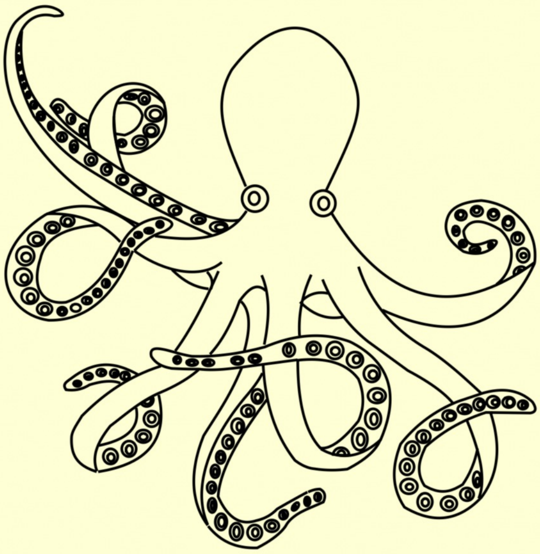

Diving & ROV specialists

Saturation diving handbook

Book 3 of 4

Bell procedures

June 2024

Diving & ROV specialists is a branch of CCO ltd

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This document is the book number three of the ensemble of four books constituting the "Saturation diving handbook" described underneath.

Books	Description
Book #1: Definition and elements for preparation	The document describes the scope of saturation procedures, the NORMAM 15 PLC saturation procedures, and some elements to consider when organising a saturation diving project such as the necessary personnel, weather conditions, surface supports, systems of communications, work procedures with ROV, supply chain to be in place, etc.
Book #2: Gas supplies & chamber management	This document describes safe practices and emergency procedures to manage chambers and gas supplies for successful operations.
Book #3: Bell procedures	This document describes the main rules for the organization of safe bell diving operations
Book #4: Diving accidents	This document indicates and explains accidents linked to saturation diving operations and how to solve and avoid them.

February 2021	*First publication*
August 2021	*Modified:* *- 1.1.6 - Bailout systems* *- 1.2.7 - Maximum divers' umbilical length and selection of bailouts systems*
September 2021	*Added:* *- 3.3.3 - surface standby diver* *- 3.3.6 - Bell tapping code*
June 2024	*Modified point 3.1.2.8 "External cardiac massage" of subsection 3.1.2 "Diver unconscious due to wrong gas, loss of supply, or other reason"*

Important Note

This book is written with the only aim of informing people interested in diving activities of elements to take into account to prepare successful diving saturation operations.
I express my sincere thanks to the people and companies listed below who have supported this project and provided me with useful documents and advice.

Christian CADIEUX - manual author

- Sheldon Hutton - CEO/Chairman Ultra Deep Solutions & Flash Tekk Engineering, and the personnel Ultra deep solution and Flash Tekk Engineering
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- Jean Pierre Imbert - Divetech
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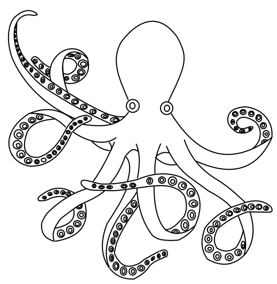
- Comanex - Patrick Laboure (Managing Director)
- Parkburn systems, particularly Mr Shon Laird (Business Development Asia Pacific)
- Gareth Kerr - Director Fathom systems (Fathom system is a part of JFD group)
- Jord Lucas - Head of the diving department Total E&P
- Franck Muller - Diving specialist diving department Total E&P

About this book

This book gives an overview of the elements and procedures for bell management that should be in place to organize saturation diving operations. It is based on the saturation manual published by CCO Ltd, elements indicated in the documents Diving & ROV specialists “Description of a saturation diving system”, and the diving study CCO Ltd “Implement NORMAM-15 saturation diving procedures”.
The reason for using the NORMAM-15 is that it has proved its efficiency for the organization of numerous deep dives in Brazil and other countries. So it is one of the safest saturation procedures currently available. It is confirmed in the “DMAC statement on deep saturation diving conducted using appropriate procedures”, published in March 2019.
However, people using a decompression process, and thus divers excursions limits, other than those indicated by Normam 15 can adapt the elements described in this document to the decompression procedures they use.

Note that we only suggest what we consider the best practices and favour the diffusion of every procedure we think relevant for people involved in diving and ROV operations, whatever the emitter. Also, we are not influenced by any third-party organization, as we are not a member of any.
The policy of Diving & ROV specialists policy is to publish only official and scientifically proved documents and never change the original structure of these publications. For these reasons, there is no change of the procedure published by the Brazilian Navy Directorate of Ports and Coasts and those of other competent bodies.
However, there have been some improvements in some diving procedures since the publication of the NORMAM-15/DPC. It is the same for the other guidelines taken as references. For this reason, some complementary procedures from other competent bodies or implemented by various teams working in the offshore industry have been added as reinforcements.

Note that in this document, the name “NORMAM-15/DPC” is reduced to “NORMAM-15” for convenience.



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Tables of contents

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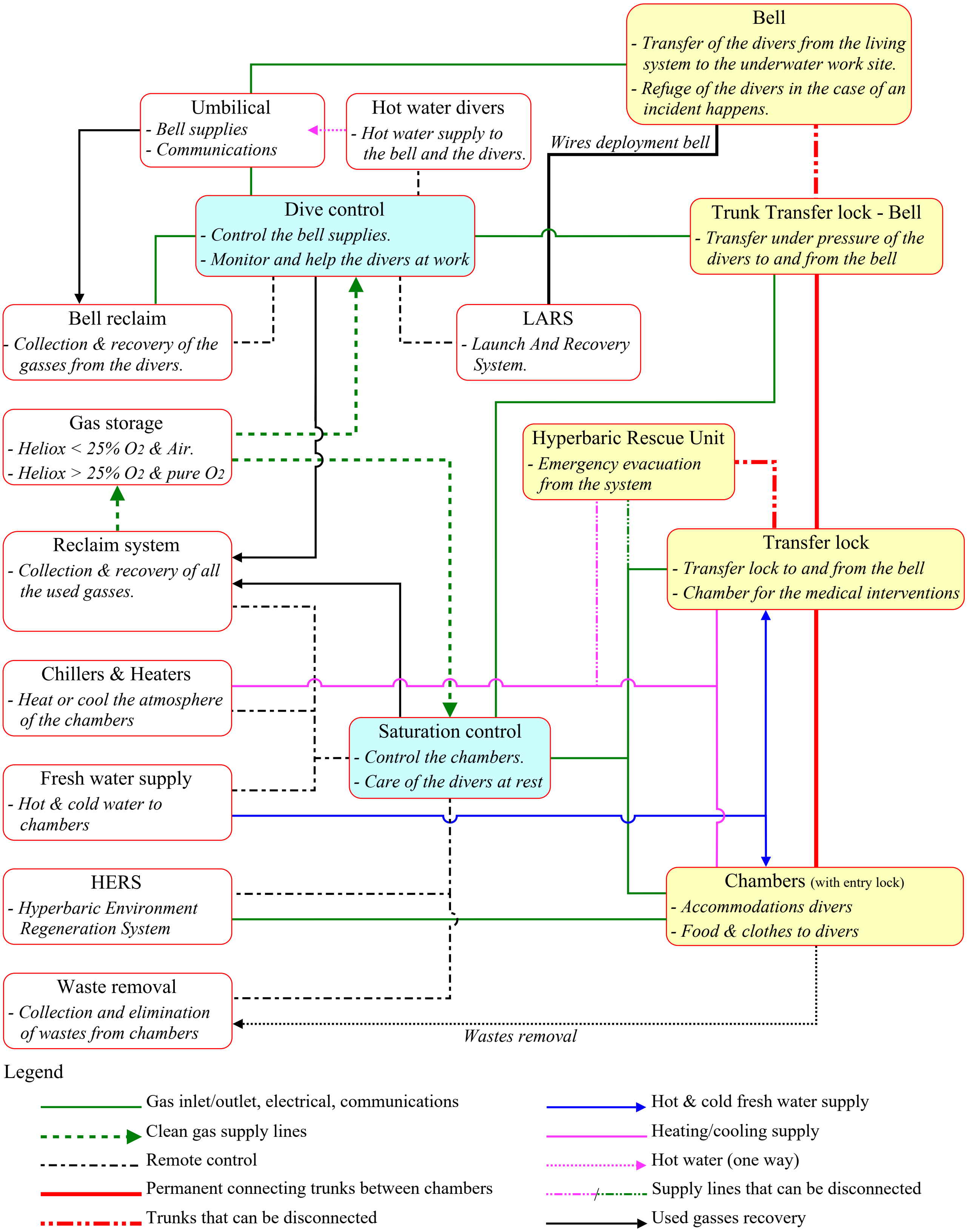
1) Prepare the dive

1.1 - Description of the bell and of the elements to control it.

1.1.1 - Overview

The scheme below is the same as the one discussed in Book #2. As said in this document, it is essential to have an overview of a saturation system's general design and how the elements that compose it are linked together to have a comprehension of their functions and conception. It is the purpose of the chart below, where the links between the modules are extremely simplified. We can see in it that the bell works separately from the living parts of the system to which a disconnectable trunk links it.



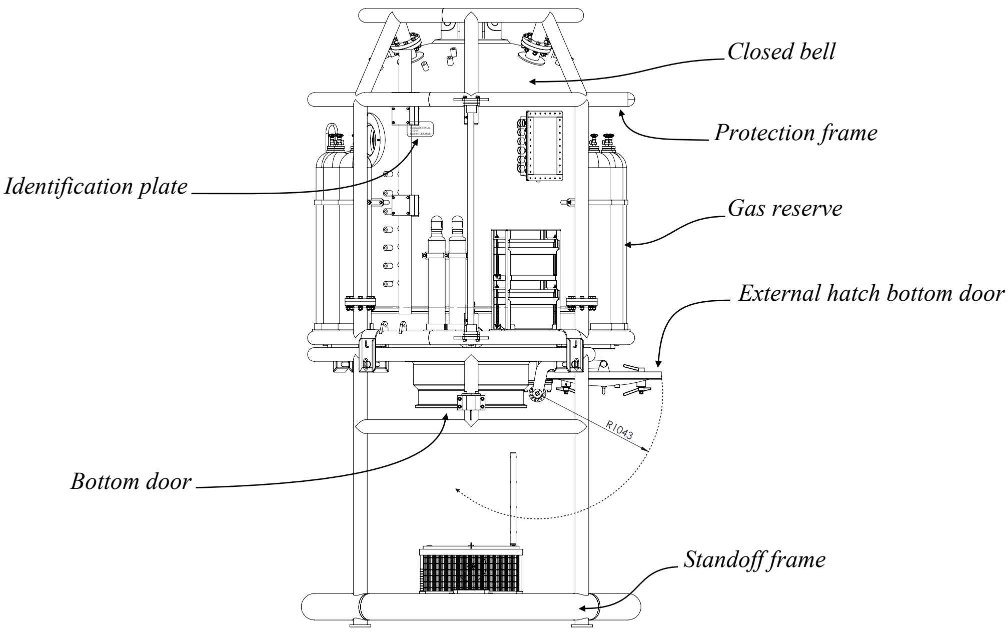
1.1.2 - Diving bells

If the saturated divers are exposed to the atmospheric pressure explosive decompression occurs and they are immediately killed. For this reason, a sealed diving bell is necessary to transfer them from the system where they are kept at the pressure planned at depth to the underwater work site. When the bell arrives at the selected depth, the bottom door is opened, and the dive can start. The bell is also the refuge of the divers in case an incident happens.
Note that doors are fitted with two hatches: The internal hatch protects the divers from decompression accident (which could be explosive decompression) when the external pressure is inferior to the internal pressure in the bell, and the outer door that protects the divers from over pressurization if the bell drops below the planned storage depth.

Bells are pressure vessels that must be built according to recognized international standards. These norms and the certification body must be indicated on the identification plate that summarizes the characteristics of the bell and its manufacturer and must be clearly visible on the outside of the shell.
As a result of technical choices of the manufacturers and their clients, a lot of models of bells are in service in the industry. However, despite some changes in configuration, the functions provided remain the same.
Bells are generally designed and built for two, three or four divers. IMCA says that depending on their configuration, they should have the following minimum volume:

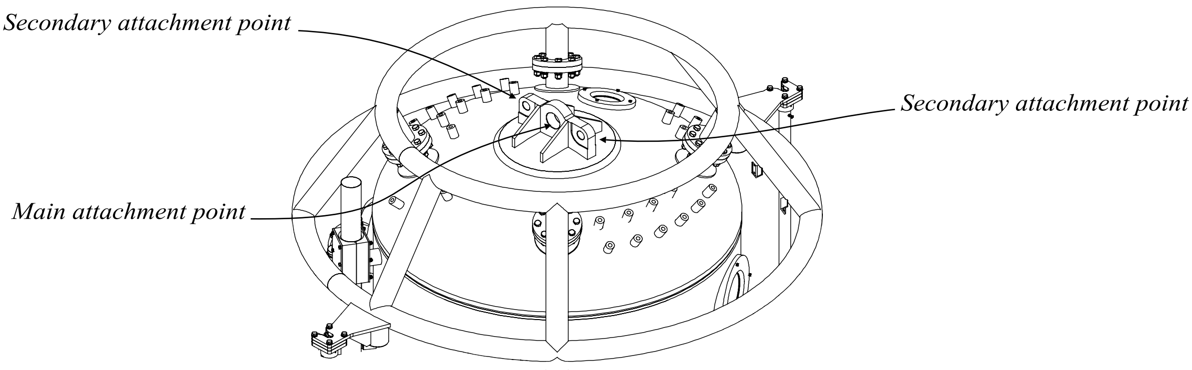
- 2 divers bell – 3.0 m 3 (105 cu ft)
- 3 divers bell – 4.5 m 3 (160 cu ft)
- 4 divers bell – 6.0 m 3 (210 cu ft)

Note that NORSOK standard U-100 says:
Diving bells intended for two divers shall have an inside volume of at least 4,5 m³. Diving bells intended for more than two divers shall have an extra inner volume of 1,5 m³ per diver in excess of two. The specified volume should be usable, i.e. apportioned around what is normally within the height required for a diver to stand up



1.1.2.1 - Deployment cable attachment point

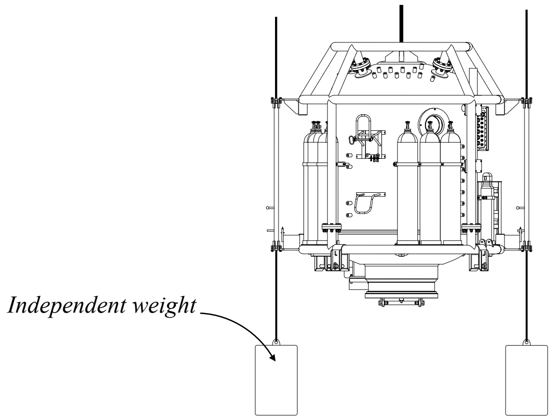
The bell is deployed to the bottom using the main wire that is coiled in a winch that is part of the Launch and Recovery System (LARS). This cable is connected to the top of the bell.
IMCA D 024 says in section 4 that the main lift attachment point to the bell should be by means of a properly designed pad eye or similar.
Also, there should be a secondary attachment point on the diving bell if the main one is damaged. This secondary point should also be a properly designed pad eye or similar *(it may be a second hole in the same pad eye)*. A soft sling should be installed on a secondary lifting point, ready to be deployed by a diver or a ROV.

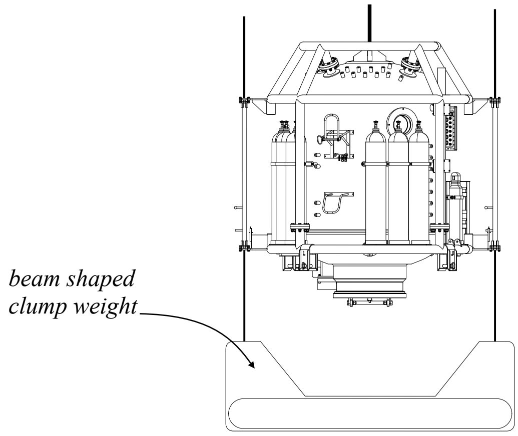


1.1.2.2 - Anti gyration systems

To avoid the bell gyration around its main cable, two parallel cables are installed at each side of the bell. Two configurations are possible:

- Two weights that are deployed by two separated winches. This solution that was used with some systems in the past is not found with the last generation systems.
- A beam shaped clump weight which is deployed by a single cable passing through it. The deployment cable that is adjusted by a single winch pass through the clump weight by the means of pulleys and is connected to the other side of the deployment frame. This clump weight is generally adjusted to create a platform under the bell that allows the divers to enter and leave it easily. Also, some clump weights are fitted with closed boxes where the divers can store tools.

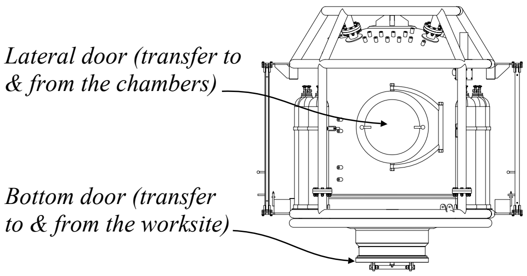


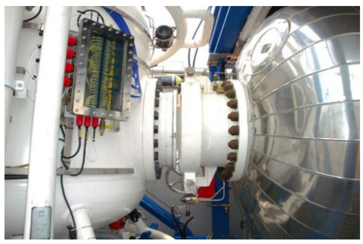


1.1.2.3 - Transfer to and from the living chambers

The transfer from the living chambers to the bell can be performed through a lateral door or the bottom door:

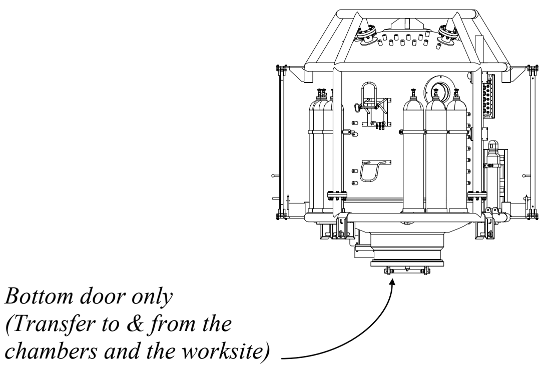
- Bells with lateral doors were common with systems made by COMEX and it is still the case with some last generation systems. As an example, the system displayed in point 2.2.1. The advantage of this system is that the transfer lock and the chambers are at the same level of the bell which reduces the risks of falling during the transfer to and from the bell and that the transfer trunks are generally short.
  Also, the bells of some systems which are connected to the chambers by the bottom door have a lateral door which allows entering into them without disconnecting them from the system. However, this configuration seems no more used with the latest products proposed by the manufacturers.





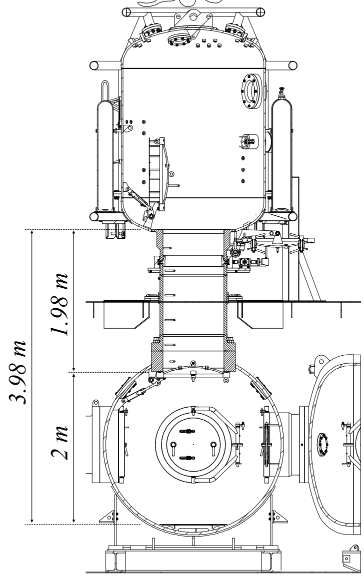
Bell connected laterally

- Bells with only a bottom door are often adopted with the last generation systems. This configuration has the advantage to simplify the design of the bell and avoids the problems of water intrusion between the internal and external hatches of lateral doors that may happen if the external hatch is not correctly sealed. Also, some engineers say that the connection to the system is easier with a bell that is hung and lowered to the connecting flange than with a bell that is approached laterally. However, the transfer of the divers to and from the bell is more dangerous as a fall from more than 2 m height is possible *(see in next page)*.



Connecting the bottom hatch

Internal view of the bottom trunk of the bell



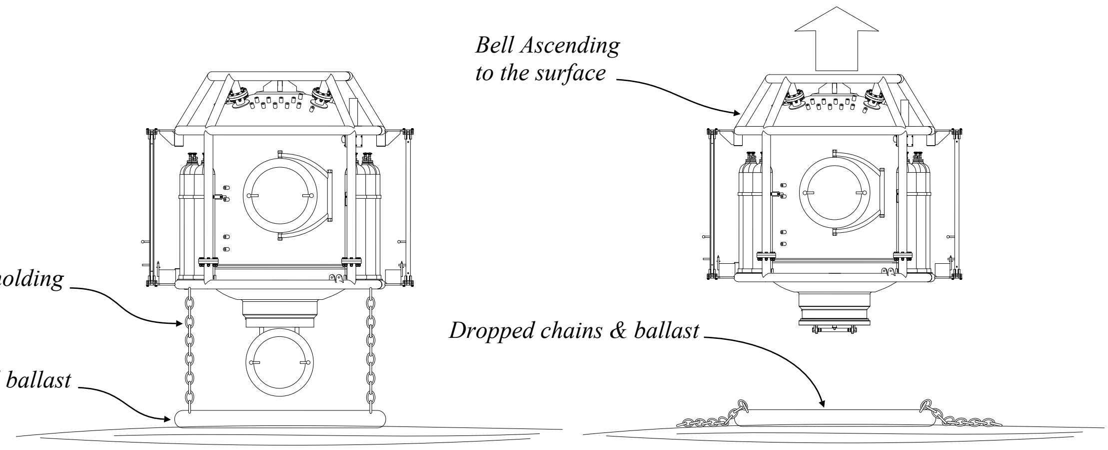
Note that due to the configuration of some systems, there is a risk that a diver falls from a height that can be up to 4 metres.
For this reason, precautions should be implemented to avoid such an incident during the transfers and the checklist of the bell.

