.
- If the dive is performed using a basket (or a wet bell), the divers stay in the deployment device as long as the supervisor does not give the green light to leave it. The reason is that some final adjustments and, eventually, a recovery to the surface may happen. The time the divers are arrived at depth and leave the basket must be indicated in the logs.
- Before leaving the basket, the divers ensure that the underwater conditions are practicable: The basket is stable, the current is fair, their equipment works appropriately.
- The divers ensure that obstacles do not jeopardize their umbilicals and that they can immediately return to the basket without being entangled. If that is not possible, one of the divers should act as a tender.
- If not already installed, the divers install the down-line at the dedicated place.
- The job's installation must be done according to the task plan.
- The divers should be reminded of potential dangers to avoid, such as intakes, electrical equipment and cables, pipelines, ROV, etc.
- If the divers are working from a DP vessel using a taut wire, the taut wire's location must be remembered with the fact that it may periodically be readjusted.

Possible undesirable events

Events	Potential risk / consequences	Action divers	Action surface
Loss of gas supply	Diver deprived of air - Panic - Asphyxia - Drowning	<u>If the surface is not informed or the supply is not reestablished:</u> - Report to the surface - Open the bail out / free flow off - Return to the basket - Use the reserve from the basket (and close the bail out) - Inform the surface that they are secured and ready for ascent <u>If the surface is informed and the supply has been reestablished:</u> - Close the bail out if opened previously (ensuring it is really closed) - If not in the basket, return to the basket. Dive is aborted	- Switch on backup air on panel - Instruct the divers to return to the basket - The dive has to be aborted - Warn the standby diver in the case assistance is needed (If the gas is not reestablished, send the standby) - Start ascent when the divers are ready - Prepare the team surface O2 decompression or omitted decompression procedure if the gas is not reestablished. Note: The reason of the incident will have to be investigated and solved before launching another dive
Problems linked to diving equipment: Regulator not working properly	- Difficulties to breathe - Fatigue - Hypercapnia - Panic	- Open the free flow - Inform the surface and return to the basket if already outside - Prepare for ascent	- Switch on backup supply line on panel to ensure that the problem is not from the regulator of the panel. - Dive to be stopped: Request the diver to prepare for ascent. - The standby diver is warned in case of an assistance is needed - Assess the problem and prepare the transfer to chamber if needed.
Problems linked to diving material: Inaccurate display of the depth gauge	Decompression accident due to table selection not corresponding to the real depth	- Follow the instructions of the diving supervisor.	<u>The supervisor discovers the problem during the dive:</u> - Ask the diver to return to the basket - Check with the 2nd diver, or send the standby diver to give a reading. - Apply the decompression for the maximum depth on the job site. <u>The supervisor discovers the problem after the dive:</u> - Apply an hyperbaric treatment for omitted decompression.

Events	Potential risk / consequences	Action divers	Action surface
Diver injured but conscious	- Diver suffering - Panic - Unable to return to the basket *See chart #1 at the end of this chapter.*	- Inform the surface - Give information that can be used for rescuing - Try to return to the basket	<u>Supervisor:</u> - Prepare and send the standby diver - Alert the team & diver medics - Alert the bridge - Request ROV monitoring if available - Come up on the umbilical if the injured diver is able to speak and give indications - Wait for the standby diver if the casualty is not able to speak clearly - Apply the procedure for an unconscious diver if the casualty does not answer appropriately to questions. - Prepare the chamber]for decompression in (if needed). - Organize the MEDEVAC <u>Diver Medic or Nurse (if available):</u> - Assess the injury and report - Apply adequate 1st aid treatment - One medic goes in the chamber with the casualty, the 2nd one assists him from the external. - Establish communication with the Diving Medical Specialists - Prepare the casualty for MEDEVAC if required
Diver unconscious Due to wrong gas supply , loss of supply , or other reason (explosion, shocks, etc.)	- Multiple injuries - Diver not able to speak - Asphyxia *(loss of supply or wrong gas)* - Fatality *See chart #2 at the end of this chapter.*	<u>Stand by diver:</u> - Follow the diver's umbilical to locate the diver. - If the diver's gas supply is lost, open the bailout supply. - If the gas supply is correct, open the free-flow valve, flush the line and inform the surface to be sure that the casualty is on the proper supply. - Report the status to the surface - Recover diver to the basket as quickly as possible. - Check the ventilation of the casualty, and assist if necessary and possible. - Secure the diver in the basket. - Report when ready for the ascent - On ascending, maintain the airways open and ensure the casualty is exhaling. Check also for any limb that may be at the external of the basket and crushed during the recovery.	<u>Supervisor:</u> - Switch to Backup supply - Raise the alarm (inform the bridge) - Alert the team & diver medics - Send the standby diver - Request monitoring from the ROV if available - When the standby diver is on the casualty, request him to flush the helmet (to be sure that there is no wrong gas in the line) - Record the status of the casualty and instruct the diver medic. - The tenders recover the umbilicals when requested only. - Prepare the chamber in case of omitted decompression - When the casualty is secured in the basket, start the ascent - During the ascent, remind the standby diver about the airways and ensure that the casualty has no limbs that could be injured. - When the casualty is on deck, ensure a smooth transfer to the chamber as soon as possible if decompression is needed. - When the casualty is in the chamber, (if needed) apply the appropriate table. - Inform the company management - Organise the MEDEVAC <u>Diver Medic or Nurse (if available):</u> - Remove the casualty from the basket - Check airways; CPR may be necessary. - If defibrillation is mandatory and the chamber is not equipped with an adequate defibrillator, do it outside the chamber. - Report the 1st assessment. *Continuation on the next page*