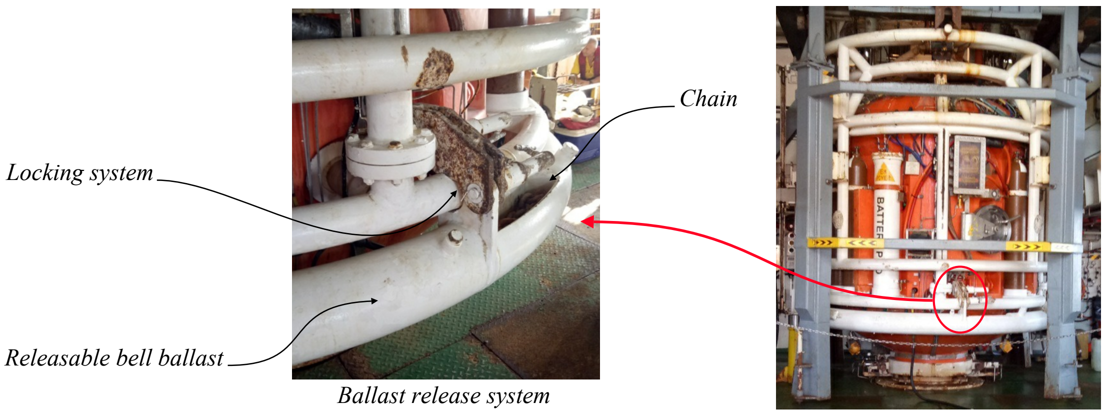
The bottom internal diameter of the hatch in the previous page is 90 cm which is sufficient to enter and leave the bell with a bailout. Note that NORSOK U 100 says: "*The bottom trunk for entry into and exit from the diving bell shall have an inner diameter of minimum 80 cm*".
IMCA does not give precise dimensions of the hatches and only says that the diver must be able to exit and re-enter the bell and that there should be the possibility to open the doors from either side. It is also said that the doors must be in perfect condition and their seals protected by a slight film of silicone grease.

1.1.2.4 - Bell ballast release option

Bell ballast release systems and buoyant ascent in offshore diving operations are explained in AODC 061 and discussed in the document "Bell diving operations". Two options are currently available:

- Bell equipped with a ballast release system.
  This option that was common with old systems is still used with last generation systems. Its function is that if the bell has fallen to the bottom, it allows dropping the ballast that is still attached to the bell by chains to the bottom. As a result, the buoyancy of the bell becomes positive allowing it to take off from the seabed to which it is maintained by the chains attached to the ballast, which allows the divers to leave and enter in it.
  Also, the system allows a complete release of the ballast to let the bell ascend to the surface as a result of its positive buoyancy.





Ballast release system

IMCA says that such a system must meet the following criteria:

- It must be designed to be operated from inside of the bell and the release mechanism must be protected against accidental release. For this reason, two independent actions must be necessary to release the weights.
- Also, the weights must be secured so as not to be shed accidentally. For this reason, if the system utilizes only one weight then there must be no single component whose failure could cause the weight to become detached. This requirement does not apply if there are two or more weights operating independently.
- In addition, IMCA says that if the release mechanism is operated by means of pressurisation (gas or hydraulic), then isolations need to be in place such that they cannot be activated accidentally by external water pressure or internal gas pressure.

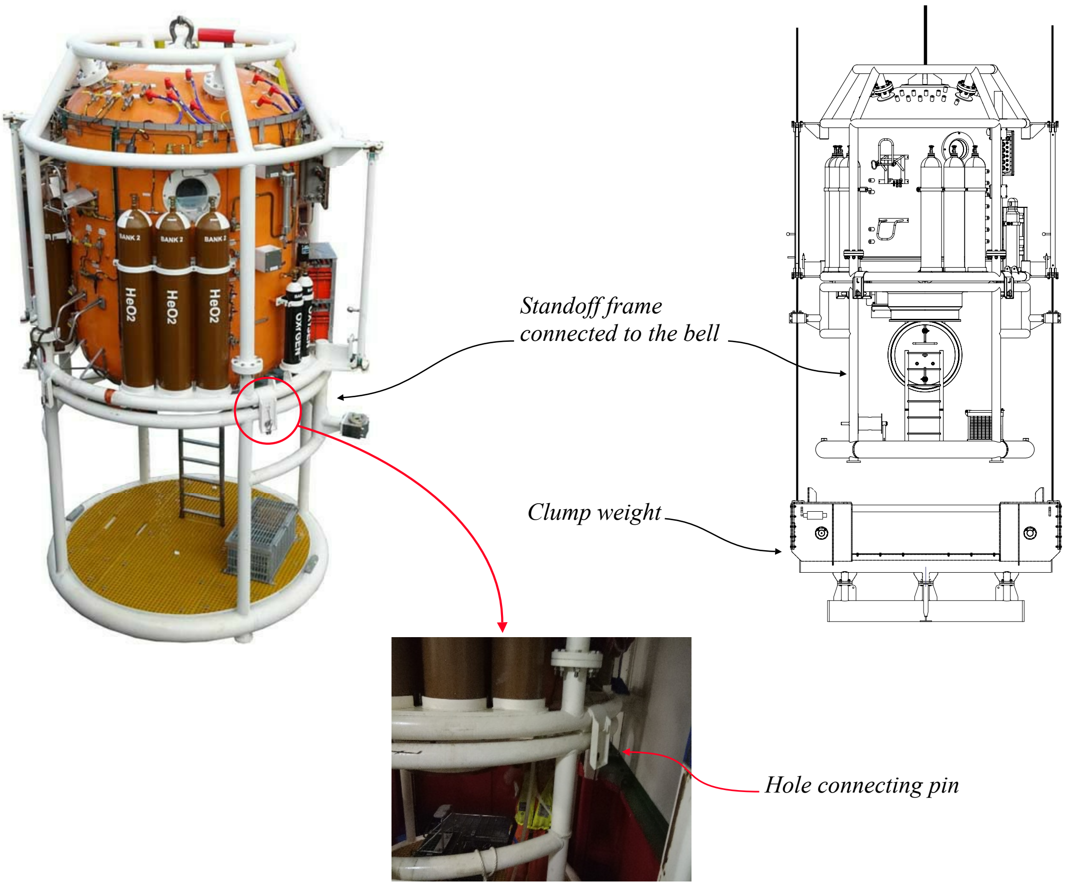
- Bell without ballast release system.
  Some companies consider dangerous the use of bells that can float as the ascent to the surface is uncontrolled and the bell may hit a structure or a vessel during its ascent. For this reason, they prefer recovering it using a crane and another bell and remove this option to avoid the divers having the temptation using this system.
  IMCA says that this decision must be clearly recorded in the appropriate documents and made known to all on the work site. Also, the ballast weights must be secured not to accidentally come off. In addition, the alternative recovery method must be identified
  Note that the equipment used to permanently secure bell ballast weights and neutralize the components forming part of the buoyant ascent system not intended to be used must be inspected every 6 months.
  IMCA D 024 also says in section 5 that the diver must be able to exit and re-enter the bell if it is resting on the bottom using a standoff frame or a ballast release system. It means that if the ballast release system is fully neutralized, a standoff frame must be physically fitted to the bell.

1.1.2.5 - Bells with standoff frames

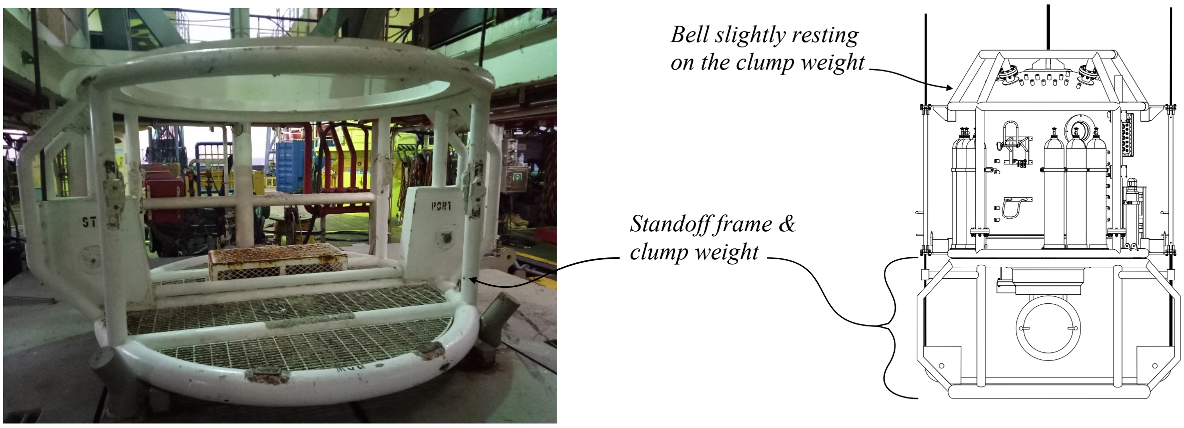
Standoff frames can be found with some models of bells.
The function of the standoff frame is to allow the divers to easily enter and leave the bell and provide them a place under the bell where they can standby in the case of an alert or if a small change of working area has to be performed without recovering the bell. Also, it is designed to protect the bottom door of the bell.
As explained in the previous point, IMCA says that standoff frames are mandatory with bells that have no ballast release system to allow the divers to leave and return to the bell if it has dropped to the seabed.

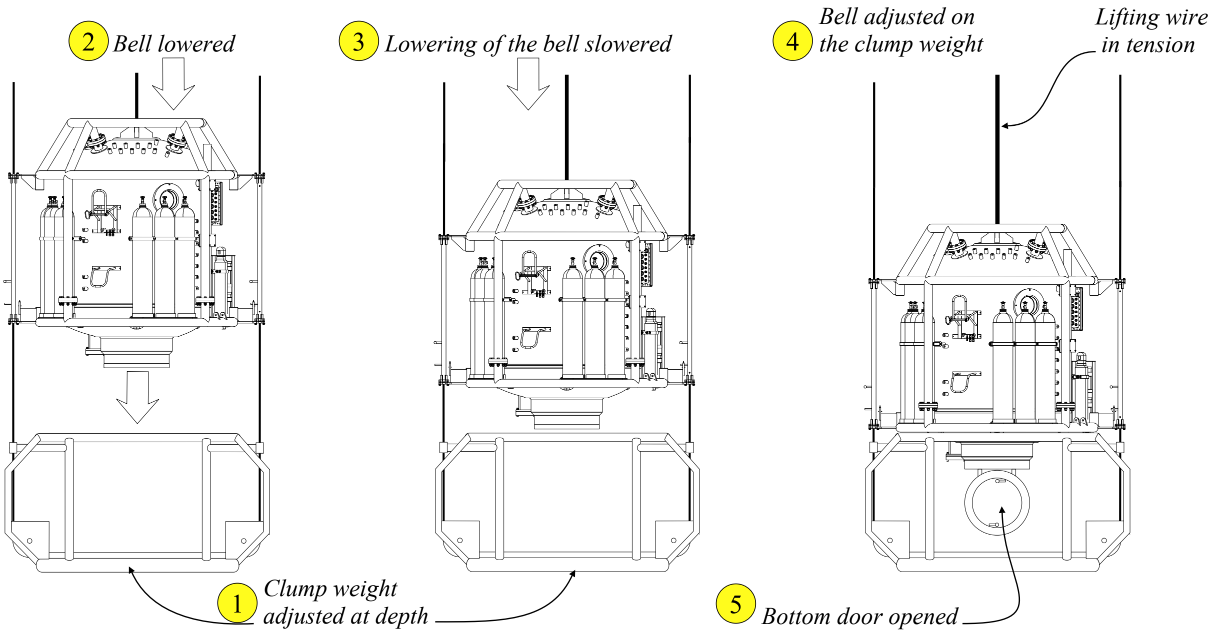
Two types of standoff frames can be found currently:

- A standoff frame that is connected to the bell which does not act as a clump weight. So the clump weight is deployed and adjusted below it.



- A standoff frame that is also used as a clump weight on which the bell slightly rests when arrived at depth. Note that because this model of standoff frame is not physically fitted to the bell, it can be used only with bells that are equipped with a ballast release system.





1.1.2.6 - External equipment

Equipment and gas reserves are installed all around the bell to provide a minimum autonomy in the case that the bell is lost on the bottom:

- IMCA D 024 says that There must be an emergency supply of breathing gas carried on board sufficient to support each working diver plus the bellman outside the bell for a minimum of 30 minutes at a breathing rate of 40 litres/minute at the maximum depth of the diving operation.
  Also, sufficient oxygen must be available for metabolic consumption by the maximum number of divers at 0.5 litres per minute per diver for at least 24 hours at the end of a bell run.
  As an example, the bells of UDS Lichtenstein are fitted with the following gas reserves that can be filled using a panel installed on the side of each bell:

- Two oxygen banks 2 x 10 litres x 200 bar.
- Three heliox banks 3 X 67 litres x 300 bar filled with bottom mix.

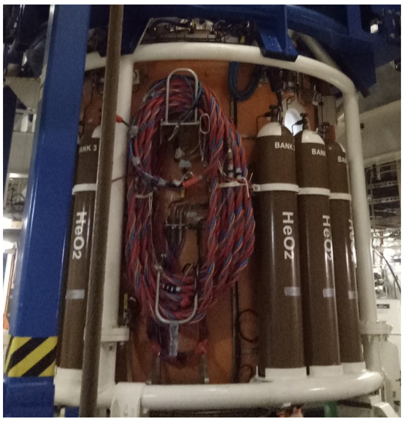
As with any gas stored on the worksite, the cylinders must be colour-coded and marked with the name and chemical symbol of their contents. The stamp of the last test date should be on the shoulder of each cylinder and painted over with a small patch of distinctive colored paint to help for its localization. If this is inaccessible then the cylinder serial number should be visible or else stenciled in a visible location.
Note that the valves of the cylinders and the bell must not be corroded and easy to close or open. In addition, the onboard gas *(oxygen and heliox)* must be regulated not to be above 30 bar over the ambient pressure in the bell.

IMCA D 024 also says that valves carrying oxygen (or mixes containing more than 25% oxygen) at a pressure higher than 15 bar must not be quarter turn *(Due to the depths involved in saturation diving, the pressure of such gases will often require to be above 15 bar)*. The reason is that extreme heat can happen if the compression occurs quickly enough to create a pneumatic impact and adiabatic compression. These phenomenon result from the conversion of the mechanical energy when the gas is rapidly compressed from low to a high pressure. 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)

To continue with oxygen and mixes above 25% oxygen, particles may aggregate inside the pipes and be ignited later on. For this reason, the valves and pipework must be cleaned for oxygen service when used for gas mixes containing more than 25% oxygen.

Bell charging panel heliox



Onboard gas colour coded

The bell must be designed to be visible so that the diver can see it during the operations. Also, it must be discoverable if it is lost. For this reason, the following equipment should be installed.

- Lights should be arranged such as the bell is visible from any direction (360º), and that the failure of one does not affect the others. They should be supplied by the electricity coming from the surface and, in the case of an emergency, from the onboard batteries that are installed at the external of the bell.
- The onboard batteries that are designed to supply the lights and other functions in the bell should be isolated and protected against short circuits and polarity reversal (a shunt diode should be installed). The housing of the batteries should be designed for the pressure the bell is rated for, and fitted with appropriate mechanisms such as relief and equalization valves. Batteries and their housing should be inspected at least every six months.
- A strobe light that is designed to work independently for at least 24 hours must be installed at the top of the bell.
- A transponder is fitted to the bell to allow for it's detection electronically. Its specifications must be in line with those described in AODC 019 and can be summarized as follows:
  - A pressure housing capable of operating to at least the depth the bell is designed for.
  - Common emergency reply frequency 37.5 KHZ
  - Individual interrogation frequencies:
    Channel A 38.5 KHZ ± 50 HZ
    Channel B 39.5 KHZ ± 50 HZ
  - Receive sensitivity + 15 DB RE 1 Microbar
  - Minimum interrogation pulse width 4 MS
  - Turnaround delay 125.7 ± 0.2 MS
  - Reply pulse width 4 MS ± 0.5 MS

- Reply frequency 37.5 KHZ ± 50 HZ
- Maximum interrogation rate:
  More than 20% of battery life remaining once per second.
- Less than 20% of battery life remaining once per 2 seconds.
- Minimum transponder output power 85 DB RE 1 Microbar at 1 metre
- Minimum transducer polar diagram -6 DB at ± 135°
  solid angle centred on xponder
  vertical axis
- Minimum listening life in water 10 weeks
- Minimum battery life replying at 85 DB 5 days
- A means of testing and interrogating this transponder must be available on the surface at the dive site.

Transponder

Waterproof lighthouse equipped with the last generation Light Emitting Diodes (LED).

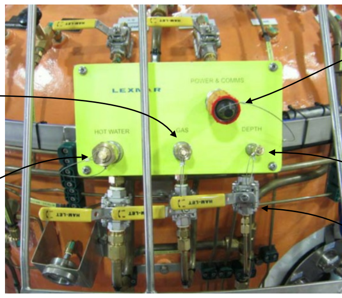
The bell must be designed to be supplied in an emergency if the main umbilical has been severed. For this reason, emergency connectors are provided in a very accessible part of the bell that should be highlighted with a bright colour to connect a 2nd umbilical.

- IMO says that at least the two following connectors should be in place:
  - ¾" NPT (female) for hot water.
  - ½" NPT (female) for breathing gas

  However, a depth gauge, and power supply and comms connections are desirable and are in place on most bells.

Gas supply

Hot water



Power + comms

Depth

Control valves

- NORSOK recommends more connectors than IMO and says that they should be designed to be operated by divers and ROV. They are described as follows:

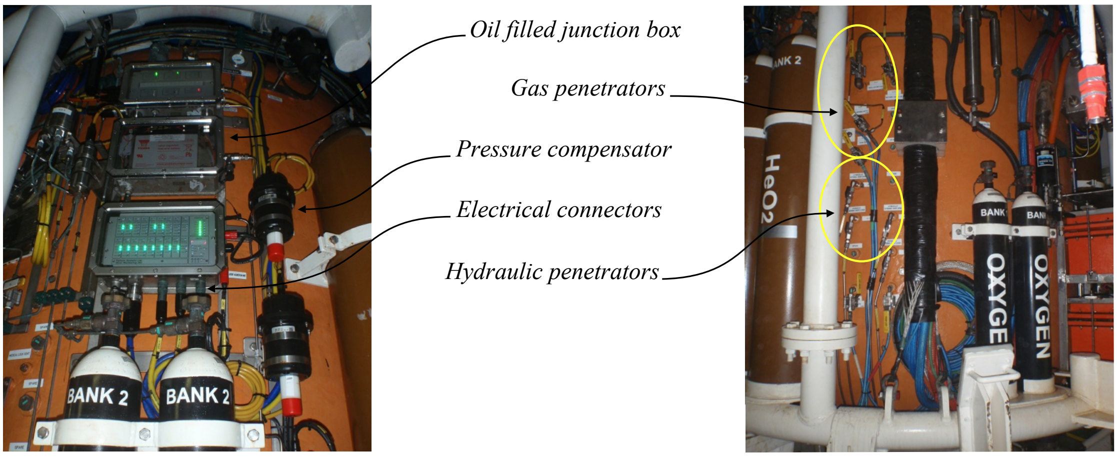
Item	Diver operable	Diver and ROV operable
Breathing gas	1/2" NPT Female	1/2" Male Snaptite SVHN-8
Hot water/heating	3/4" NPT Female	3/4" Male Snaptite SVHN-12
Depth	1/4" NPT Female	1/4" Male Snaptite SVHN-4
Communication	8-contact-4-pins-EO connector (Contacts 1 and 2 used, others n.c.)	8-contact-4-pins-EO connector (Contacts 1 and 2 used, others n.c.)
Emergency power	4-contact-4-pins-EO-connector (Pin 1: 24V, pin 2: 0V, pin 3: ground, pin 4: n.c.)	4-contact-4-pins-EO-connector (Pin 1: 24V, pin 2: 0V, pin 3: ground, pin 4: n.c.)
Gas analysis	1/4" NPT Female	1/4" Male Snaptite SVHN-4

Key:
- EO: "Electro Oceanics"- trade mark - underwater electrical connector
- n.c.: not connected
- NPT: National (standard) Pipe Tapered (threads)
- Snaptite SVHN: trade mark and type designation

As communications to the bell could be lost, a copy of the IMO/AODC/IMCA bell tapping code must be mounted on the outside of the bell in a clearly visible position *(Generally, at the top of the bell)*.

Tapping code	Situation
3.3	Communication opening procedure (inside and outside)
1	Yes or affirmative or agreed
3	No or negative or disagreed
2.2	Repeat please
2	Stop
5	Have you got a seal?
6	Stand by to be pulled up
1.2	Get ready for through water transfer (open your hatch)
2.3.2.3	You will NOT release your ballasts
4.4	Do release your ballast in 30 minutes from now
1.2.3	Do increase your pressure
3.3	Communication closing procedure (inside and outside)

Electrical, communication, and video connections should be made in junction boxes filled with oil and pressure compensated to avoid water intrusion. Also, penetrators that are designed to seal the electrical cables coming from the external of the bell to its inside should be in place and be certified as fit for purpose by a competent person *(IMCA D 018 category 3 or 4)*. They should be installed in strategic points and be appropriately marked.
Penetrators are also in place to seal the hoses coming into the bell. They must be fitted with protection valves or other devices to stop catastrophic pressure loss and be appropriately marked.