Events	Potential risk / consequences	Action divers	Action surface
Diver unconscious Due to wrong gas supply , loss of supply , or other reason (explosion, shocks, etc.) *Continuation*	- Multiple injuries - Diver not able to speak - Asphyxia *(loss of supply or wrong gas)* - Fatality *See chart #2 at the end of this chapter.*	Stand by diver: See the relevant actions on the previous page	*Continuation of the previous page* - Transfer into the chamber as quickly as possible if decompression is needed. - One medic goes in the chamber with the casualty, the 2nd one assists him from the external. - Apply adequate 1st aid treatment. - Establish communication with the Diving Medical Specialists - Prepare the casualty for MEDEVAC if required
Underwater current coming up	- CO_2 poisoning (Hypercapnia) - Fatigue - Inability to return to the basket - Possible panic - Launching of the standby diver compromised	If not informed by the surface: - Inform the surface that the status of the current is changing, and return to the basket . If informed by the surface: - Return to the basket when requested	Information by: - Indicators on deck (current meter, ropes with loads, visual on surface) - Breathing rate of the diver (normal rate is 1 breath every 4-5 seconds) -Information from the diver. Action: - Recover the diver as soon as possible - The dive must be stopped if the stand- by cannot be launched also. Thus if the stand by is launched using a ladder, the limitation must be calculated according to this means of transfer
Swell and sea motion increasing / Sudden bad weather (squalls)	- Diving difficult at the surface with potential injuries and fatalities (The divers can be thrown into structures) - Difficulties to stabilise - Surface support becoming unstable - Recovering difficult and potentially dangerous - launching of the standby diver impossible	- Report to surface and return to the basket - Hold the handles during the recovery	- Recover the diver without delay. - Prepare the chamber for surface O_2 decompression - Warn the team regarding the movements of the vessel during the recovery - If diving from DP vessel , and if possible, request the DP officer to change the heading for a more stable heading for the recovery of the basket
Poor visibility or No visibility	- Diver lost (he may be near dangerous appliances) Panic (with all the consequences) - loss of production	- Umbilicals and down lines are the references lines - The diver follows his umbilical and returns to the basket if lost	- Recover the diver to the basket (using the umbilical). - Send the standby diver to assist if needed Note: The supervisor ensures that the divers are sufficiently trained to work in the conditions planned.
Narcosis	- Illogical behaviour - Panic and all the consequences associated	- The diver feeling incoming narcosis (if he can) report to surface and return to the basket Note: Most of the young divers will not notice the narcosis coming.	- Ask the diver(s) to return to the basket - Prepare and send the standby diver if no answer - Recover the diver to deck.
Misunderstanding	- Actions not corresponding to what is requested and that can trigger dangerous acts - Potential injuries & fatalities - Job improperly performed - Damage to material	- Always repeats the instructions of the supervisor to indicate him that the instructions are understood. - When the instructions are unclear, request clarification.	- If the diver does not perform the task correctly the diver must stop him and ensure that the procedure explained during the toolbox talk is followed. - If he considers that he has not the control of the diver, the supervisor must stop the dive
Injuries or electric shocks by ROVs	- Caught by thruster - Umbilical entanglement - Obstruction - Diver caught on bottom - Injured by collision - Electrocution *Note:* *See Diving with Remotely Operated Vehicles (ROV)/Point 10.4.2 of chap. B of Book #2*	Precautions to apply always: - The divers must never be at direct proximity of the ROV - In case of entanglement, request the ROV to be stopped and “cold” before recovering the umbilical	Precautions to apply always: - Ensure that the ROV is sufficiently far from the divers and umbilicals In case of accident: - Request the ROV to be “cold” - Send the standby to recover the diver. - The procedure to recover a casualty is the procedure for unconscious diver.