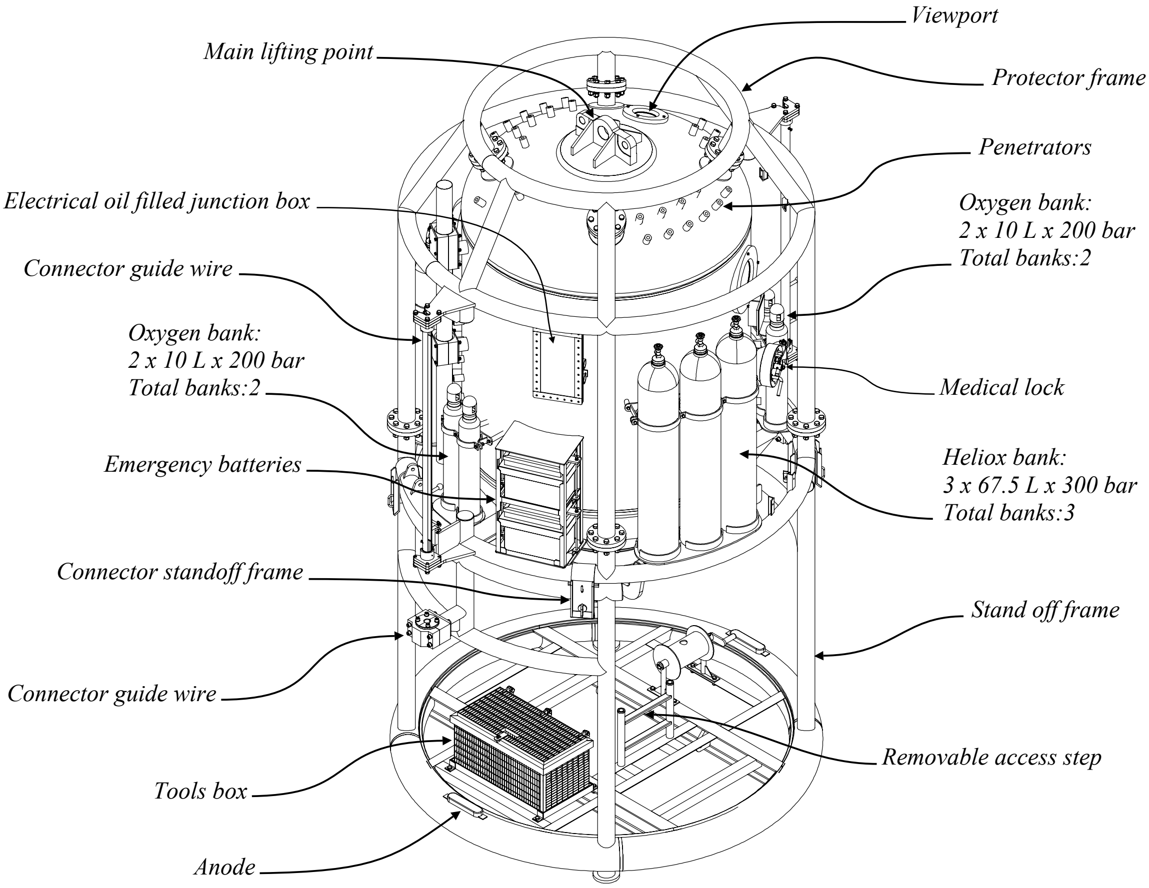
Bells are fitted with a food/medical lock and viewports:

- The medical lock must be equipped with a safety interlock that prevents the opening of the door if the lock is still under pressure. Also, the system should make it impossible to obtain a gas-tight seal on the lock if the clamp is not properly closed.
- Viewports are designed to see what happens around the bell. Those that are in the lower half should have both internal and external protective covers. Those that are in the upper half require external protective covers only. The serial number or other identifying mark for each viewport should be visible and be prominently marked on the outside of the bell adjacent to each viewport. Also, the date of installation should be indicated.
  During the inspection, the person in charge must ensure that they are free of cracks or scratches that could affect their integrity. Note that they must be changed every 10 years.

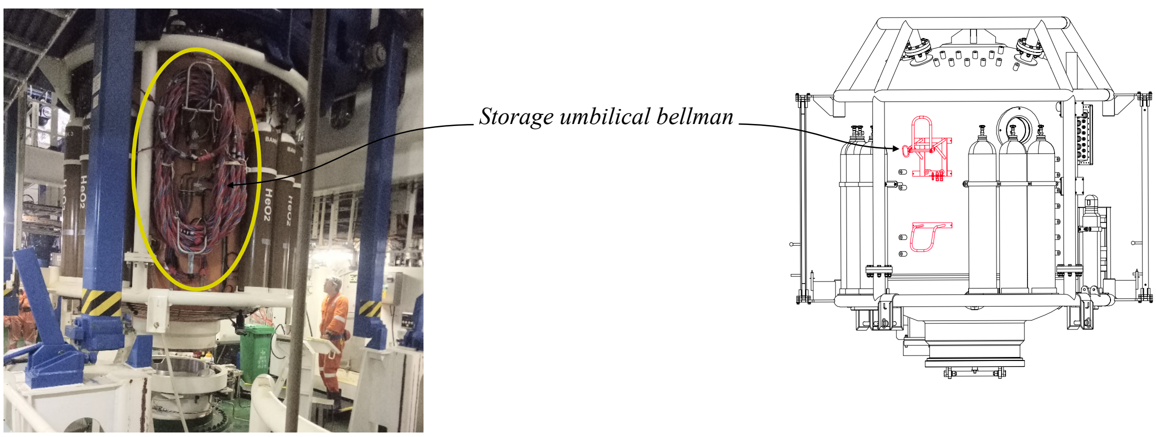
A protector frame is fitted to the bell to protect the pressure vessel and the elements described above from shocks during the launching and the recovery. Note that the pressure vessel must always be in perfect condition.

- The protective paint must be in good condition and there not be serious corrosion visible with anodes that are reasonably depleted. Note that anodes should never be painted.
- Some bells are fitted with external isolation. If it is the case, it must be clean and in good condition. During the inspection, the auditor should ensure that there is no crack or disjointing that could lead to water intrusion and then internal corrosion.

- Note that the identification plate must be clearly visible on the outside of the bell. It should indicate the name of the manufacturer, the reference number of the pressure vessel, its date of fabrication and characteristics *(dimensions, test pressure, max working pressure, etc)*, and the name of the certification body. Note that the bell cannot be used if the plate is missing or suspicious.
- As every pressure vessel, the bell must be fitted with a relief valve. Note that IMCA D 024 says that the relief valve can be replaced by an overpressure alarm.



It often happens that the umbilical of the bellman is stored on the outside of the bell. That gives the advantage to recover some space for the divers and equipment inside the bell. IMCA D 024 says that this umbilical must be secured on an adequate storage point that allows to protect it from damage during the launching and the recovery of the bell. Also, the storage system must be designed such that the bellman is able to quickly release his umbilical once he is out of the bell in an emergency.
IMCA also says that if it is planned to undertake two man bell runs using a bellman's umbilical stowed outside the bell, then the end of the umbilical must be arranged in such a way as to allow the bellman to attach his mask or helmet and test it before the working diver exits the bell.

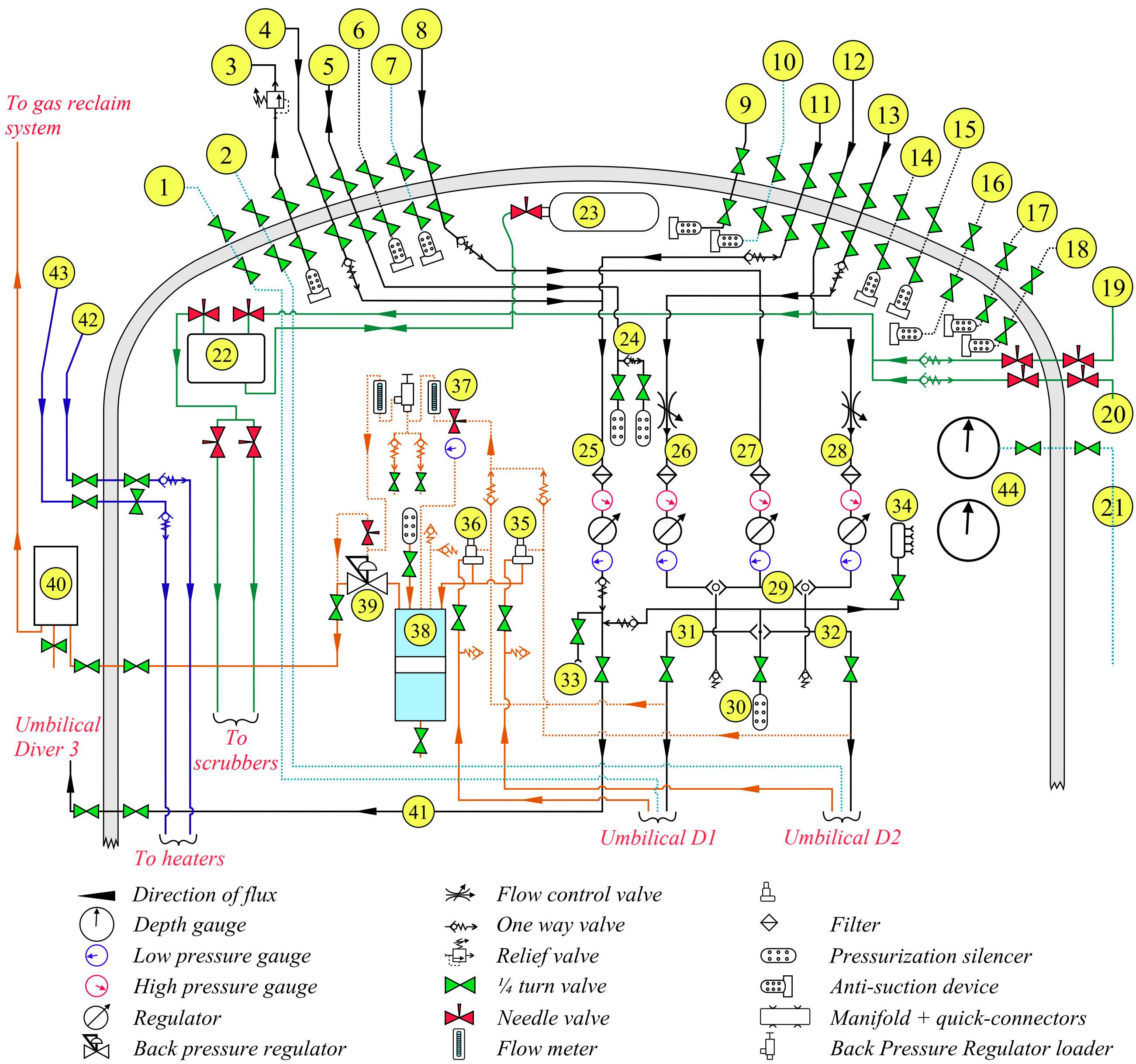


1.1.2.7 - Internal equipment

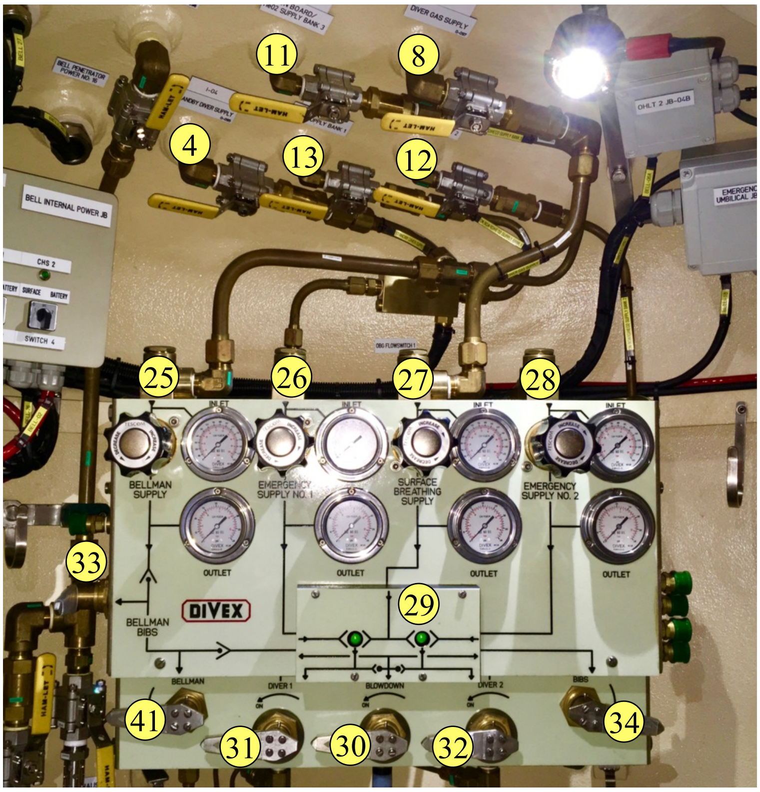
The following gas supplies and exhaust systems, but not limited to, that are also described in the documents #2 "Gas supplies and environmental control" and #4 "Bell diving operations" should be in place:

- Depth Diver 2 *(#1 in the drawing next page)*
- Depth Diver 1 *(#2 in the drawing next page)*
- Safety pressure relief valve bell *(#3 in the drawing next page)*

- Standby diver supply *(#4 in the drawing)*
- Bell blow down and exhaust *(#5 & #24 in the drawing)*
- Analysis from dive control *(#6 in the drawing)*
- Bell internal depth monitoring from dive control *(#7 in the drawing)*
- Divers' gas supply from surface *(# 8 & 27)*
- Emergency blow-down and exhaust *(#9 in the drawing),* designed to be connected to the replacement umbilical.
- Emergency internal depth monitoring *(#10 in the drawing)*
- Dedicated supply to diver 3 from onboard bank 3 *(#11, #25 & #41 in the drawing)*
- Emergency supply from onboard bank 2 *(#12 & #28 in the drawing)*
- Emergency supply from onboard bank 1 *(#13 & #26 in the drawing)*
- Tracking regulators banks 1, 2, & 3 *(#14, #15, & #16 in the scheme)*
- Tracking regulators O2 banks #1 *(#17 in the scheme)* & #2 *(#18 in the scheme)*
- O2 banks #1 & #2 *(#19 & &20 in the drawing)*
- External depth bell *(#21 & #44)*
- Manifold O2 add *(#22)* and Buffer tank (#23 *in the drawing*)
- Shuttle block *(#29 in the drawing below),* which is designed to protect the divers from loss of gas supply.
- Emergency blow-down bell *(#30 in the drawing)*
- Gas supply to diver 1 (#31) and gas supply to diver 2 (#32 *in the drawing*)
- Bibs bellman (#33) & bibs divers 1 & 2 (#34 *in the drawing*)
- SEACO (supply actuated exhaust cut-off) valves *(#35 & #36)* protect the diver(s) from too elevated suction.
- Tracking pneumo & back pressure regulator loader (#37) that reduce the depression of the exhaust.
- Internal & external water traps *(#38 & #40 in the drawing)*
- Main and emergency hot water supplies *(#42 & #43 in the drawing)*

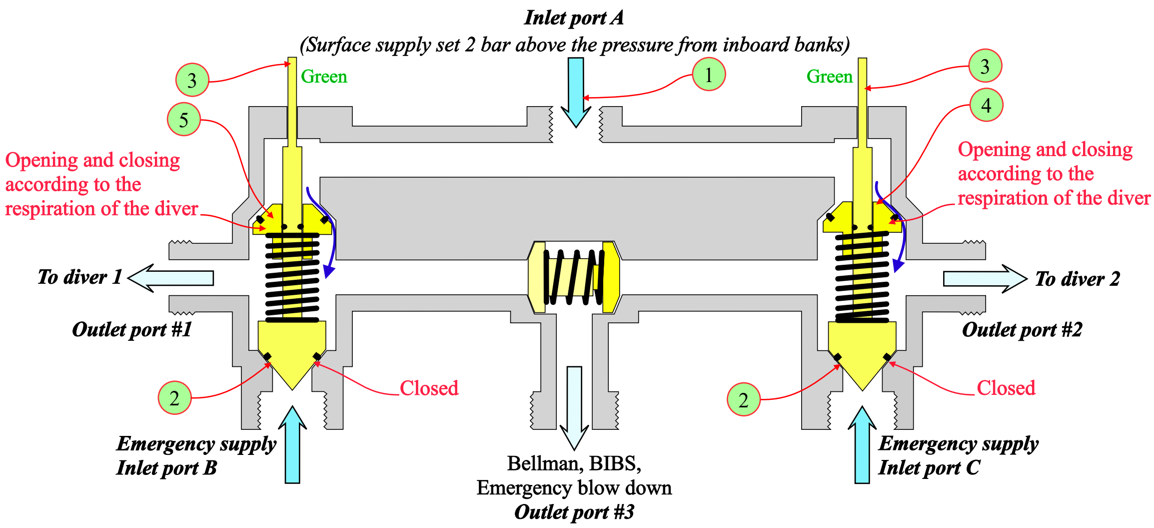


IMCA D 024 says that gas supplies must be arranged so that blowing down or flushing the bell does not interfere with the gas supply of any diver outside the bell (item 6.31).
IMCA also says that there must be a primary gas supply for the bellman, which can be from on board bottles or from the surface, sufficient to allow him to exit the bell and recover an injured diver. This supply must be independent of the primary gas supply to the diver(s) in the water. The bellman must also have a secondary supply but this supply may be common with the working divers primary supply, provided it is protected if the working diver's line fails.
It is achieved by the means a gas management panel similar to the model below from DIVEX that allows opening and isolating the supply lines indicated in the scheme on the previous page according to the requirements from IMCA.



The isolation of the supply lines described above is performed by means of the shuttle valves opening or closing according to the scenarios that are described below:

- Scenario A - Normal diving conditions
  1 - The breathing gas is supplied from the surface to the inlet Port A at a pressure slightly above the gas from the emergency onboard gas banks (2 bar).
  2 - The lower part of shuttles closes ports B and C due to the differential pressure (2 bar) between the set up of the emergency onboard gas and the surface supplied gas that pushes them against their seal.
  3 - As a result, surface gas is available to all outlet ports #1, #2, and #3. Also, the emergency indicators on the panel are green.
  4 - If the divers do not breathe, the upper parts of the shuttles that slide on the tails of the lower parts are sealed against their respective housings by the pressure of the springs.
  5 - When a diver inhales, the depression created in the outlet port is sufficient to open the upper part of the shuttle. As a result, surface gas from port A enters in the outlet port until the pressure is equal to the pressure from inlet port A.



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- Scenario B - Surface Supply umbilical severed

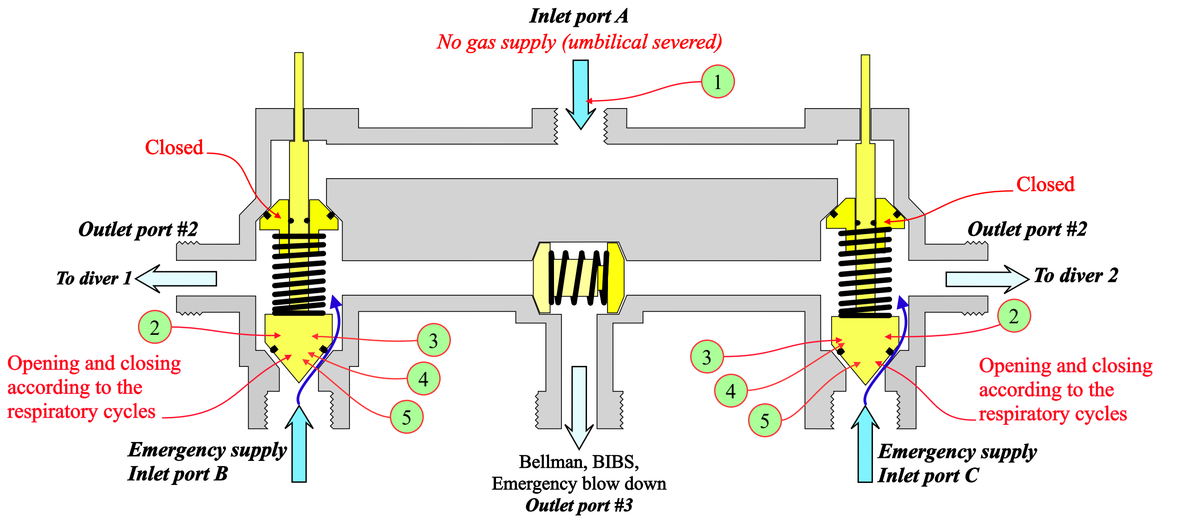
1 - As a consequence of the main umbilical ruptured, no gas is delivered to port A and the pressure in the outlet ports #1 & #2 falls below the supply pressure of inlet ports B and C from the onboard banks. As a result, the bottom part of the shuttles open and the upper parts of the shuttles that slide on the tails of the lower part of the shuttle close as they are pushed by the pressure of the gas from inlet ports B & C.

2 - The onboard supply "Inlet Port B" supplies the outlet Ports #1 and #3 and the onboard supply "Inlet Port C" supplies outlet Ports #2 and #3. The indicator rods rise, and the emergency indicators are red.

3 - When the pressure has been reestablished and if the divers do not breathe, the springs maintain the lower parts of the shuttles against the opening of inlet ports B & C.

4 - As a diver inhales, the reduction in pressure created in the outlet port causes a differential of pressure sufficient to open the lower part of the shuttle.

5 - As the diver exhales the pressure in the outlet port plus the force of the spring are above the one from the emergency supply and the lower part of the shuttle closes again. The opening and closing of the shuttle valves continue according to the respiratory cycles. Note that both emergency indicators on the panel are red.



- Scenario C - Diver 1 umbilical severed

1- In the case of an umbilical being ruptured during the dive, as an example diver 1 umbilical, the continuous free flow in outlet port 1 results in the pressure in Port A falling below the preset differential (2 bar) and the surface supply is unable to maintain a correct flow to supply the divers.

2 - As a result, the auxiliary shuttle closes the side affected (outer port #1) to protect the other half of the block.

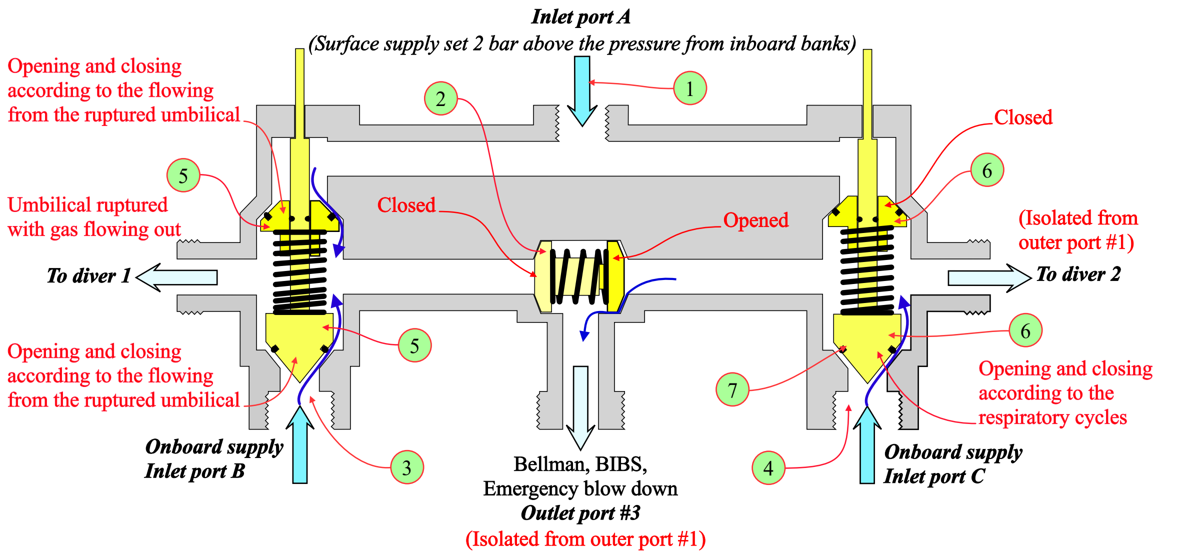
3 - The onboard supply No.1, Port B supplies outlet Port #1.

4 - The onboard supply No.2, Port C supplies outlet Ports #2 and #3 that are isolated from port B by the auxiliary shuttle.

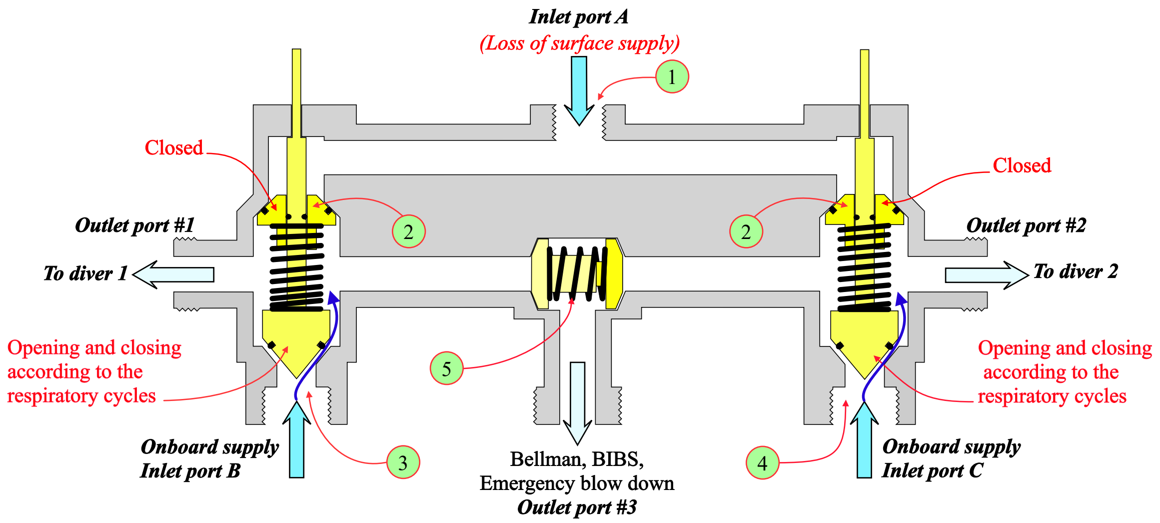
5 - Due to the ruptured umbilical, the continuous free flow in Outlet Port #1 causes both the upper and the lower halves of the shuttle to provide gas. Note that Diver 1 indicator on panel remains red until the emergency supply 1 bank has been depleted and the shuttle spring resets the lower half of the shuttle. At this point, diver 1 indicator will revert to green. the indicator rods lift to give a red indication.

6 - In the outer port #2, the lower half of the shuttle opens to compensate the loss of pressure and the upper half closes as the result of the pressure of the gas from inlet port C and the force of the spring.

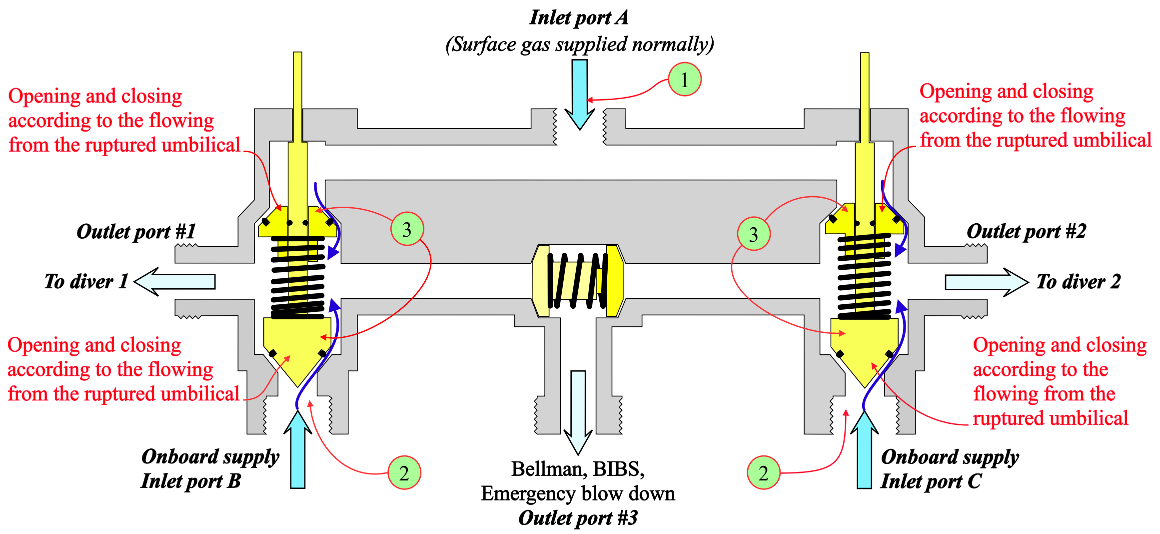
7 - The lower half of the shuttle diver 2 opens and closes to replace the inhaled gas in Outlet Port #2 according to the respiratory cycles. Diver 2 panel indicator remains red.



- Scenario D - Loss of surface supply
  1 - In the case of a loss of surface supply the pressure differential of 2 bar, initially set up between the surface and the onboard supplies, diminishes and eventually equalises with or becomes lower than the onboard supply pressure.
  2 - As a result, the upper parts of the shuttles close and the lower parts open. At this point the indicator rods lift to give a red indication.
  3 - The onboard supply No. 1, Port B, supplies the outlet ports #1 and #3. When diver #1 inhales, he creates a depression that opens the lower shuttle, allowing the gas from the onboard banks to flow in the outlet port #1. When diver #1 exhales, he creates an overpressure which, with the help of the spring, closes the lower shuttle. The process is renewed at each respiration cycle. Due to the differential pressure, the upper part of the shuttle remains closed.
  4 - The onboard supply No. 2, Port C, supplies the outlet ports #2 and #3. The lower shuttle is opened and closed according to the respiration cycles described above.
  5 - Under static conditions the spring loaded auxiliary shuttle valve seals against each half of the block. They open and close when the port #3 is solicited to supply Diver #3, Bibs, or the emergency blow down.
  6 - When the surface supply is restored and the 2 bar differential pressure reinstated, the lower shuttles close and the upper shuttles return to their original status. Note that the indicator returns to the green status.

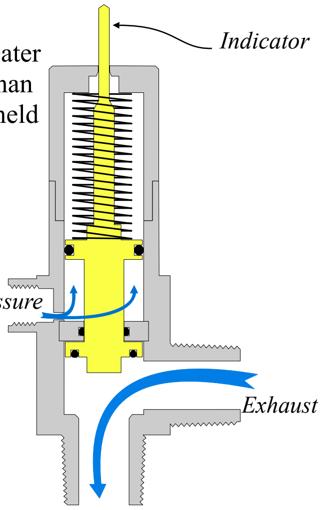


- Scenario E - Divers 1 and 2 umbilicals are severed
  1 - In the case that divers 1 and 2 umbilicals are ruptured during the dive, the surface supply is unable to maintain the flow and the pressure in Port A falls below the preset differential pressure (2 bar).
  2 - As a result, the on board emergency banks 1 and 2 will be brought on line to both Ports B and C.
  3 - Due to the ruptured umbilicals causing excessive free flow in the outlet ports #1 & #2 both the upper and lower halves of Diver's 1 and 2 shuttle provide gas until the contents of the surface and onboard banks are depleted or the inlet valves are closed. Note that both indicators will remain at red until the two on board banks are depleted or the valves closed, at which point they will revert to green.
  4 - The bellman is supplied from emergency bank #3 *(supply line #25 in the photo)* and remains unaffected by the loss of gas to divers 1 and 2.

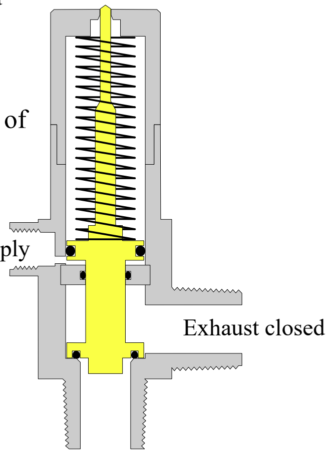


Modern bells are connected to gas reclaim systems that recover the gas mixture breathed by divers, re-process it, and deliver it into the supply system. The breathed gas is removed from the helmet, pass via the bell *(see #35, to #40 in the general scheme)* from which it is sent to the reprocessing unit at the surface where the carbon dioxide, moisture, and particulate or biological contaminant, are removed and oxygen is added. It is then compressed and stored for further use. The gas is recovered to the surface by the suction resulting from the differential pressure between the surface and the depth the bell is stored. However, a too lofty aspiration may injure or kill the divers. For this reason, a back pressure regulator *(#36 in the general scheme)* is used to reduce the differential pressure to only 1 or 2 bar. Also, SAECO (supply actuated exhaust cut-off) valves *(#35 & #36 in the general scheme)* are in place to isolate the divers from the exhaust line in the case that the surface supply drops below the predetermined value. The principle of the SAECO valves is as follows:

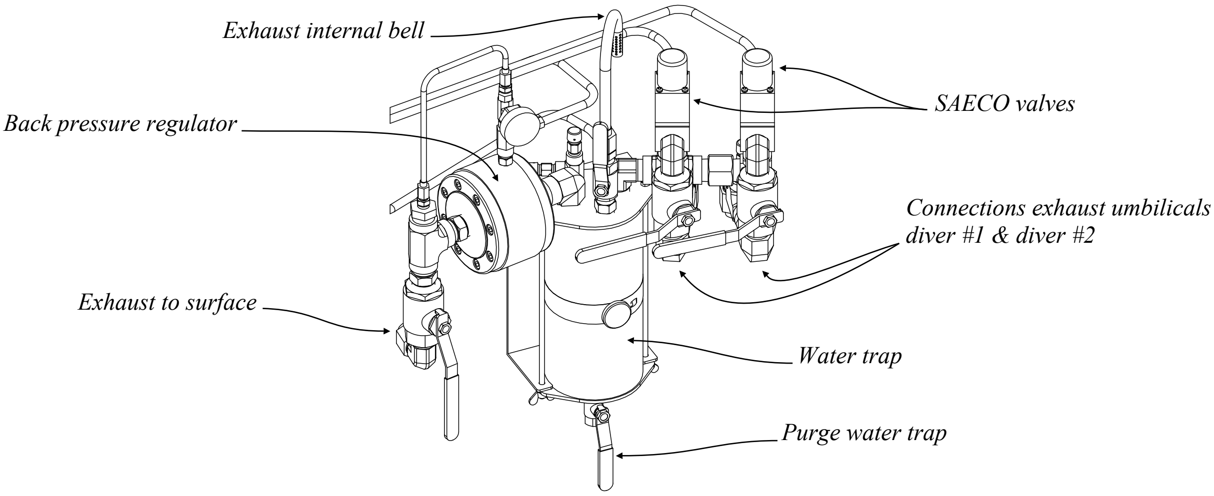
In a normal condition, the supply pressure exerts a greater force on the plunger body than the springs, so the valve is held open.



If the diver gas supply pressure falls below a predetermined value, the springs force the piston to close.
Note that an indicator is provided to show the status of the valve.



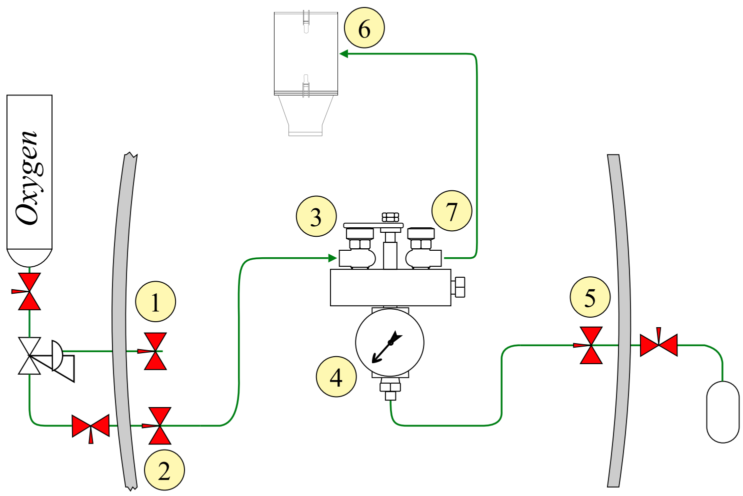
Water traps are installed to remove the excess moisture from the gas sent to the reclaim system *(see #38 in the general scheme)* They are made of robust transparent materials such as polycarbonates or similar. IMCA says that that the water trap inside the bell must be readily accessible to the bellman. Also, NORSOK U100 also says that they must be designed for simplicity of cleaning, disinfecting and drying, to prevent microbiological contamination.



The metabolic consumption of oxygen of one diver during 1 hour is thirty litres. This oxygen must be renewed during the bell run and in the case that the bell is lost. This is the function of the oxygen add system.
IMCA says that the oxygen supplied to the inside of the bell must be reduced to low pressure (normally < 40 bar). Also, there must be a system which limits either the rate of flow or the volume which can enter in the bell to minimize the risk of O_2 building up. This is done through the oxygen add manifold and the buffer *(#22 & #23 in the scheme)* which is explained below.
The O_2 add manifold controls the O_2 injection in the bell (or the HRC) by means of a buffer tank. The interlock between the two valves prevent the O_2 storage gas bottle to be in direct communication with the hyperbaric vessel when the buffer tank is pressurised. The buffer tank is generally designed to contain 30 to 35 litres of oxygen.

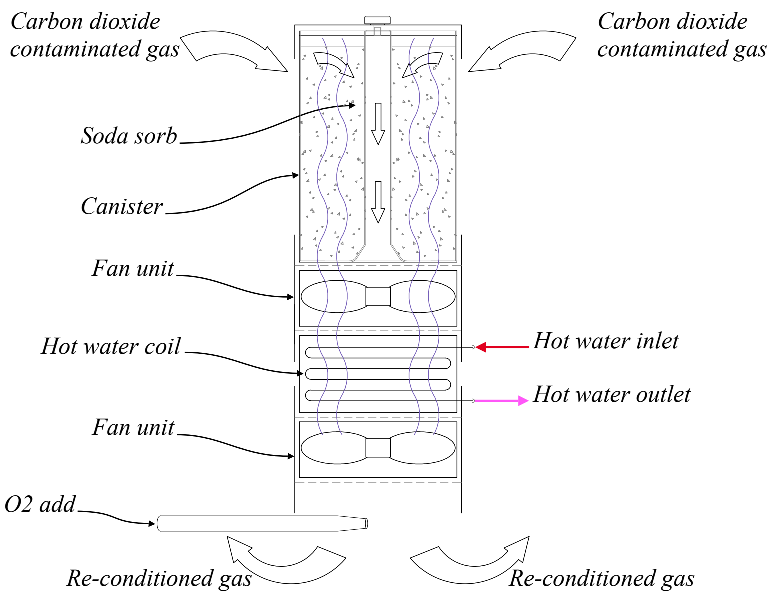
The principle of use is as follows:

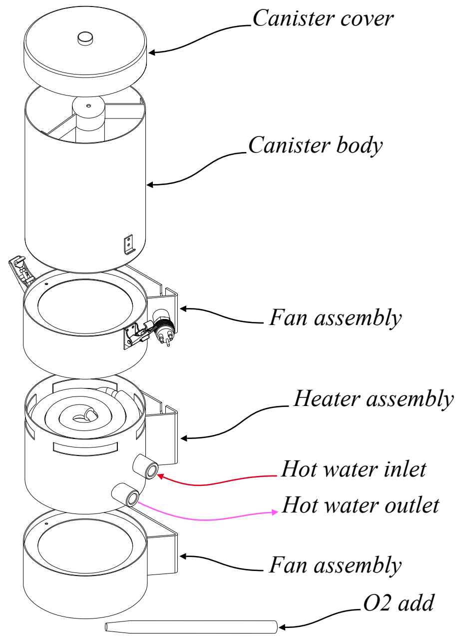
1. *Open the pilot valve of the O2 regulator (#1).*
2. *Open O2 supply valve (#2).*
3. *Move the interlock plate and open the manifold valve No 1 (#3).*
4. *Adjust the pressure to 5 bar above the ambient pressure (#4).*
5. *Open the valve of the buffer cylinder, and fill the cylinder (#5). Close the valve No 1.*
6. *Scrubber on (#6)*
7. *Move the interlock plate above valve No 1 and open the manifold valve No 2 (#7). At this moment the dose of O2 is introduced in the bell.*
8. *Close O2 supply valve (#2), Pilot valve (#1), Buffer valve (#5).*



As already said, valves carrying oxygen (or mixes with more than 25% oxygen) at a pressure higher than 15 bar must not be quarter turn *(See #1 in the picture on the next page)*. Note that the American Society for Testing and Materials (ASTM) recommends needle valves with a non-rotating stem. IMCA says: *"Due to the depths involved in saturation diving, the pressure of such gases will often require to be above 15 bar. All valves and pipework must be cleaned for oxygen service when used for gas mixes containing more than 25% oxygen. This may be demonstrated by means of a suitable procedure to ensure cleanliness which is applied when any components are new, first installed, or moved."*

CO_2 may quickly build up if it is not regularly removed. IMCA D 024 says: *There must be a powered scrubber unit to provide primary CO_2 removal from the atmosphere.*
The scrubbers in use in bells are composed of a cartridge of soda sorb into which a blower pushes the bell atmosphere. Note that the hot water coil is sometimes fitted to the bottom of the scrubber *(see below)*. However, it often happens that the hot water coil is in a separated device. Besides, the blower is used to mix the O2 added through the O2 add system to the chamber atmosphere. The scrubbers are designed to be energized by the onboard batteries of the bell.