Events	Potential risk / consequences	Action divers	Action surface
Diver entangled in fishing lines or down-line & messenger line	- Unable to return to the basket - Injuries due to fishing hooks - panic.	- Inform the surface of his situation - Stay calm and try to cut the lines methodically	- Send the standby diver to assist the diver (approach prudently). - Keep in communication with the diver and reassure him
Diver adrift at the surface	- The diver may have cut his umbilical in an emergency, or had it cut accidentally. - He may have had to jettison his helmet and bail-out bottle and may be injured.	- If conscious, try to attract the attention of the people on deck.	- If the diver cannot be recovered immediately, alert the installation's safety boat and standby vessel - Members of the diving team keep the drifting diver in sight for as long as possible and note his direction of drift.
Failure of the mooring	- Collision with the structure with possible damage to the dive station. - Surface support adrift and erratic. - Diver pulled off. - Vessel and passengers endanger.	- Return immediately to the basket , and prepare for ascent. - Inform the supervisor if injured - If the basket is damaged, ascend along the cables.	- Alert the divers and request to return immediately to the basket. - Recover the basket as soon as possible and transfer the divers in the chamber for surface O2 decompression on the deck. - In case of an injured or unconscious diver, send the stand by diver , and recover accordingly.
DP yellow alarm	- A failure in a sub-system has occurred causing a loss of position; - Vessel's position keeping performance is deteriorating and/or unstable; - Vessel's indicated position deviates beyond limits - Risk of collision exists from another vessel; - Weather conditions are judged to be becoming unsuitable for DP diving; - Any condition which could reduce the status from normal	- Suspend the work and move to safe location as instructed by the supervisor. - Ensure that they can move quickly into the basket if required.	- The diving supervisor should instruct the divers to suspend operations and move to a safe location. - The diving supervisor contacts the bridge to be informed of the evolution of the status - If the diving supervisor is unable to get clear advice from the DPO he will instruct divers to return to the bell/basket
DP red status	- 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	- Suspend the work and move to the basket as quickly as possible - If some stops: Prepare for surface O2 decompression, or procedure for omitted decompression.	- 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
Vessel in critical status while the divers are in decompression in the chamber	- Possible sinking… - Possible capsize - Abandon vessel *See chart #3 at the end of this chapter.*	The divers: - Keep communications with the supervisor and the chamber operator and be ready to follow the instructions. The chamber operator: - Follow the instructions from the supervisor, and prepare for 2 scenarios: • The decompression can be completed. • The decompression must be interrupted and the return to surface accelerated.	1) Abandon vessel unlikely: - Keep informed by the bridge - Try to complete the decompression 2) Abandon vessel: - Divers performing surface O2 deco: Try to perform the maximum decompression time at 12 m (40 ft) and prepare for ascent to surface in one minute - Divers on treatment table (table 5, 6, etc.): Apply the procedure in case of a disaster in Book #1 "Description & prevention of diving accidents" - Pure O2 to be breathed at the surface and during transfer to the closest facility.
Main basket's wire parted	- Recovering not possible - The basket may be entangled with the cable	- Remove the cable and ensure that the umbilicals are not caught - Go into the basket and prepare for recovering using the guide wires - If the removal of the cables is not possible on time, the divers should ascend along the cables or in the basket of the standby diver	- Inform the divers and request to remove the parted cable if disturbing the recovering of the basket - Send the standby diver to help - Recover the basket using the guide wires - If no time, recover without basket or using the standby diver's basket