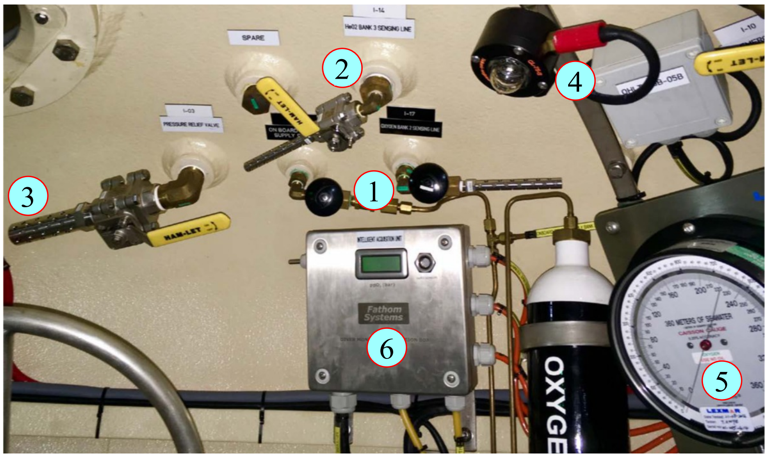




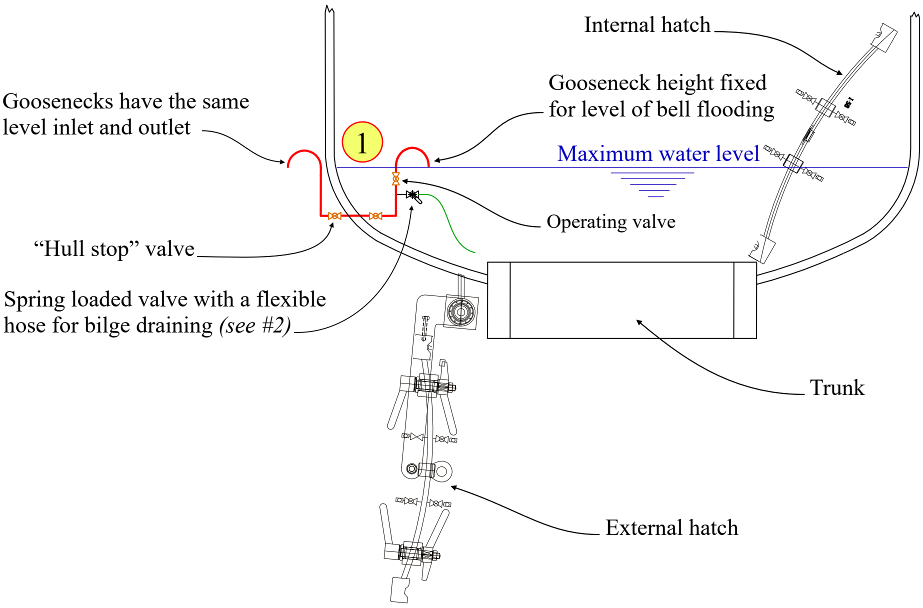
Note that the following elements should be taken into account:

- IMCA D 024 says: *The bell diving supervisor should have control of the bell blow-down at all times*
- As with the external of the bell, Hollow penetrators must be fitted with protection valves or other devices to stop catastrophic pressure loss. They must be clearly marked to show their function *(see #2 in the photo on the next page)*. Also, IMCA D 024 says that any open-ended exhaust pipework must be fitted with guards for finger protection *(see #3 on the next page)*. Any gas inlet pipework should be fitted with some form of a diffuser.
- Valves must be free of corrosion and should move freely through their full range of operation.
- Lighting must be provided to allow reading gauges or documents, operating the gas control panel and any other instruments, and dressing and undressing the divers *(see in the photo above and #4 on the next page)*. These lights are often composed of 24 volts bulbs powered by the main electrical supply from the surface. Also, battery-powered backup lighting must be provided. Note that there must be sufficient energy in the onboard batteries to supply the backup lighting system for at least 24 hours. A lot of modern bells are designed with lights that are automatically switched to the onboard batteries in the case of loss of electrical supply from the surface. These systems must be tested during the checklist.

- Depth gauges must be provided to let the divers know both the internal and external depth of the bell *(see #5 in the picture below and #21 & #44 in the general scheme)*. Also, there must be gauges or an alternative system to monitor the pressure of the onboard gas cylinders from both inside and outside the bell. The frequency of calibration of the gauges must not be less than six months.
- O_2 and CO_2 analysers must be available in the bell so the divers can monitor the atmosphere independent of the surface *(see #6 in the picture below)*. Also, hydrocarbon and H_2S analysers are mandatory and must be in place.



Bottom flooding system:
The lifting of a helpless body fully inside the bell from a point below floor level requires strenuous physical effort. Raising the level of the water inside the bell can help in this matter as a higher water level will help the bellman or the divers to climb back inside. Nevertheless, care must be taken not to fully flood the bell.
For this reason, a partial flooding system is designed to avoid the bell being totally flooded if the valve is left open while the bellman is leaving the bell to rescue the diver *(see #1 in the pictures below)*.
IMCA D 024 says point 6.12: *"There should be a valve fitted to allow partial flooding of the bell by the bellman. This should be in an easily accessible position and clearly visible. This valve should be in addition to the internal hull stop valve. This valve should be protected from accidental opening".*
Important: The operating valve must be reachable from the trunking. Note that, with some bells, if the bellman does forget to raise the level before leaving the bell, he may have great difficulty in getting back inside.



Heating system:
As the water is very cold at depth, the bell must be fitted with a means for warming the divers in the water and inside the bell. Conventional systems in use are based on hot water flowing from the surface through a heater in the bell and the suits of the divers. The heater in the bell is generally integrated into the scrubber. That gives the advantage that the exchanges with the chamber atmosphere are speed up by the fan of the scrubber. IMCA says that this requirement only applies to areas of the world where the ambient water temperature at the diving depth requires the diver to be heated. However, even though the water is hot at shallow depths in tropical and equatorial seas, it generally becomes too cold for long interventions at depths deeper than 40 metres. For this reason, hot water supply to the bell should be ready for use anytime and everywhere in the world. IMCA also says that there should be:

- A means of monitoring the hot water supply temperature inside the bell.
- A means of isolating the bell heater from the divers' hot water supply.
- Note that new bells are equipped with sensors allowing to monitor the temperature of the bell and the divers.

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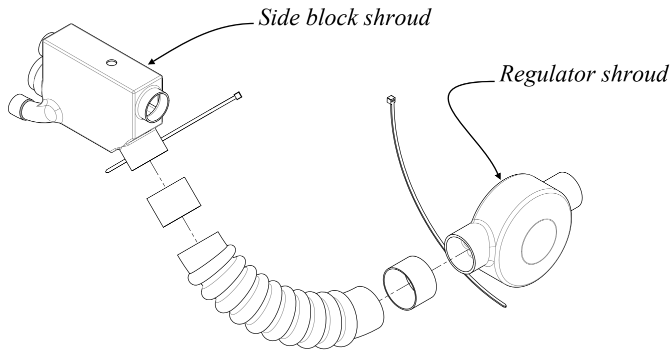
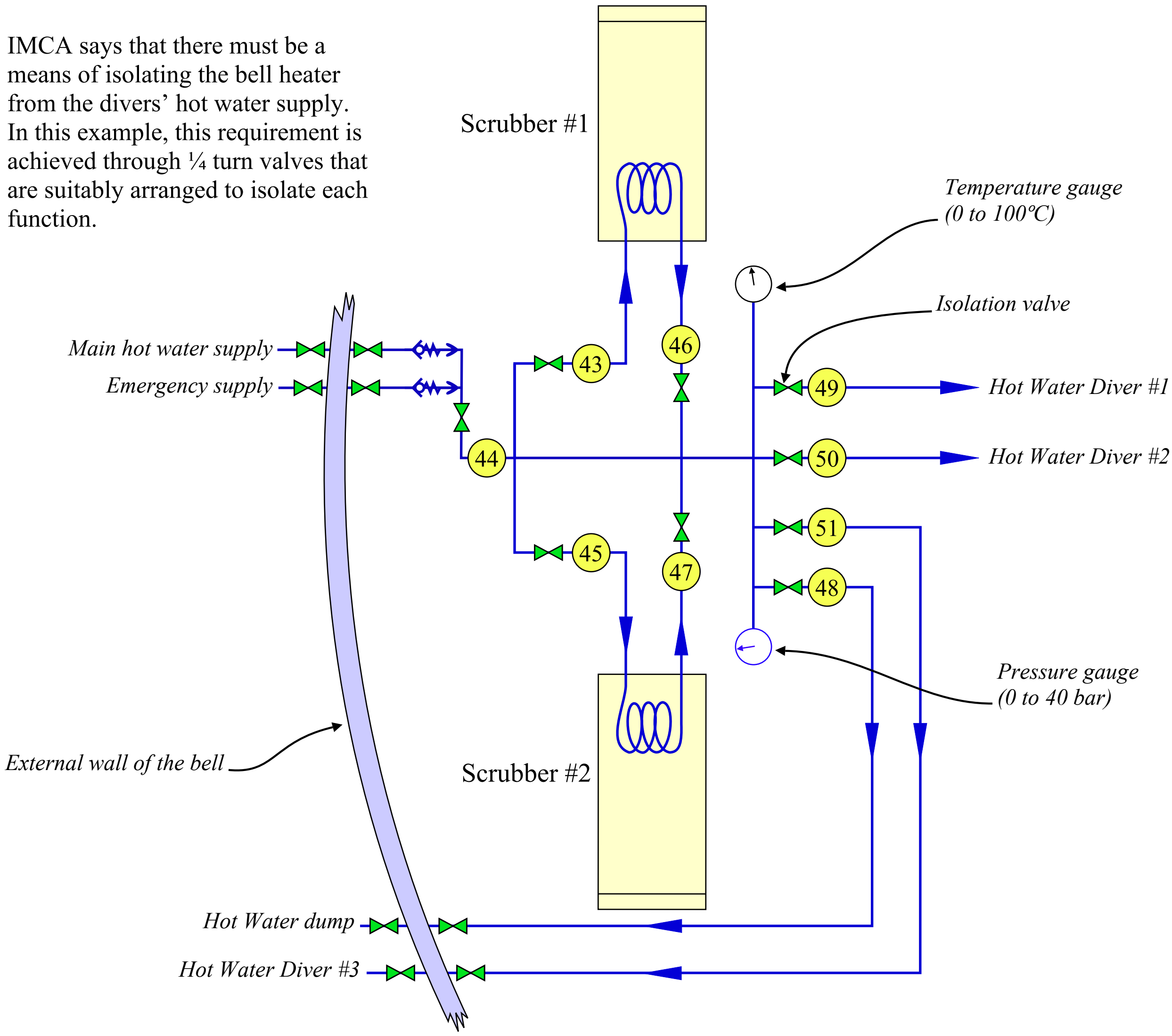
- A means of heating the divers inspired gas if diving at depths below 150 msw:
  The system consists of a rubber shroud inside which hot water flows. This shroud completely encases the side block, bent tube, and the regulator of the helmet to isolate the hot water flow from the surrounding cold water and so provide efficient gas heating. It is connected to the hot water supply of the diver by a splitter block assembly.

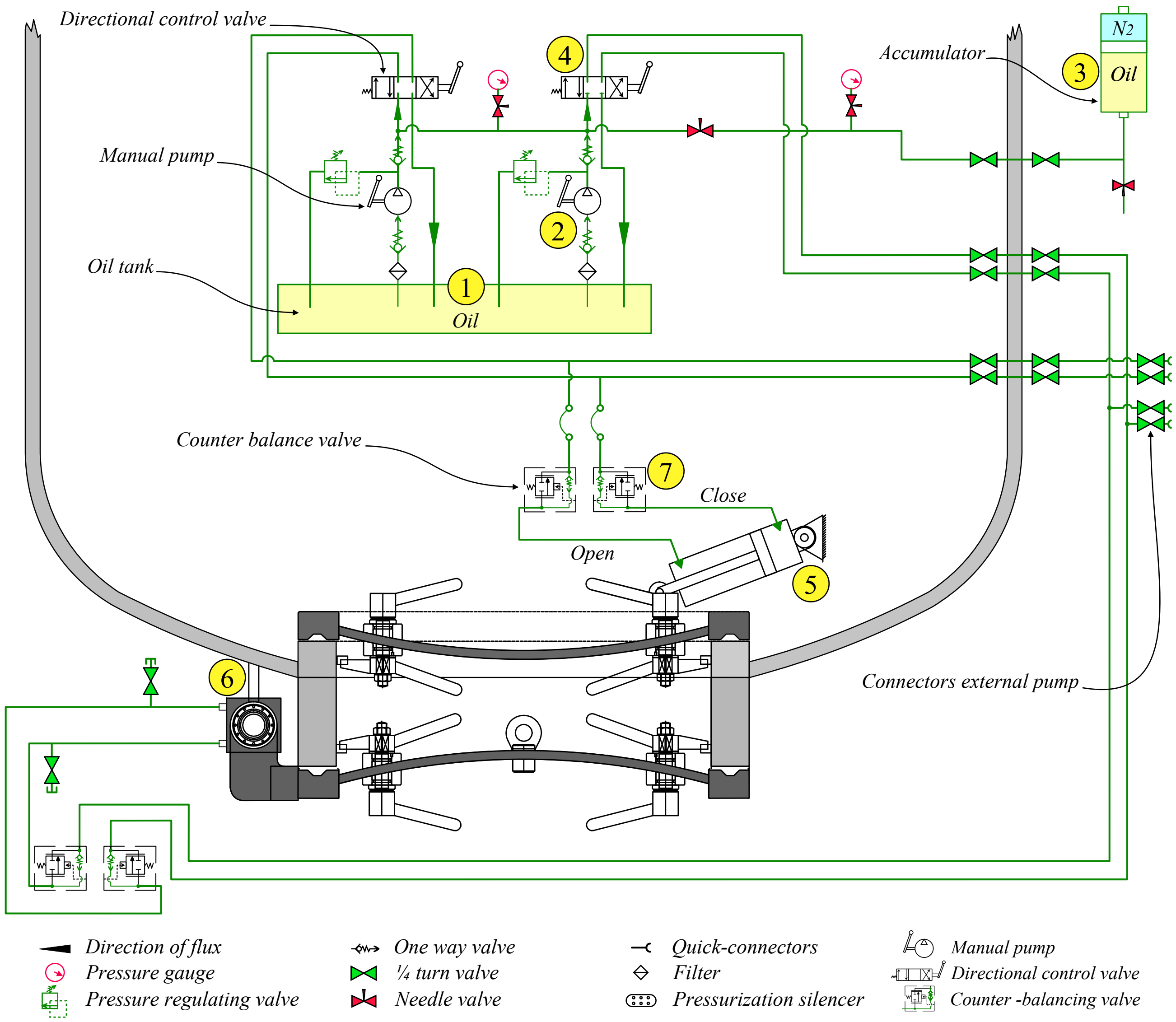


IMCA says that there must be a means of isolating the bell heater from the divers' hot water supply. In this example, this requirement is achieved through ¼ turn valves that are suitably arranged to isolate each function.

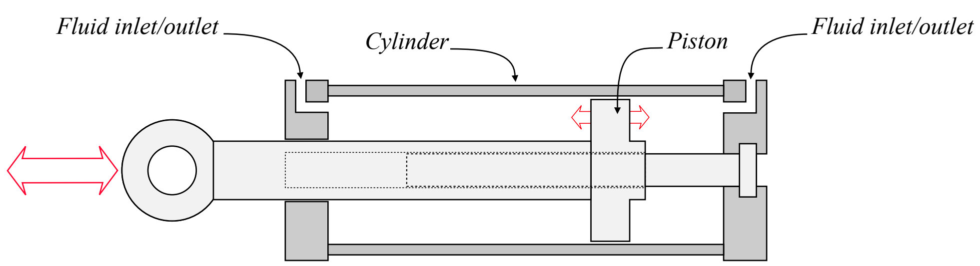


Bottom doors opening and closure *(source: LEXMAR & UDS)*:
As the bottom doors are weighty, moving them manually requires extreme efforts. For this reason, they are opened and closed by hydraulic actuators that are operated from the inside of the bell using manual hydraulic pumps. They can also be operated from externally. In addition to the comfort they provide, the hydraulic actuators prevent the divers from being injured and the seals and the hatches from being damaged. The system is generally designed as follows:

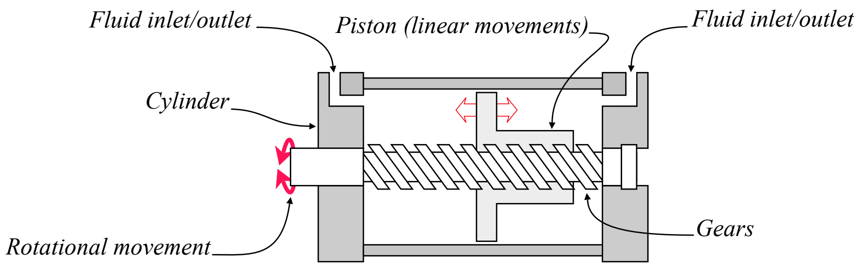
- The hydraulic oil that is stored in a hydraulic tank *(see #1 in the drawing below)* is pumped manually to the hydraulic circuit *(See #2)*. An accumulator *(see #3)* maintains the system at the ideal pressure.
- The Directional Control Valves *(see #4 in the drawing)* allows selecting whether the door is going to be closed or opened.
- The hydraulic fluid is pushed inside the actuator that opens or closes the door, depending on the direction of the flux *(see #5 & #6 in the drawing)*.
- Counterbalance valves *(see #7 in the picture)* are installed to create a back-pressure that prevents the door from free falling when the directional valve that controls the actuator is shifted to lower the load. This system protects the divers from being injured by a door closing unexpectedly and prevents the doors and their seals from being damaged as a result of shocks resulting from uncontrolled closing or opening.



- Note that two types of actuators are used:
  - Linear actuators are composed of a piston that moves out and retracts from and in a cylinder, which creates motion in a straight line such as with hydraulic jacks *(see scheme below)*. They are often used to open and close the internal bottom door of the bell *(see #5 in the drawing above)*.

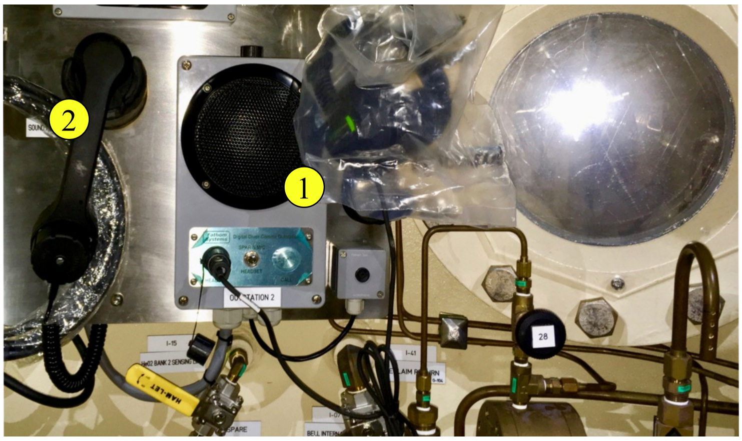


- Rotary actuators are composed of a piston moving in a cylinder that activates gears that create a rotational motion *(see the scheme below)*. They have the advantage of being compact and are often used to open and close the external bottom doors *(see #6 in the general drawing)*.



Communications to and from the diving supervisor should be provided to each diver and the bellman:
The communications of the divers are those of the helmets. The communications of the bellman are composed of an intercom, a sound powered-telephone, and a through water communication system. These devices should be water resistant and be installed in the upper parts of the bell.

- The intercom that is directly connected to the dive control is generally installed on the wall of the bell *(see #1 in the picture below)*. It should be equipped with a "bell button" that can be used by the bellman to attract the attention of the supervisor when a conversation is required.
- A sound-powered telephone *(see #2)* is a communication device powered by the sound pressure of the voice of the user rather than batteries or an electrical power source. When the user speaks into the mouthpiece, the sound waves of his voice cause a diaphragm to vibrate. The vibrations are transferred from the diaphragm through a drive rod to an armature centered in a wire coil that generates an electrical current. The current then is transmitted to the earpiece of the receiver, where the process is reversed. As a result, the person at the other end of the circuit hears the sounds transmitted. Note that the earpiece and the mouthpiece can be used interchangeably. As a result, the user can talk into the earpiece or hear through the mouthpiece, which allows continuing a conversation if one of these two elements fails. Ringing is accomplished by a manually activated magneto producing sufficient electrical power to operate a howler at the called station.
- Through water communications, also called Emergency bell communicator, are wireless communications that must be available to allow the supervisor to talk to the divers inside the bell when it is in the water and communications through wired systems are no more possible. The system operates by using high frequency ultrasonic sound waves that are passed through the water between the bell and the surface vessel. The set installed in the bell is powered by the onboard batteries of the bell or a dedicated battery pack *(see #3).*



Note that NORSOK U100 says that a means for processing of speech (unscrambling) should be available when using helium mixtures and used when required. A Modified Rhyme Test (MRT) should be used to verify that the operational communications systems are in accordance with the requirements of the table below.

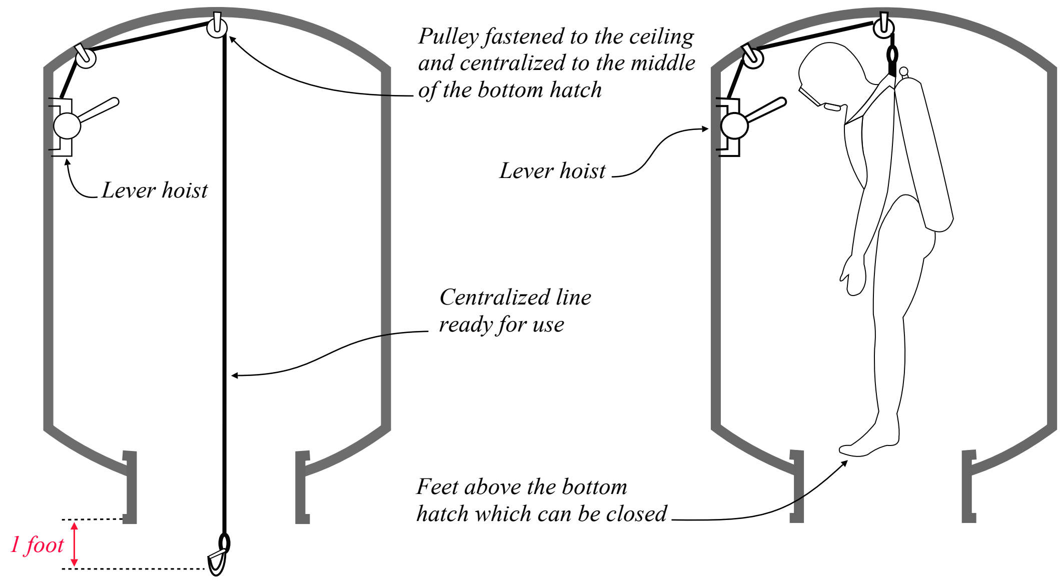
Communication requirement	***MRT score***
Exceptionally high intelligibility; separate syllables understood	0.97
Normally acceptable intelligibility; about 98 % of sentences correctly heard; single digits understood	0.91
Minimally acceptable intelligibility; limited standardized phrases understood; about 90% sentences correctly heard (not acceptable for operational equipment).	0.75

Cameras connected to a Close Circuit Television must be installed in the bell. They should be arranged in such way that the diving supervisor has a panoramic internal view of the bell and can observe the bellman and the divers during the dives and when performing the checklists.

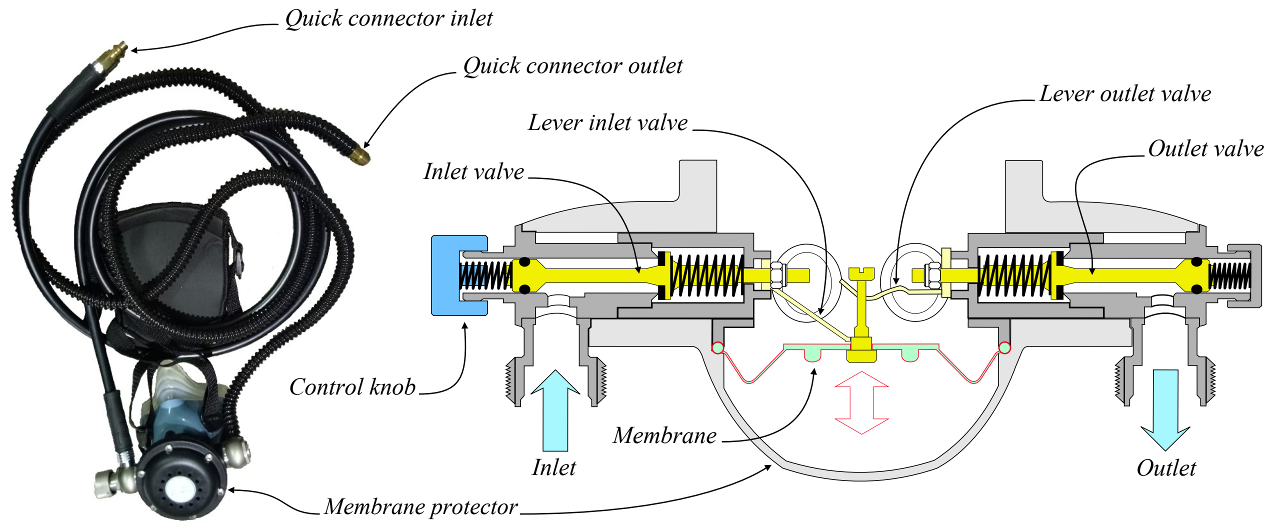
Other requirements to take into account:

- The umbilicals must be appropriately stored. It is achieved by the means of dedicated supports to which they are secured. In the bell taken as an example below, only divers' 1 & 2 umbilicals are stored inside the bell despite its internal volume of 6 m³ *(see the photo below from the CCTV).*
- IMCA D 024 says: *There must be a seat provided in the bell for the bellman. This seat should have a restraining harness or lap belt fitted which is available for use. There must also be a means of restraining each diver during ascent and descent in order to minimise the risk of injury. Note: This does not signify a separate seat for each diver.*
  The restraining of divers can be achieved by the use of handles adequately positioned. Nevertheless, a lot of bells, such as the bell from UDS Lichtenstein below, are equipped with a seat for each diver *(note that these seats are provided with lap belts instead of harnesses)*. These seats usually are retractable, so they can be folded up not to disturb the divers if necessary.

- IMCA also says: *Consideration should be given to providing a means to stop the bellman falling into the open manway either as a result of a slip or of losing consciousness*. Note that this requirement is optional
- A lifting device must be installed in the bell to recover and secure an unconscious diver into the bell. The system must be arranged to lift the casualty up as high as possible inside the bell to clear the trunking. For this reason, the topside pulley is connected to a padeye which is welded to the top of the bell and centralized above the middle of the bottom hatch. IMCA says that consideration should be given to providing a second pulley system in the case of bells where more than one diver may be locked out. Also, the attachment points for the pulleys inside the bell should be designed for the purpose and approved by a competent person.
  Note that during the bell run, the hook of the lifting device should be deployed and adjusted around 1 foot below the hatch.



Individual emergency breathing system:
IMCA D 024 says: *An oral/nasal or full face BIBS mask must be supplied for each occupant of the bell. This should be capable of providing breathing gas either from the surface or from the on board cylinders.*
Built-In Breathing System (BIBS) masks are also used in chambers to provide breathing gas in an emergency. These masks must be always ready for use. In the LEXMAR bells taken as an example, they are connected to the sides of the gas management panel using quick connectors. Note that there must be one mask for each diver plus one that is kept as a backup.
Depending on the model, the supply pressure for the mask generally ranges from 5 bar to 12 bar over the ambient bell pressure. Most masks can be adjusted to the optimum breathing resistance using a flow control knob.
The system consists of one membrane connected by two levers to an inlet valve and an outlet valve. When the diver inspires, the movement of the membrane opens the inlet valve and closes the outlet valve. When the diver expires, the movement of the diaphragm closes the inlet valve and opens the outlet valve.



Individual emergency CO_2 removal and heating systems:
IMCA says: *There should be a means provided, independent of surface supplies, to maintain the diver's body temperature and reduce CO2 for a minimum period of 24 hours in an emergency. This will normally be by means of survival bags and emergency scrubbers. Note: The heating requirement only applies to areas of the world where the ambient water temperature at the diving depth (or the depth the bell may descend to) requires the divers to be heated. The CO2 reduction requirement will apply in all circumstances.*
Lung Powered Scrubbers are used in hyperbaric environments to ensure the scrubbing of carbon dioxide contained in breathing gases in the event of a breakdown of gas supplies and ventilation.
The system consists of a mask connected by a ringed flexible hose to a cylinder that contains a cartridge of soda sorb. This cartridge that is designed to be used for 4 hours can be easily and quickly changed.
Sufficient refills must be provided to ensure at least 24 hrs breathing in case of a lost bell. They must be stored in sealed containers that fully isolate them from the atmosphere.
Lung powered scrubbers must be included in the survival kit of the bell and be regularly checked for integrity.

The survival bags should be specifically designed to be used in diving bells and may have active heating systems.
Regarding this point, NORSOK U100 says: *Shallower than 180 msw it may or may not include active heating (from e.g. electric energy). However, deeper than 180 msw it shall include active heating (from e.g. electric energy). The survival system shall ensure the occupants' ability to participate in the rescue operation.*
They should be stored in dry and fully sealed bags to protect them from the moist atmosphere found in bells.

Other emergency devices:
A copy of the AODC/IMCA emergency tapping code must be easily accessible to the bell occupants. Remember that this code must also be displayed on the outside of the bell. Also, IMCA says that a plasticized copy of the relevant emergency procedures must be available inside the bell with the list of valve positions to be adopted in an emergency. These procedures and list should duplicate those kept in dive control.

A medical kit that conforms with DMAC 15 list must be available and stored in a dedicated waterproof container that is marked with a white cross on a green background. This kit should be checked at least every 6 months

Also, the following tools that are not listed in IMCA D 024 should be available in the bell. Note that they must be adequately stored.
- Pliers and spanners that can be used to disconnect the wires and the umbilical or perform a quick repair.
- A cable cutter and a saw to cut the ruptured umbilical.
- A blank for closing a damaged porthole.

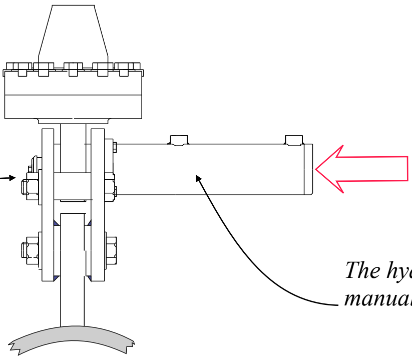
1.1.2.8 - Optional cutters or release mechanisms of the umbilical and lift wires operated from inside the bell

In the case of a lost bell that has to be recovered to the surface, the remaining parts of umbilical and wires should usually be cut or released.
Several systems exist to cut or release the umbilical and wires from inside the bell, avoiding the need to send a diver or the supporting ROV to perform this task. Nevertheless, note that these systems are only optional and that the majority of bells currently in service are not fitted with them.

IMCA says that:

- The system must be capable of operation from inside the bell, and the operating mechanism must be protected against accidental operation.
- Two independent actions are needed to operate the cutters or release mechanisms.
- If the cutters or release mechanisms are operated by means of pressurisation (gas or hydraulic), then isolations need to be in place such that it cannot be activated accidentally by external water pressure, internal gas pressure, or leakage of the hydraulic circuit.
- Visual examination and function test should be performed at least every 6 months and a full examination and function test every year

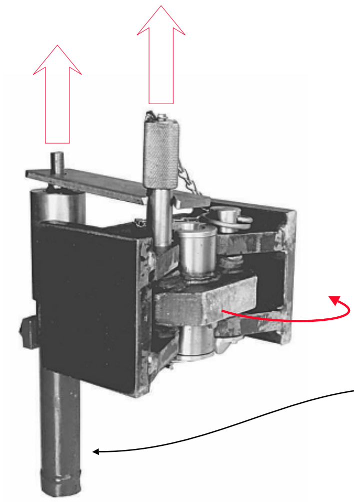
Example #1: Lifting wire release system



The socket eye is held directly by the ramrod. Removing the rod releases the socket

The hydraulic ram is actuated by a manual pump located inside the bell.

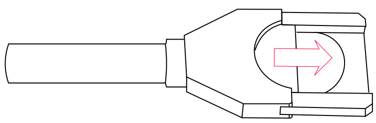
Example #2: Guide wire release system

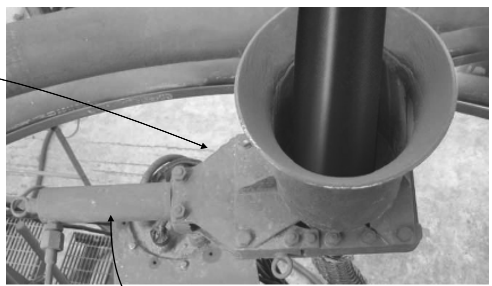


As for the lifting wire release system,the hydraulic ram is actuated by a manual pump located inside the bell.

Example #3: Umbilical cutter

The hydraulically operated device presented allows cutting an umbilical of a diameter up to 120 mm.





The system consists of a guillotine of which the blade is actuated by a hydraulic piston

Hydraulic piston

1.1.2.9 - Maintenance

During the operations, all the components of the bell must be visually checked and function tested before every dive. Also, the manufacturer provides the following guidelines regarding daily, weekly and monthly maintenance:

- Daily maintenance:
  - Visual inspection of the inside and the outside of the bell for damage.
  - Washing of the exterior of the bell if prone to oil / mud etc.
  - Battery diaphragm checks and removal of the gas in excess.
  - Tests of the Through Water Communication System.
- Weekly maintenance:
  - Close visual inspection of the sealing faces and O-rings
  - Close visual inspection of the batteries and their containers.
  - Checks of the quality and clarity of the mineral oil of the external bell enclosures. (Note that a degraded quality may indicate water intrusion).
- Monthly maintenance:
  - Visual check of viewports, pipework, electrical wiring, and hull penetrators.
  - Lighting, heating, and scrubber checks.
  - Inspection of the hull beneath the floor plates (possible accumulated water or corrosion).
  - Valve function tests.
  - Verification of the Labels of the penetrators.
  - Visual inspection of webbing straps and stitching on bags.

The six-monthly and longer frequencies inspections recommended by the manufacturer conform with those of IMCA Diving Equipment Systems Inspection Guidance Note (DESIGN) D 024. They are used for the regular audits and certification of the bell:

Items	*Visual external + function test , calibration*	*Visual internal + external + leak test at max. Working pressure*	*Internal + external+ leak test 1,5 max. working pressure*	*Other*
Design and manufacturer				According to the certification body
Pressure vessel	6 months	2 ½ years	5 years	
Viewports	6 months	2 ½ years	5 years	10 years old max.
Buoyant ascent: Secure mechanism.	6 months			
Buoyant ascent: Other components	6 months			Test buoyancy: 1 year
Ballast release system	Dry function test: 1 year		1 year (Overload static test)	NDE of critical items: 1 year
Cutter/ release system	Visual: 6 months Dry function test : 1 year			
Transponder	6 months			
External cylinders	6 months	2 years	4 years	
Interlock pipework	6 months	2 years		
Overpressure relief valve	6 months	2 ½ years		
External battery pack : overpressure relief testing	6 months	2 ½ years		Renewal bursting discs: 10 years
Valves, Pipework, fittings (external)	6 months	2 years	1st installation	
Electrical	6 months			
Gauges	6 months			

Items	*Visual external + function test , calibration*	*Visual internal + external + leak test at max. Working pressure*	*Internal + external+ leak test 1,5 max. working pressure*	*Other*
Emergency survival packs and passive scrubbers	6 months: (Water ingress and integrity packaging)			Fully checked and repacked: 12 months
Gas monitoring (O_2 and CO_2)	6 months			
Bell contamination control	6 months			
Gas cylinder pressure gauges	6 months			
Communication (all systems)	6 months			
Approval pulley attachment point inside the bell				Permanent
Medical equipment (DMAC 15)	6 months			
Valves, Pipework, fittings (internal)	6 months	2 years	1st installation	
Electrical (internal)	6 months			
Alarm (internal)	6 months			

1.1.2 - Divers' excursion umbilicals

1.1.2.1 - Function

Divers' excursion umbilicals are life lines that link the divers to the bell and provide the following functions:

- Gas supplies and exhausts:
  - Gas supply hose
  - Divers' #1 & #2 gas reclaim exhaust. Note that this function is not available for the standby diver as his mask is not equipped with reclaim.
- Temperature & depth control
  - Hot water supply
  - Depth control through pneumo hose which can also be used as a backup gas supply in the case of an emergency.
  - Telemetry. Note that this function is optional and performed through an electronic sensor installed at the end of the umbilical and sending information such as the depth and dive profile of the diver to a computer in the dive control.
- Communications & video recording
  - Communications to the dive control
  - Helmet camera wiring
  - Helmet light wiring

The excursion umbilical is also used to recover an injured or unconscious diver into the bell. For this reason, it must be extremely robust and resist the traction exerted by the diver and the tender during a critical recovery.

1.1.2.2 - Fabrication requirement

A good umbilical must be in one piece and able to slide easily to allow a recovery of the diver in any circumstance. Umbilical assemblies in use in the diving industry are of two basic constructions; spiral-wound and parallel.

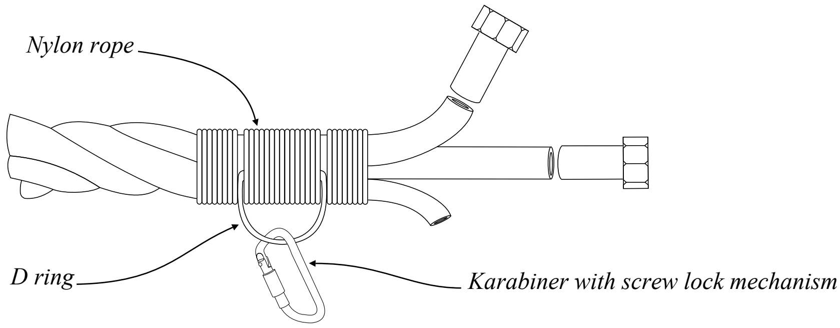
- Spiral-wound umbilicals are manufactured industrially as only machines allow producing this type of equipment with perfect twisting. Their strength comes from their spiral construction where hoses and cables are supporting each other. They resist kinking and abrasion and provide good flexibility, which allows them to slide along obstacles without being caught and damaged. As a result, they are recommended and imposed by most clients.
- Parallel (taped) assemblies are generally homemade umbilicals where hoses and cables are bought separately and taped together around a rope that is designed not to extend while under traction. These umbilicals are no more used in the majority of the saturation diving sites as most clients request manufactured spiral-wound umbilicals with a guarantee from the manufacturer.
  Also, even though some isolated clients do not impose these requirements, home umbilicals are far from the level of safety of industrial umbilicals because it often happens that the cables and hoses are not perfectly grouped, which results in an umbilical with asperities and buckles that can be caught in debris or parts of the structures and can preclude the recovery of the diver. Besides, they do not offer the degree of flexibility of spiral-wound umbilicals, and the grey tape commonly used to keep the hoses and cables together has to be replaced often. For these reasons, such umbilicals should not be used.

The previous generation of umbilical breathing hoses was made of rubber or PVC compounds. New generation hoses are made predominantly from polyurethane, which is a polymer without potentially harmful additives. Also, US Navy says that the maximum life of a rubber breathing hose should be limited to twelve years, and that synthetic umbilical assemblies do not deteriorate significantly with age, and may remain in service as long as it is deemed to be satisfactory.
The size and working pressure of the hoses and cables that compose the umbilicals are commonly as follows (*Note that the telemetry cable, which is optional, is not indicated in this table)*

Item	***Common colour***	***Internal diameter***	***External diameter***	***Working pressure***	***Burst pressure***	***Weight in seawater***
Gas supply hose	*Yellow or blue*	*9.5 mm (3/8")*	*17.5 mm (0.69")*	*35 bar*	*140 bar*	*52 g/m*
		12.7 mm (1/2")	*21 mm (0.83")*	*35 bar*	*140 bar*	*128 g/m*
Pneumo hose	*Blue or yellow*	*6.5 mm (1/4")*	*11.5 mm (0.45")*	*35 bar*	*140 bar*	*16 g/m*
Hot water hose	*Black*	*12.7 mm (1/2")*	*21 mm (0.83")*	*25 bar*	*100 bar*	*105 g/m*
Reclaim hose	*Black*	*16 mm (5/8")*	*27 mm (1.6")*	*69 bar*	*276 bar*	*95 g/m*
Comms cable	*Red*	*N/A*	*10.8 mm (0.43")*	*N/A*	*N/A*	*21 g/m*
Light cable	*Not specified*	*N/A*	*8 mm (0.31")*	*N/A*	*N/A*	*20 g/m*
Video cable	*Orange*	*N/A*	*11 mm (0.43")*	*N/A*	*N/A*	*70 g/m*

Also, note the following:

- Hoses and cables that compose the umbilical must be in one piece.
- There must be four wires into the communication cable to allow the installation of duplex communications. A duplex communication system enables all parties connected to the system to talk and listen at the same time.
- Safety and manufacturer organizations say that only swaged/crimped fittings should be used with hoses. Precautions must be implemented to be sure that these fittings conform with those of the helmet and the bell.
- The communication, light, and video fittings that are installed onto the cables at the diver's end must be waterproof. US Navy says that the preferred method of construction is to have the fitting molded onto the cable as with "marsh marine" connectors. However, there are several commercial self-curing rubbers, or epoxy kits can be used for sealing these types of connectors. Also, electrical and communication fittings which body is made of copper or brass and are waterproofed by the use of O rings and mechanical sealing systems can be used. However, these fittings which are often employed on bells and ROVs are expensive.
- Hoses must be tested at 1.5 times the working pressure when new or repaired.
- IMCA recommends that the diver's end of the umbilical is fitted with a means which allows it to be securely fastened to the diver's safety harness without putting any strain on the individual whip ends. This is generally done by the use of a D ring that is seized by nylon ropes onto the umbilical. US Navy says that the D ring must be welded and be able to hold a weight of 227 kg (500 pounds). US Navy also says that when seizing the D-ring to the umbilical assembly, wraps must be tight, but care must be taken to ensure that the hoses and cables are not crushed or pinched.
  A device with a locking mechanism should be used to link the D ring of the umbilical to the D ring of the harness. A 3¾"/100 mm carabiner is often used for this purpose.



Also, the lengths of the hoses and cables after the D ring must be adjusted to allow comfortable movements to the diver. However, these lengths must not be in excess. Thus, they must be calculated in function of the position of the attachment of the umbilical on the harness.

1.1.2.3 - Installation in the bell

IMCA D 024 says that the umbilical must be marked for length at least every 10 m using a recognized system which allows easy visual identification of the length paid out. However, NORSOK and a lot of organizations say that the umbilicals must be marked for length at least every 5 metres using a system similar to the one displayed below which is the system recommended in this manual:

Umbilical length	*Black tape*	*Red tape*
5 m		*1 turn*
10 m	*1 turn*	
15 m	*1 turn +*	*1 turn*
20 m	*2 turns*	
25 m	*2 turns +*	*1 turn*
30 m	*3 turns*	
35 m	*3 turns +*	*1 turn*
40 m	*4 turns*	
45 m	*4 turns +*	*1 turn*
50 m	*1 broad turn*	
55 m		*1 turn*
60 m	*1 turn*	

NORSOK U 100 says that when determining the maximum umbilical length, the following safety factors should be taken into consideration:

- The distance from the diver to the nearest hazard point *(thrusters, seawater intake, etc.)* should be a minimum of 5 metres;
- duration of bail-out equipment;
- breathing resistance;
- thermal conditions;
- umbilical storage, deployment, handling and recovery;
- wet tendering;
- ROV survey with mapping of debris/ obstructions;
- positioning and stability of the work-site

Also IMCA & NORSOK say that the bellman's umbilical should be 2 metres (6½ feet) longer than the working diver(s) umbilical.
As a result, the maximum allowable distances of the divers must be clearly identified for each diving operation and the umbilicals restricted in the bell to these maximum lengths. The means of restriction must be sufficiently solid not to be removed unexpectedly, and smooth enough not to damage the umbilical. Dedicated ropes securing the umbilicals to their supports are commonly used for this purpose. Also, the fittings of the umbilicals in the bell must be protected from direct tractions. For this reason, the fastening of the umbilical must be designed in the same manner as for the diver's end.