Events	Potential risk / consequences	Action divers	Action surface
Snagged umbilical	- Unable to return to the basket. - Panic.	- Report to the supervisor. - Sort out the situation, ensure that the umbilical is not entangled and in direct way to the basket.	- Inform the tenders of the situation - Warn the stand by diver - Send the stand by to assist if the diver has difficulties to sort out the situation
Loss of communication	- No instruction and information coming to and from the diver.	<u>If the surface is not aware:</u> - Attract the attention of the tender using line (umbilical) and supervisor using video signals - Return to the basket and prepare for recovering <u>If the surface is attracting attention using line or flashing signals</u> - Return to the basket , prepare to ascend and inform the surface using line signals or hand signals to video	<u>If the diver is not aware:</u> - Attract the diver's attention by line signals, flashing signals. - If available, the ROV, can be used to flash the diver. <u>If the diver is not answering, or any doubts of his condition</u> : - Send the standby diver - Start ascent if the problem is not solvable immediately in a reliable manner.
Fire in control room	- Diving supervisor unable to manage the dive - The system may be damaged *See chart #4 at the end of this chapter.*	- Return immediately in the basket - Prepare for eventual loss of supply and communications	- Wear a BA set if necessary and recall the divers to surface. - Alert the bridge (fire crew) - Fight the fire (extinguishers) <u>If the panel or the chamber is still working:</u> - Start deco accordingly to what is available and the most practical <u>If the panel and the chamber are out of order:</u> - If possible, organise direct supply from the compressor and the quads to the basket. <u>If nothing possible:</u> - Organize O2 at the surface and transfer to the facility to shore as soon as possible.