Note that NORSOK standard U100 says: *"The length of the diver's umbilical shall be limited to the length considered necessary at any given time, and shall not exceed 45 m from point of tending in the bell/wet bell/basket."*

1.1.2.4 - Backup excursion umbilical and their storage

Note that backup excursion umbilicals are not mandatory with IMCA or NORSOK. However, they should be available on site in case one of those in service has to be repaired.
It must be understood that repairing a damaged umbilical may take time and require specific equipment. As a result, the diving operations may be delayed which is not conceivable in the scope of expensive operations such as saturation diving. For this reason, replacement excursion umbilicals are often required by the clients. They should be ready for immediate use and stored in such condition that they will not be damaged by the surrounding activities and the external weather conditions.
Also, regarding the umbilical of the surface standby diver, IMCA says that an adequate stowage allowing it to be coiled up away from risks of damage and such that a minimum bend radius of components is not compromised should be provided. These recommendations should be applied to stored umbilicals.

1.1.2.5 - Maintenance

Umbilicals must be checked and function tested before every dive. Also, IMCA D 024 says the following:

- The continuity and resistance of all cables must be checked every six months. Also, the other electrical components of the umbilical should be examined and function tested at the same time.
- Hose components should be carefully monitored, and function tested every six months. Also, they must be tested to their maximum working pressure every two years. Besides, they must be hydro tested to 1.5 times their maximum working pressure when they are new or as recommended by the manufacturer or the certification body.

1.1.3 - Diving suits

Diving suits are of primary importance to protect the diver from wounds, marine growths, venomous animals, and of course, isolate him from the effect of cold waters that are often encountered at depth. Note that water has a thermal conductivity of 0.606 Watt per metre Kelvin (W/mK) at 25 ºC when air is only 0.0262 W/mK.
Two means of protection are proposed by the manufacturers: Passive and active protection.

- Passive protection suits are based on materials, such as foamed neoprene, that isolate the diver from the surrounding medium. Thus, they slow down the loss of heat during a limited time that depends on the temperature of the water, the convection due to the underwater current, and the pressure at depth, which crushes the isolation materials. As a result, depending on the surrounding conditions, the divers may become hypothermic if these suits are used for too long exposures.
- Active protections suits are designed to supply heat that is monitored to provide a comfortable temperature allowing the diver to work a long time. Modern systems are all based on suits heated by hot water. However, electrically-heated diving suits have been studied and tested in the past.

As diving operations in saturation imply long dive times, active protections suits are the most appropriate..

1.1.3.1 - Neoprene hot water suits

These suits that are made of pre-compressed 4 mm neoprene or thicker standard neoprene are reinforced by an anti-abrasion lining and are designed with a zip to allow easy dressing. Besides, rubber protections are glued to the knee and elbow areas, which are the most exposed to shocks and wear.
They are the continuation, and in fact, the termination of the hot water circuit installed in the bell: Thus, the hot water is delivered from the surface to the bell, and then to the divers through the water hose of the umbilical. This hose is connected to a manifold situated on the right-hand side at a hip level using a quick connector that must be designed to be secured. This manifold, that must allow for easy adjusting of the flow of water, must be designed with a water dump option to divert the water flow outside the suit if necessary.
The hot water is distributed by small flexible tubes carrying it from the manifold to the wrists and ankles, in addition to those in place to heat the bulb and the spinal cord. This hot water distribution system should capable of supplying a flow of up to 30 litres per minute. Note that the flow and the temperature of the hot water are monitored and adjusted by the diving supervisor according to the indications of the diver. The manifold of the suit is only used to refine the adjustments made at the surface or shut off the water supply if it becomes scalding.
The suit is closed by appropriate boots and gloves that are selected according to the operation to perform. These items are generally fitted with long sleeves to slow down the flow moving out of the suit by these openings.
In the case that the hot water supply is lost the neoprene allows sufficient passive protection to return to the bell safely.
Note that when performing the pre-dive checks, the following points should be closely monitored:

- There must not be tears or excessive wear of the neoprene cloth, and the teeth of the zip must be in perfect condition with the slider moving smoothly.
- The manifold must be easy to open and close, and the small tubes must be all in place and connected.
- The quick connection of the hot water hose of the umbilical must be able to be secured and not to be disconnected unexpectedly; The male coupler must not have any visible shock, and the ring of the female coupler should move and lock easily with all the locking balls in place.

1.1.3.2 - Hot water suits made of linen cloth or similar

The neoprene hot water suits described above are often too hot in shallow tropical waters and outfits that are made of heavy linen cloth are usually preferred. They can be suits that are specifically manufactured for this purpose or modified and reinforced robust coveralls. They are supplied with hot water with the same components as a neoprene hot water suit. However, they do not offer any extra buoyancy and passive thermal protection, which limits their usage to depths less than 100 m.
Rubber gloves and reinforced boots generally close them. However, neoprene socks are worn when fins are used. As with neoprene suits and standard working coveralls, a sturdy zip allows easy dressing.
Suits made of linen are sufficiently robust to protect against corals, shells and small shocks. However, they should not be used if there is the risk of cold underwater currents. Thus, when the conditions at the location are doubtful, a neoprene hot water suit should be preferred.
Also, linen clothes are often aggressive to wet skin, and it is recommended to use soft under-suits to protect it. It is also recommended that these under suits are designed to follow the shapes of the body as the openings of the linen suits are often imperfectly sealed and wide enough to allow small venomous animals such as jellyfish and others to enter into them. As these suits do not offer any thermal protection, wet suits made of foamed neoprene 3 mm or thicker are often used.
The points to closely monitor during pre-dive checks are those already described for the neoprene hot water suits.

1.1.3.3 - Hot water undersuits

They are liners which stops suit chafe and direct contact of the hot water to the skin.
As with wetsuits used for swimming, they are made of foamed neoprene 3 mm thickness that is protected from wear and other damages by an external sheet of lycra or a similar textile. They are generally one-piece suits. Nevertheless, suits composed of two pieces can be used.
Due to their elasticity, such suits follow perfectly the shapes of the body and the flow of water entering into them is reduced to a very minimum that is then trapped underneath the neoprene layer. Thus, the body is isolated from direct contact with the hot water. Also, they offer additional isolation if the hot water supply fails.
The performances of a wetsuit depends on the number and the size of the bubbles that are in the neoprene foam. The high-density neoprenes are more compressed and have more small bubbles. As a result, they are less subject to crushing and buoyancy change than low-density neoprene. Thus, they are offering better thermal protection and are often used to manufacture diving suits such as neoprene hot water suits. However, their inconvenience is that they are not as soft as low-density neoprenes that, despite more reduced isolation, are preferred for undersuits that must allow maximum movements.
It must be noted that these undersuits are designed to be worn underneath hot water suits that are made of 4 mm high-density neoprene or thick non-compressed neoprene. However, when hot water suits made of linen cloth are used their thickness, and isolating materials can be selected to compensate for the absence of isolation offered by these suits.

1.1.4 - Diving harness

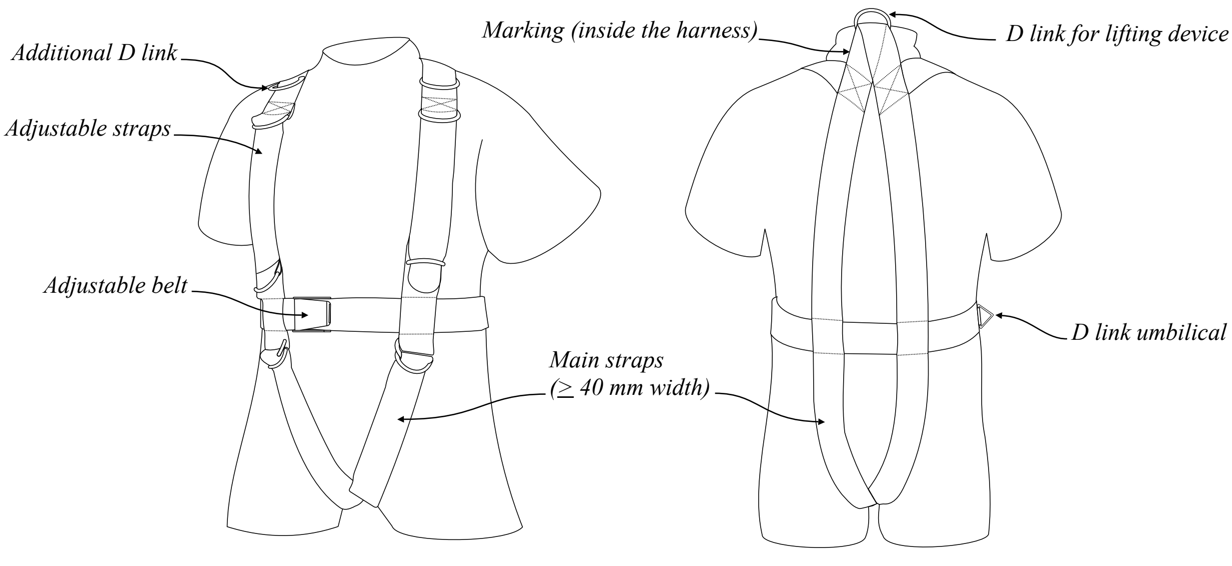
1.1.4.1 - Description

Each diver (including the standby) should be provided with a safety harness. This harness should be manufactured to an appropriate and recognized standard and be fit for the purpose it is to be used.
Note that the standards published according to which these items are manufactured such as EN 361, ISO 10333-1, ANSI Z359.11, are those for the design of "full body harnesses" which are personal protective equipment against falls from a height. However even though their conception and process of manufacturing are very similar, there are differences between harnesses that are designed to stop a fall and the diving harnesses which aim is the recovery of an injured diver from the water and the securing of his umbilical.
For this reason, diving harnesses should never be used for working at height, and a harness which purpose is to stop a fall should not be used underwater as it is not designed for that.
Among the common elements found on each type of harness we can note the following:

- Webbing and sewing threads should be made from virgin filament or multi-filament synthetic fibres suitable for their intended use. According to EN 361, the breaking tenacity (Tensile Strength) should be at least 0,6 N/tex (one N/Tex is the same as one GPa per gram per cm³).
- The threads used for sewing must be physically compatible with the webbing, and the quality must be compatible with that of the webbing. They must be of a contrasting shade or colour to facilitate visual inspections.
- A harness must comprise straps or similar elements which are placed near the pelvic area and on the shoulders. It must fit the wearer and means of adjustment should be provided.
- The harness should be designed in such a way that straps cannot migrate from their position and be loosen by themselves. Also, the width of the straps that support the body must be at least 40 mm and the other straps at least 20 mm. Note that the straps which support the torso or exert pressure on it must be the primary straps.
- The securing buckles must be designed in such a way that they can only be assembled in a correct manner. If they are capable of being assembled in more than one way, each method of assembly must conform to the strength and performance requirements.
- Metallic fittings must be treated against corrosion. As a result, evidence of corrosion of the metal is not acceptable. However, the presence of tarnishing and white scaling is acceptable.
- Marking on the harness must be in the language of the country of destination or in a common language. The marking must include the following:
  - A pictogram to indicate that users must read the information supplied by the manufacturer.
  - The model/type identification mark of the harness, the standard the harness conforms to, the name of the manufacturer, the reference number, and the date of manufacture.
  - The 1st date of service should be written on it in such a way that it is clearly visible and cannot be erased.

Regarding the particularities of diving harnesses note the following:

- The D link dedicated to connecting the lifting gear is a the top of the harness to be easily accessible despite the bailout and not in between the shoulders as with the stop fall harnesses. This D link must be sufficiently wide and robust enough to connect a sling or a small hook and recover an injured diver to the bell when necessary. As a result, it must be capable of withstanding the weight of the diver and a dynamic shock that may result from bad handling. Note that the tests performed for "full body harnesses" by manufacturers consist of a falling dummy of 100 kg on a vertical distance of 4 m.
- There must be an attachment for the umbilical of the diver that is commonly situated at a hip level for the saturation divers. However, connectors at chest level are often used for surface orientated diving. Remember that US navy says that this D link must be welded and be able to hold a weight of 227 kg (500 pounds).
- A backpack may or may not be fitted to the harness.



They are numerous models of harnesses. However, they can be classified into two main categories:

- Standard recovery harnesses are similar to the one drawn on the previous page and the blue one below. They may be fitted with a backpack. However, they are often worn underneath stabilizing jackets or backpacks that are not provided with a recovery attachment point designed to recover an injured diver.
- Vest harnesses are composed of straps similar to those used for standard harnesses that are sewed to a robust vest. These harnesses are generally designed to be fitted with a backpack. Also, numerous pockets where the diver can distribute additional weights (to control his buoyancy) and tools, are available. They are comfortable to wear, are very robust, and allow quick dressing.

Vest harness

Standard harness

Also, a lot of models that can be considered as hybrids between these two categories exist. In addition, note that recovery harness may be part of equipment such as rebreathers and Buoyancy Control Devices (BCD).

1.1.4.2 - Pre-dive check and preventive withdrawn

Harnesses must be controlled before each dive. This control consists of the inspection of the elements described above. As an example:

- There must not be any excessive wear of the straps, and the sewing threads must be in perfect condition.
- The D links must be without deformation and not be corroded
- The securing buckles must not be corroded, and the straps must not slide when they are secured
- The backpack, if fitted with, must be correctly secured so the bailout cannot be lost.

It is essential to be aware that diving harnesses have a limited life time. As a reference, IMCA D 024 says:

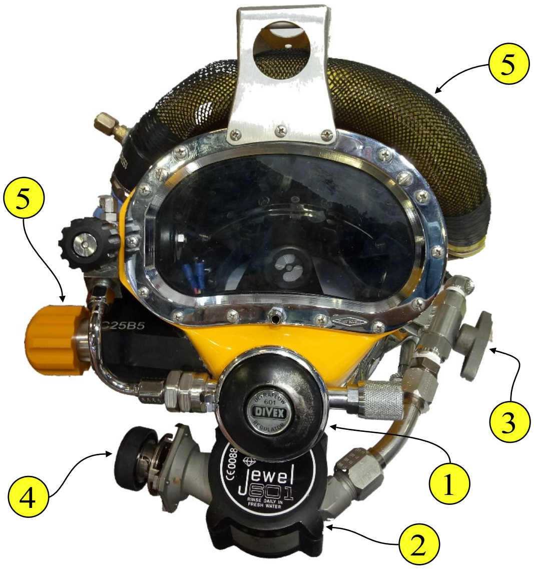
- Harnesses should be discarded 5 years from the time first put into service, or sooner if recommended by the manufacturer or deemed appropriate by the divers or the technician in charge of the maintenance of the diving system due to conditions of use.
- Harnesses should be discarded 10 years from the date of manufacture or sooner if recommended by the manufacturer or deemed appropriate by the divers or the technician in charge of the maintenance of the diving system due to conditions of use. Note that they must be discarded even though they are in service for less than 5 years.

As a result of what is said above, it is prudent to control the dates of service and the condition of these items before starting the project

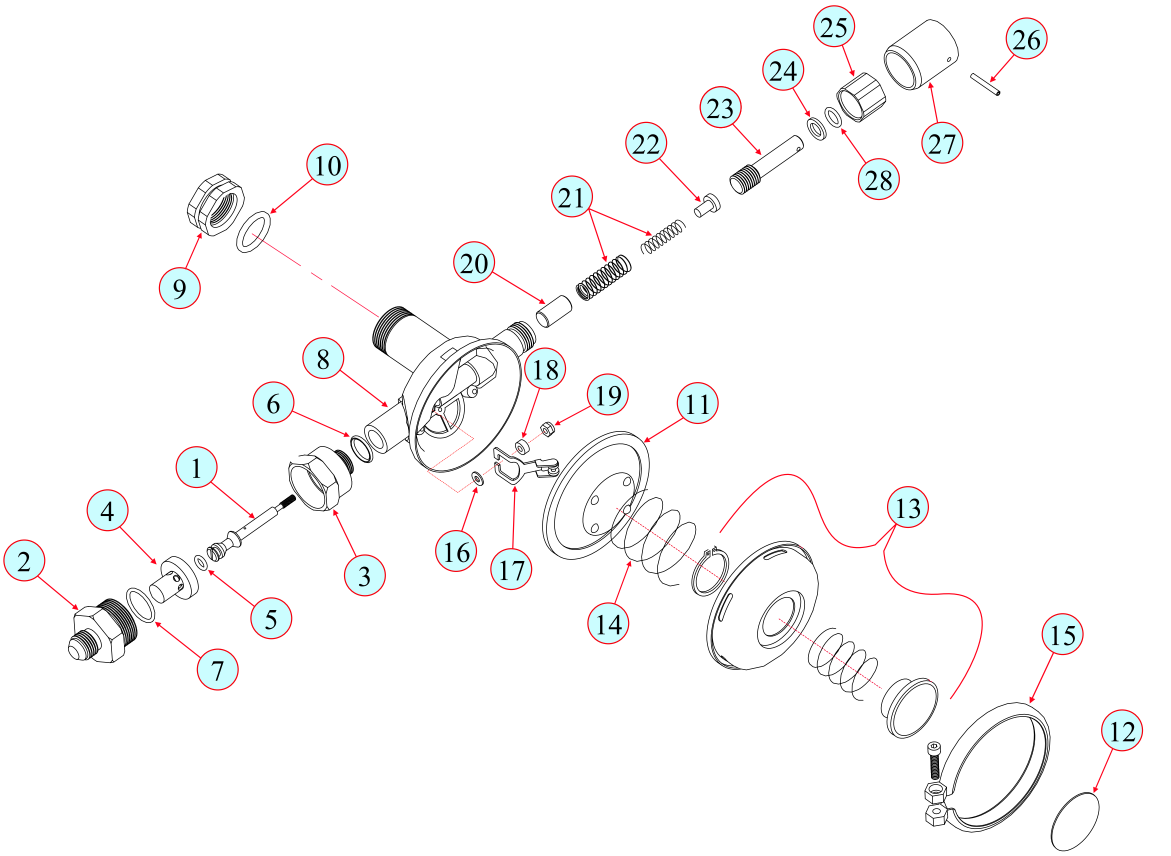
1.1.5 - Helmets and Standby diver mask

1.1.5.1 - Working divers helmets

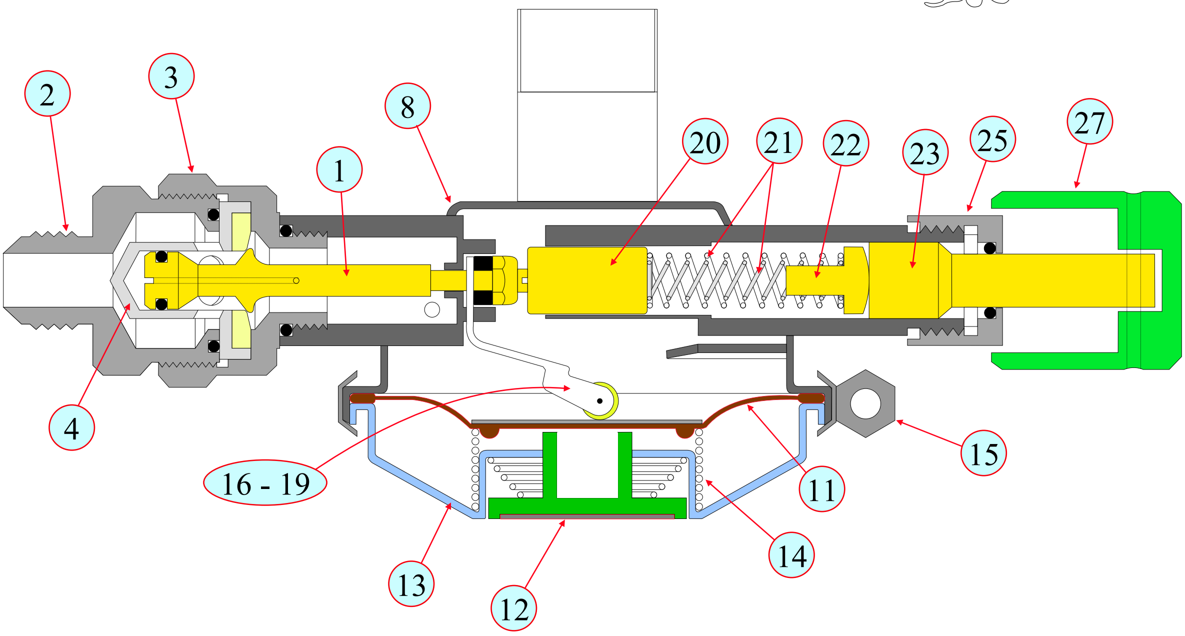
As already said, new bells are fitted with a gas reclaim system. For this reason, helmets used by the working divers must be equipped for this purpose. Also, these helmets must be designed to protect the head of the divers from shocks and dropping objects and they should be fitted with a means to stop them becoming detached from their clamp while in use.
The Divex "Ultrajewel 601" is the model fitted with a gas reclaim valve that is the most used in the industry.
It is composed of the fibreglass shell of the Kirby Morgan 17 C to which the Divex "Ultra-flow 601" balanced demand regulator *(see #1)* and the "Divex Jewel 601" two stages reclaim valve *(see #2)* have been installed.
When used with an efficient heliox reclaim system, this helmet allows a reduction of 90% of gas consumption or better.
The closed-circuit reclaim system is activated by the opening of the 1/4 turn exhaust valve situated on the left-hand side of the helmet *(see #3)* and the closing the "open circuit valve" *(See #4)* that is installed on the right-hand side of the Divex Jewel 601 two stages reclaim valve *(See #2)*. In the case of a problem with the reclaim circuit, the helmet can be operated in open-circuit mode. In this case, the "open circuit valve" is opened and the exhaust ¼ turn valve is closed to isolate the hose that returns the exhaled gas to the reclaim system.
Note that the model in the picture is also designed for the use of a Compact Bailout Rebreathing Apparatus (see #5).