Chart #1: Recovering of a conscious injured diver

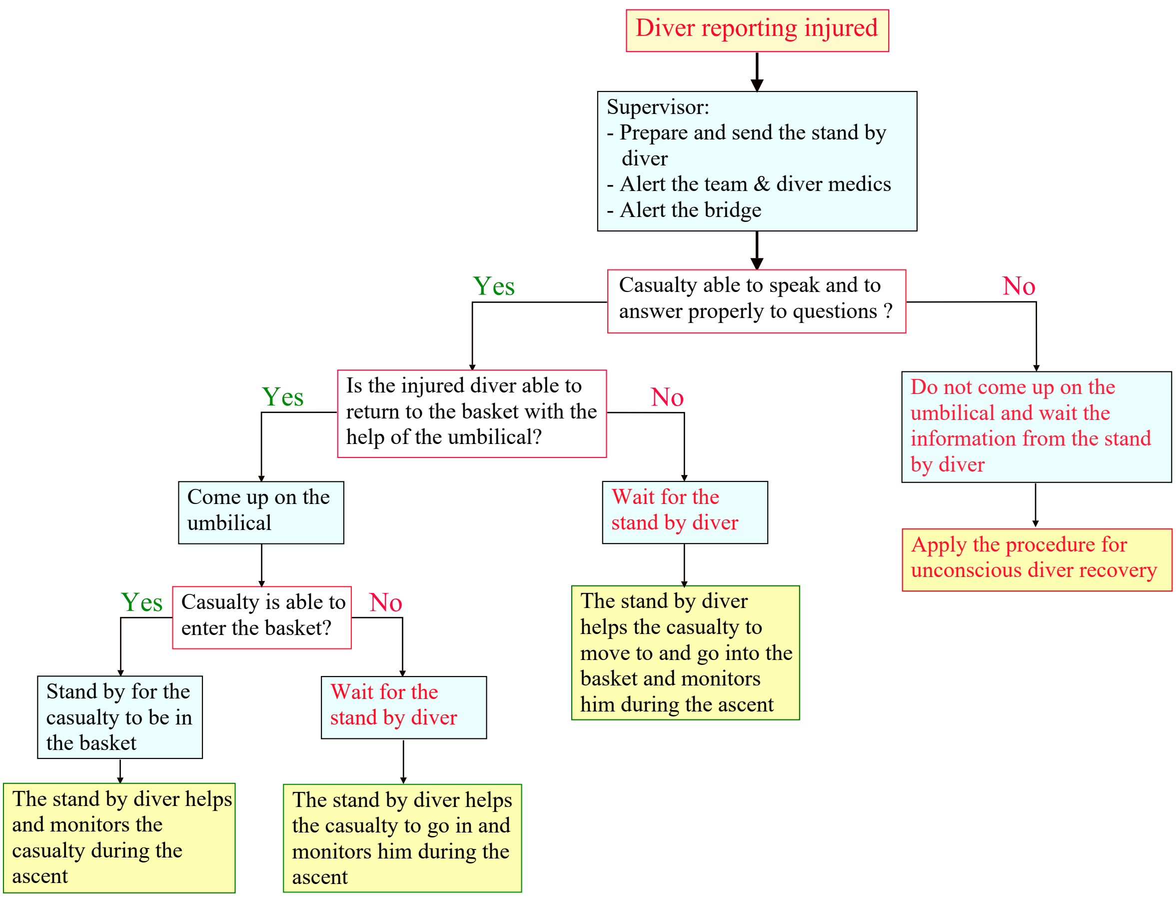


Chart #2: Unconscious diver Recovery

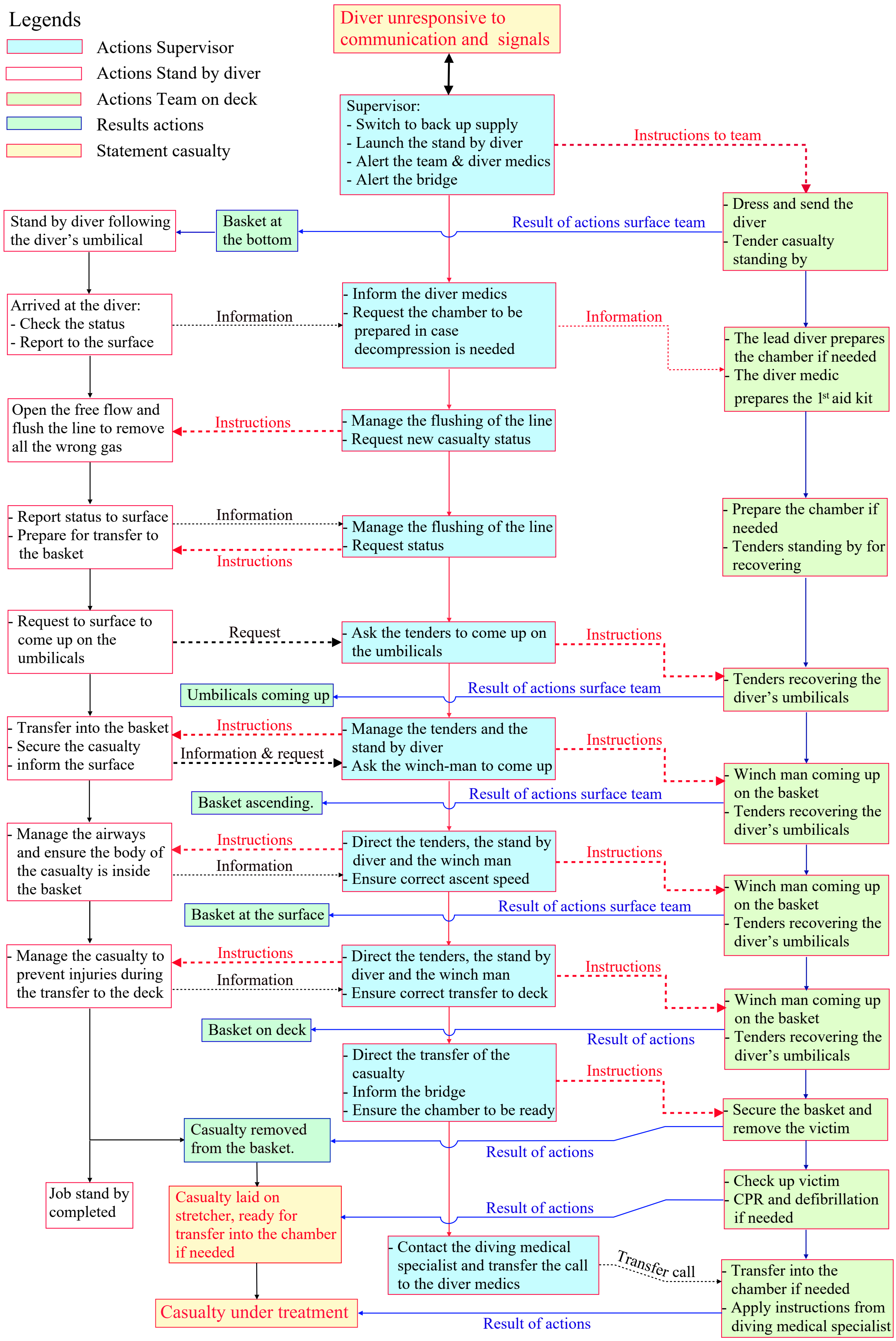


Chart #3: Vessel in critical status while divers are in the chamber

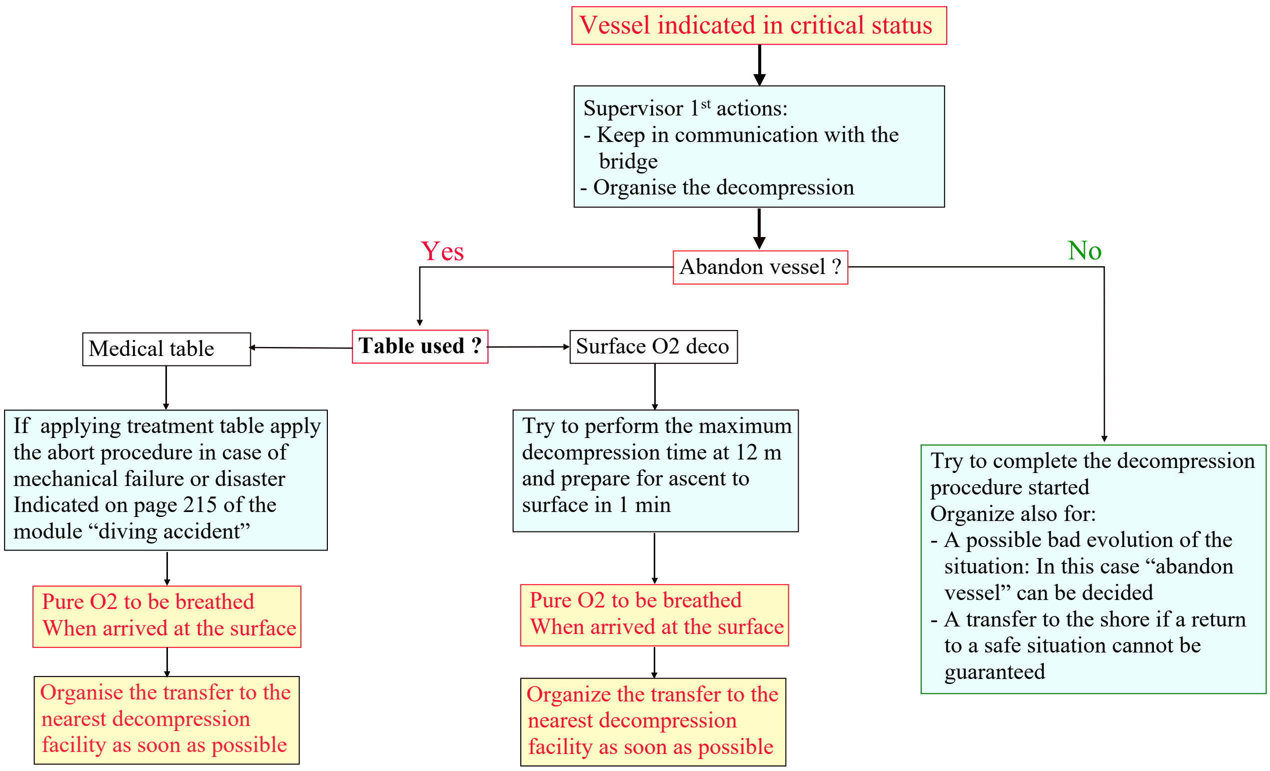
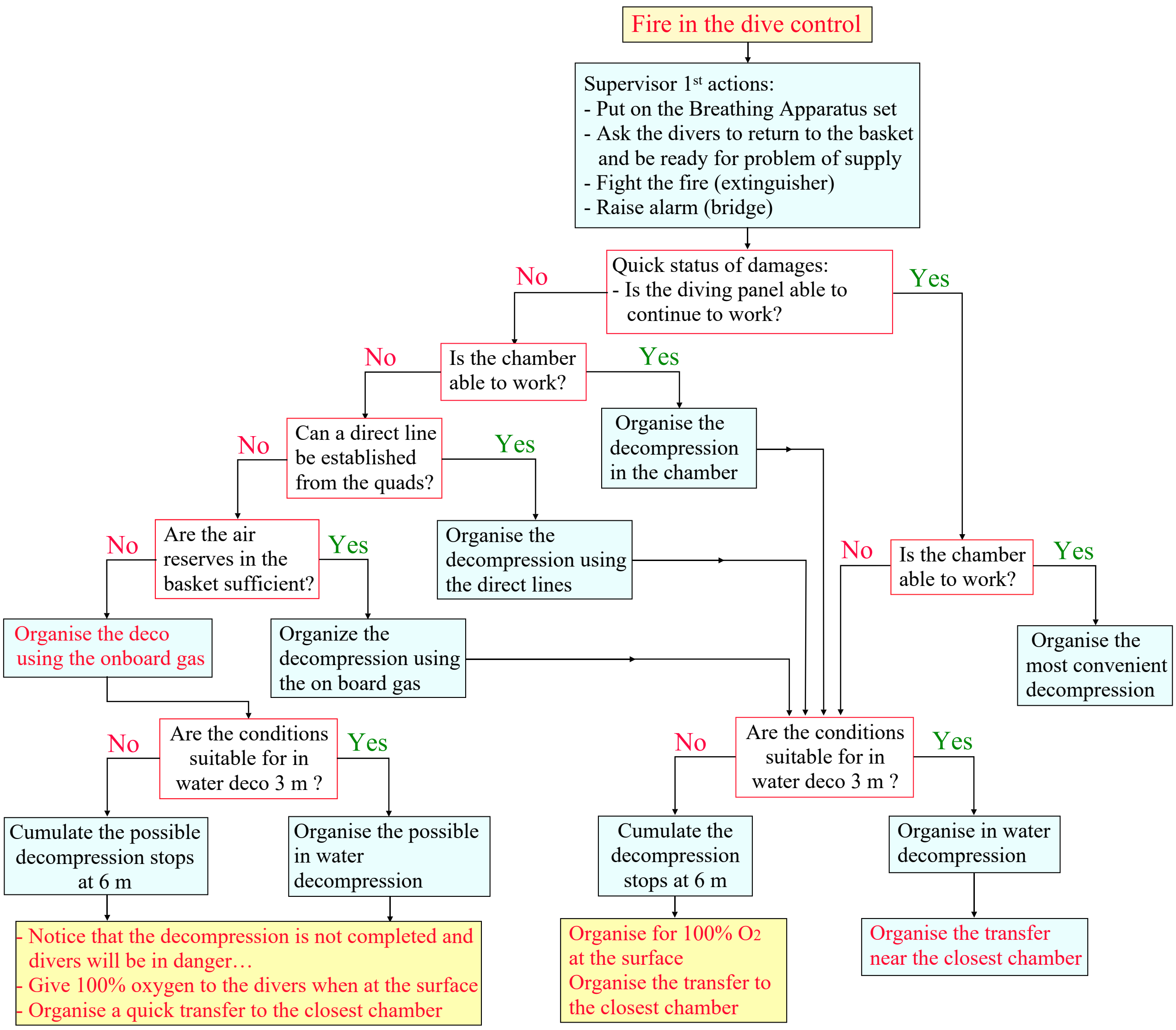


Chart #4: Fire in the dive control and divers requesting decompression



3.3 - Recover the diver

The UK-HSE bottom times limits should be strictly applied.
The supervisor informs the diver of the remaining time approximately 10 minutes before the end of the bottom time.
Depending of the distance from the basket, the diver has to be recalled between 5 and 2 minutes before the end of the planned bottom time.
The diver moves back to the basket, ensuring that his umbilical is not going to be entangled, and informs the supervisor when ready to come up. The supervisor ensures that the diver's umbilical is appropriately and gradually recovered according to the progress of the diver toward the basket.
When the diver is secured in the basket, the supervisor requests the winch-man to bring up the basket. The normal ascent rate is indicated by the table. MT92/2019 can be between 9 and 15 m /min, and DCIEM is 18 m/min.
The ascent speed must be rigorously controlled. If the ascent is too fast, the supervisor must request the winchman to slow down the ascent, wait to catch the normal ascent time scheduled, and continue the ascent normally.

The in water stops to be performed are according to the bottom time and the maximum depth reached. The procedures to apply and the contingencies are indicated in Book #7 if using the MT 92 tables and Book #8 if using the DCIEM tables.

Depending on the work done, the supervisor may select a table deeper or longer than the actual dive to provide an additional safety margin (Jesus factor).

The basket must be stable with very limited movements to be able to perform safely in water decompression. In the case of difficulties to perform in-water stops, the surface O_2 decompression procedure must be applied.

At the completion of the water stops, the diver is transferred to the deck. The hazards linked to this phase and the precautions to apply are the same as those for the launching of the dive.

If the decompression procedure is surface O_2 decompression, he will have to be transferred into the chamber in less than the maximum surface interval time allowed by the decompression table.

3.4 - Post-dive cleaning

3.4.1 - Helmet cleaning

Helmets are parts of the diving system that are the most susceptible to be contamination vectors, as pathogens accumulate here during the dive. An additional problem linked to common practices is that helmets are usually shared between divers, increasing the risk of contamination. For this reason, they must be cleaned after each dive.

IMCA suggests using a quick procedure between two dives and a full cleaning procedure at the end of the day.
The proposed quick sanitizing procedure implies the following steps:

1. Wet or immerse all components to be sanitized with an appropriate disinfectant solution for at least 10 minutes and lightly scrub over the components with a nylon brush or a clean dishrag to remove saliva mucus build up.
2. After 10 minutes, thoroughly rinse components using running potable water.
3. Allow to dry or pat dry with clean towel.

This cleaning procedure requires time to be performed adequately. Also, there is a risk that some parts of the oro-nasal remain contaminated, particularly the exhaust regulator. Thus, considering these problems and the fact that each diver uses the same helmet during the bell run, the best option can be replacing the helmet used with a clean one that have been fully cleaned and reviewed by the technicians after the bell run. Changing a helmet takes 10 minutes, which is the time given to allows the disinfectant to operate.
The full cleaning procedure presented by several safety organization implies the following steps:

1. Secure and bleed the gas supplies. Disconnect the gas connections, disconnect the communication wires, and secure the open ends with a dedicated cap or tape them to ensure that no water can enter them.
2. Transfer the helmet outside the bell.
3. The demand regulator clamp is opened, and the components such as cover, diaphragm, assembly oral-nasal mask, and nose cleaning pad are dismantled and stored adequately not to lose them.
   - The demand regulator must be rinsed with mild detergent and fresh water and then rinsed thoroughly.
   - Depending on the recommendations of the manufacturer, the parts are soaked for at least 5 minutes. Note that IMCA suggests the sanitary solution stays in contact for 10 minutes.
   - Then the elements are scrubbed using a small nylon brush. The pieces that have been in contact with the detergent must be rinsed.
4. The pieces that have been in contact with the detergent are then soaked in fresh water to ensure that the detergent is fully is rinsed off.
5. The head cushion assembly must be removed. If it is wet with perspiration or water, it must be cleaned and dried.
6. Then, the technician should inspect the spares for damages.
7. The helmet liner should be washed with soap and water, rinsed in freshwater, dripped, and dried.

8. The earphone covers and the microphone should be removed from the oral-nasal mask, washed with a mild detergent solution, rinsed with fresh water, and dried.
9. The components should be laid out to allow for drying before storing
10. The neck-dam ring assembly is then cleaned with a mild detergent solution and thoroughly rinsed with fresh water.
11. When the components are fully dried, they can be reinstalled.
12. The helmet should be then tested.

When the tests are satisfactory, The helmet is protected from contamination in a sealed bag and then be transferred into the system when required.

3.4.2 - Return the chamber and the dive station to service

If the chamber has been activated, the oxygen masks employed must be disinfected using the same methods as for helmets. The floors and bunks should be cleaned and dried, and the checklists should be performed again to ensure that the chamber is back in service.

The baskets, the launching station, as well as the dive control, should also be cleaned, and their checklists performed again.