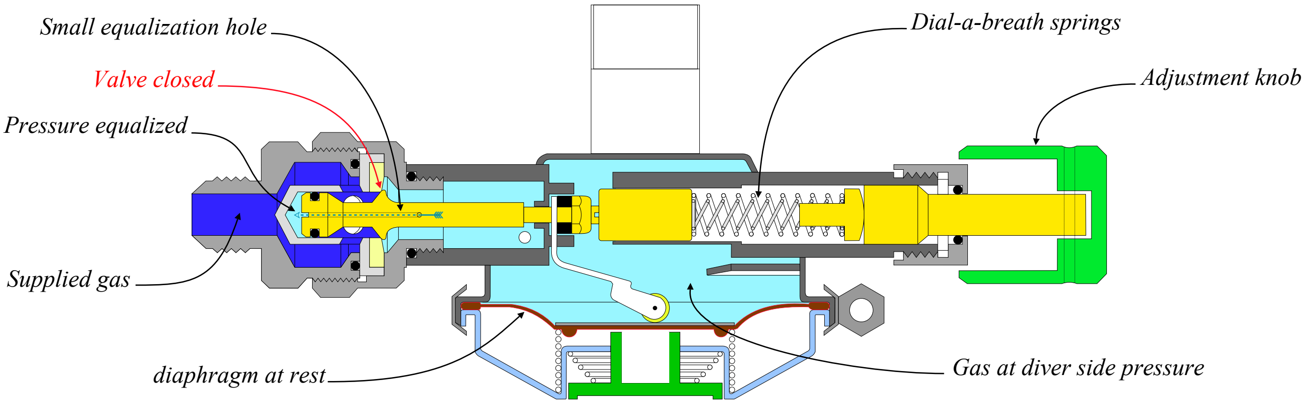
The "Ultraflow 601" is a balanced demand regulator designed to depths up to 500 m. The components of the inlet valve consist of a 316 stainless steel housing a brass seat retainer with a valve seat material and the brass inlet valve which connects to the lever.



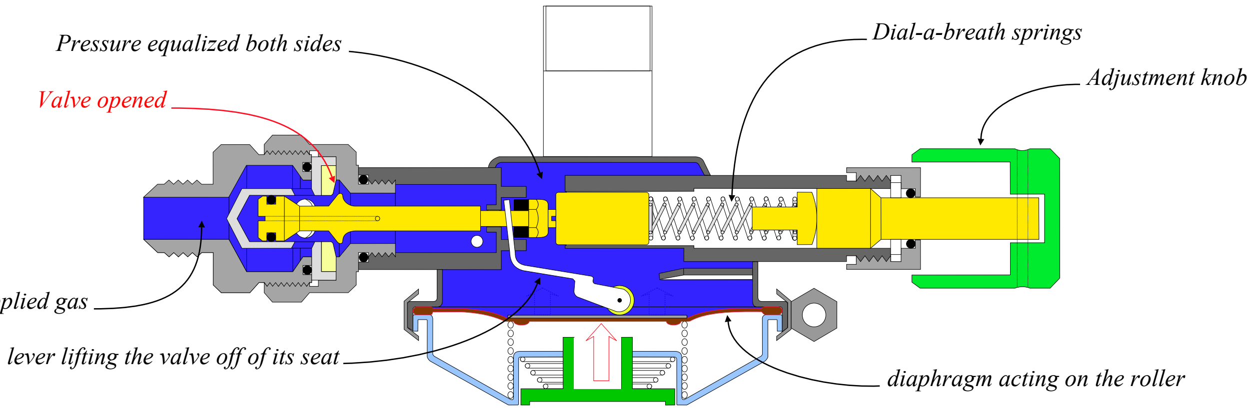
1 - Valve stem	*7 - O-ring*	*13 - Cover assembly*	*19 - Nut*	*25 - Packing nut*
2 - Inlet cap	*8 - Ultraflow body*	*14 - spring diaphragm*	*20 - Piston*	*26 - Retaining pin*
3 - adapter	*9 - Nut*	*15 - Clamp*	*21 - Spring set*	*27 - Adjustment knob*
4 - Valve seat retainer	*10 - O-ring*	*16 - washer*	*22 - Spacer*	*28 - O-ring*
5 - O-ring	*11 - Diaphragm*	*17 - Roller lever*	*23 - Shaft*	
6 - O-ring	*12 - Decal*	*18 - Spacer*	*24 - Washer*	



In the closed position, the supply pressure acts on both the valve and an ‘O’ ring on the balance piston part of the stem (see below). The balance piston is inside the seat retainer and the pressure on the other side of the piston is equalized to the body of the regulator via a small hole in the stem connected to a point sensing the pressure in the regulator body (see below). Note that this equalization that allows easiest breathing does not exist with a standard regulator.
The balance piston is slightly smaller in diameter than the inlet valve and this tends to keep the valve firmly closed using the supply pressure itself.



As the diver inhales, this reduces the pressure in the regulator body, which reduces the closing balance force enabling the diaphragm acting on the roller lever to lift the valve off of its seat easily.

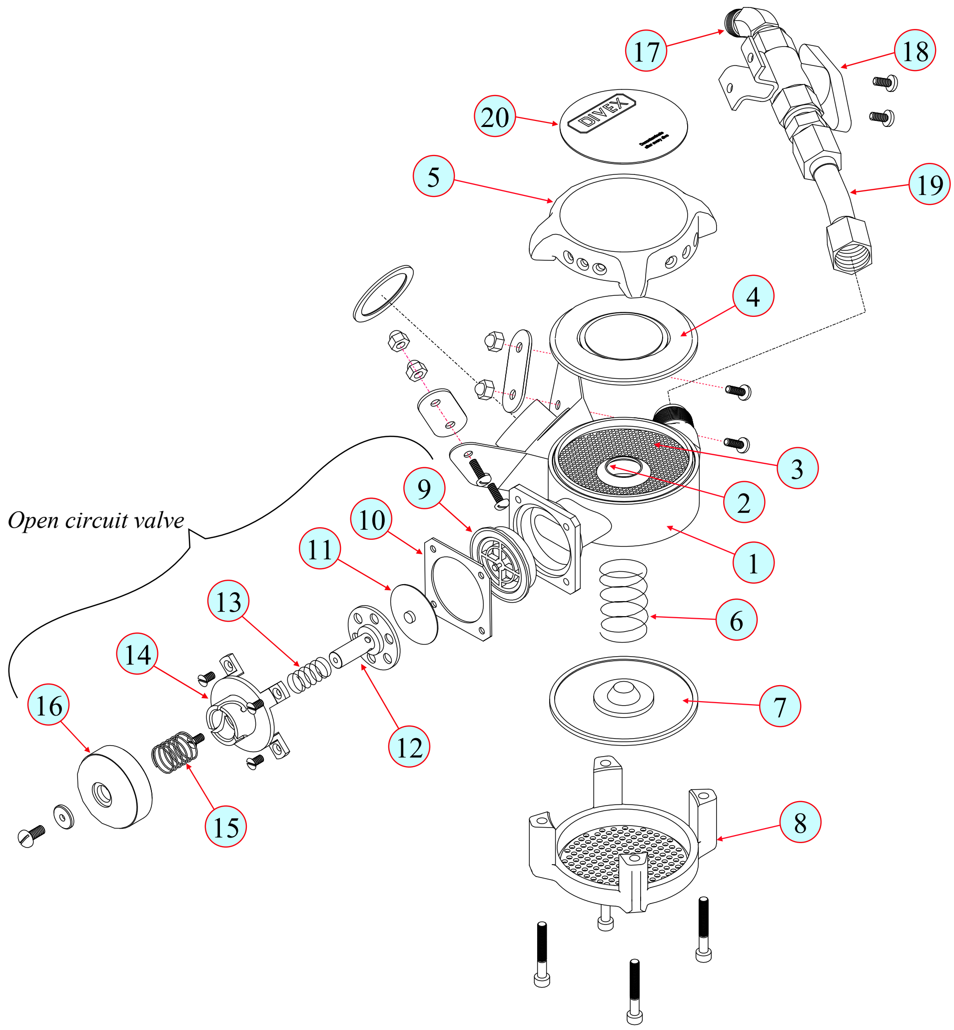


At the end of the inhalation, the “dial-a-breath” springs reseal the valve and restore the rest configuration with the supply valve closed.

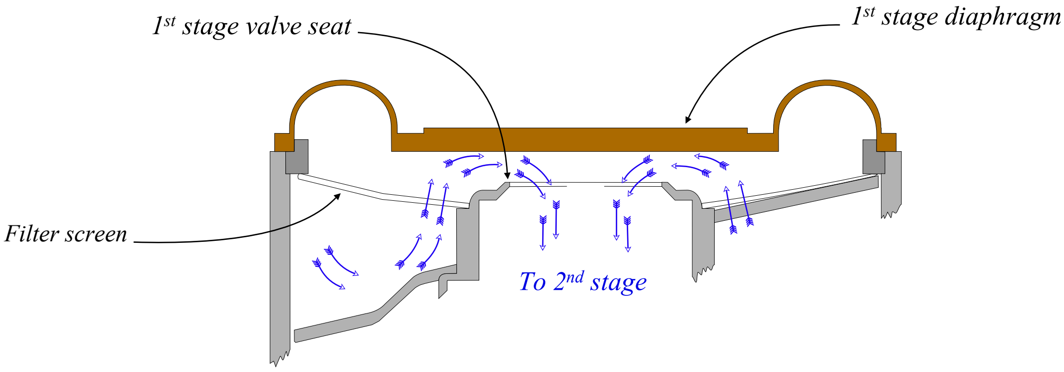
Note that Divex says that the adjustment of the springs is crucial to easy breathing.
If it is over-tightened, a large force will be required to lift the inlet valve, requiring a considerable effort on the part of the diver during inhalation.
Similarly, if there are large gas supply pressure changes, the pre-load set by the knob must be altered.
Thus, changes in gas supply pressure produced by either a change in the actual gas supply pressure or a change in the divers' depth, will require “dial-a-breath” adjustment. As the regulator inlet valve assembly is balanced, the “dial-a-breath” movement is minimal for small pressure changes compared to a standard regulator.

The “Jewel 601” exhaust regulator that is situated just below the “Ultraflow 601” demand regulator, in the place of the classical exhaust whiskers of an air helmet, is also manufactured from 316 stainless steel.
It has two stages to make it insensitive to variations in return line suction. The second stage also acts as a safety shut off valve in the event of a first stage failure. Note that the “open circuit valve” which has been already described in this presentation is also preventing excess pressure in the helmet. This is achieved by means of the spring (see #13) that exerts a force onto the insert which holds the mushroom valve (see #11) closed until the pressure in the valve exceeds the pressure of 18-23 cm of sea water above diver ambient. When in the open circuit mode, the spring is unloaded, and the mushroom valve can open freely. The “open circuit valve” must be pushed and turned clockwise to operate the helmet in closed circuit. As a result, turning this valve anticlockwise allows using the helmet in open circuit mode.

1 - Body
2 - 1st stage valve seat
3 - Filter screen
4 - 1st stage diaphragm
5 - Topside over
6 - Spring 2nd stage
7 - 2nd stage diaphragm
8 - Bottom side cover
9 - O/C Mushroom support
10 - O/C Spacer
11 - O/C Mushroom
12 - O/C Open/close insert
13 - O/C Spring
14 - O/C Body
15 - O/C Spring up rated
16 - Cover
17 - Elbow tube
18 - Shutoff valve
19 - tube
20 - Brand & model sticker

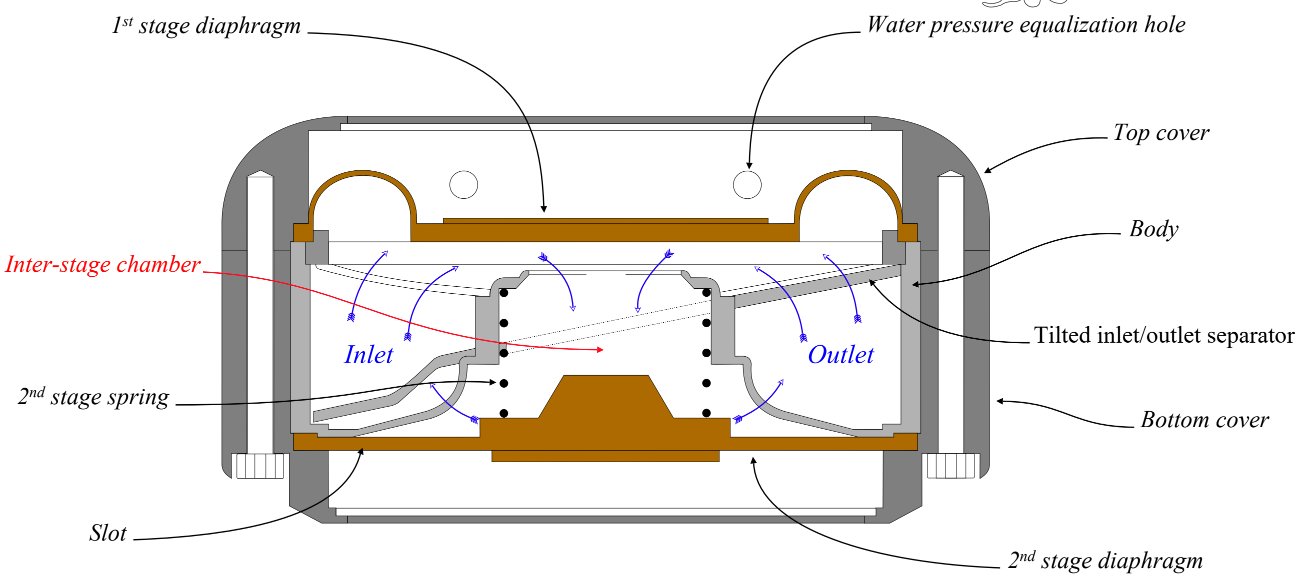


The first stage diaphragm controls the opening pressure of the regulator.
It is situated as close as possible to the “Ultraflow 601” diaphragm to minimize the hydrostatic imbalance when the diver changes orientation.
When the diver exhales, the helmet pressure increases slightly, and this lifts the first stage diaphragm off its seat and allows the exhaled gas flowing into the second stage of the regulator. The large diameter (19 mm) of the valve seat favorize very high flows into the second stage.

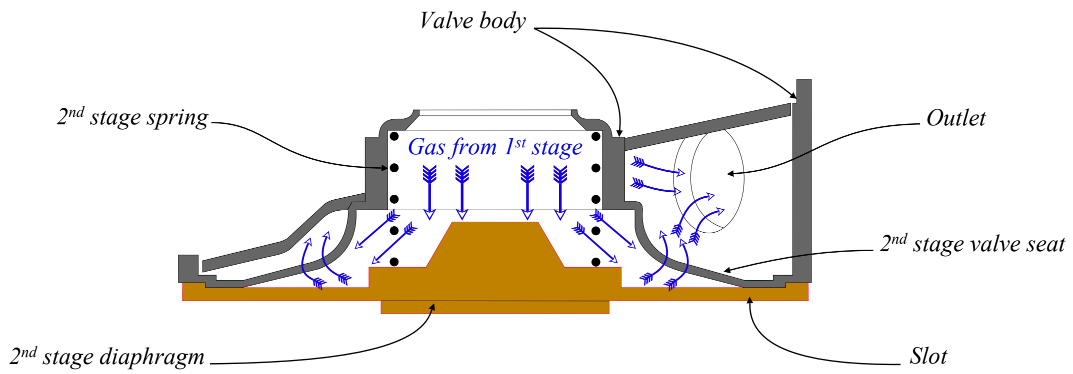


When the diver stops exhaling, the helmet pressure drops slightly below ambient water pressure and the diaphragm is drawn back onto its seat.

The gas flowing into the inter-stage chamber increases the pressure in it.



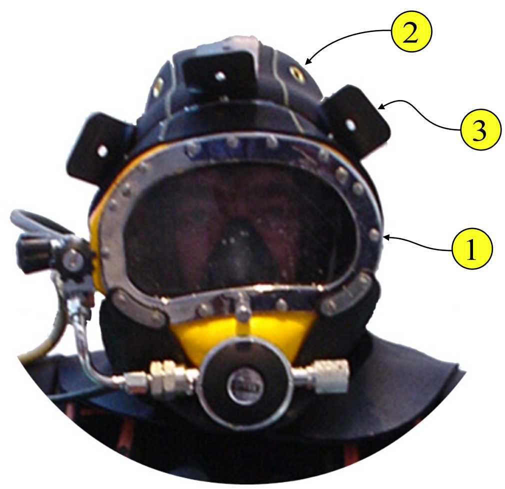
This increase in pressure, together with the second stage spring, lift the second stage diaphragm off twelve tapered radial slots and allows the exhaled gas flowing into the return line.
The second stage spring regulates the inter-stage pressure to between 30 and 60 cm of seawater below the ambient pressure.



This low suction means that there is only a small force holding the first stage diaphragm on its seat and provides no hazard to the diver in the unlikely event that the first stage fails to open and the Ultraflow demand regulator fails to shut.
The slots in the second stage are tapered so that only a small force is required to lift the diaphragm from their tips when there is a high suction in the return line.
As the flow increases and the suction in the return line reduces, the diaphragm lifts further to expose more of the slots. This allows the Jewel regulator to operate satisfactorily at suctions varying from 0.5 to 5 BAR below the diver's ambient pressure.

1.1.5.2 - Standby diver's mask

Because they are compact and can be quickly and easily set up without outside help, a face mask is commonly supplied to the tender who is also the standby diver and must always be ready to intervene.
These masks are composed of a rigid frame made of composite fibers or injected plastic with a viewport and a regulator that are similar to those used with rigid helmets *(see #1)*.
A shaped metal band secures a hood and face seal *(see #2)* fabricated from foam neoprene and open cell foam to this frame. The open cell foam forms a cushion that pushes the sealing surface of the foam neoprene against the diver's face. Pockets are fitted inside the hood to accommodate the earphones. A rubber spider is used to secure the mask to the face of the diver *(see #3)*.
Note that these masks are not equipped with a reclaim system as they are operated only in the case of an emergency. However, their regulator must be capable of supplying sufficient quantities of gas to allow the rescue of the working divers at their maximum operating depth.



An example of a mask designed for deep diving that is commonly operated in diving bells is the Divex "Ultraflow 501-18 B". This model uses the same elements like the well known Kirby Morgan KMB 18 B. However, the regulator "SuperFlow 350" from Kirby Morgan is replaced by the "Ultraflow 501" regulator, which is a balanced demand regulator similar to the "Ultraflow 601" previously described. Similarly to the "Ultraflow 601", this regulator is designed to depths up to 500 m.

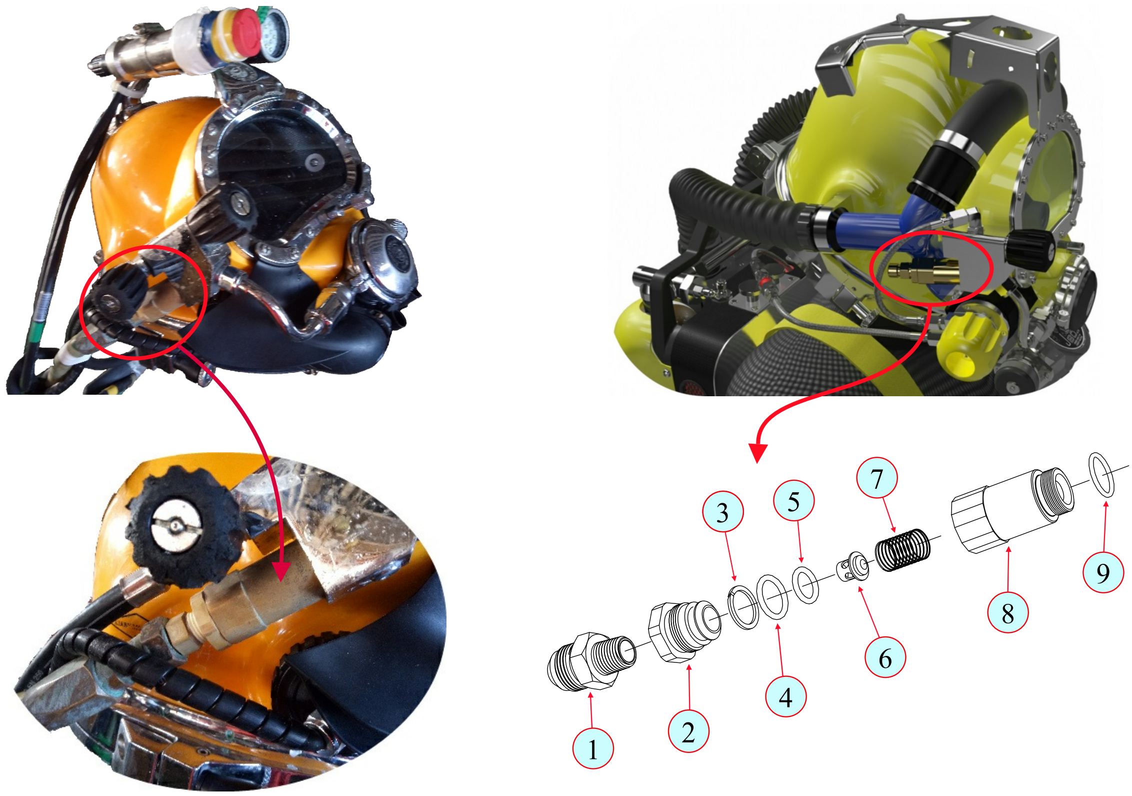
1.1.5.3 - Recommended supply pressure for mixed gas diving applications

The helmet manufacturer should provide tables and recommendation regarding the adjustment of the supply pressure. As an example, Divex recommends to provide the following minimum supply pressures in the diving bell to set up the Ultraflow regulators. Also, note that it is highly recommended not exceeding 20 bar.

Bell depth in MSW	*Diver supply pressure*		*Bell depth in MSW*	*Diver supply pressure*
30 - 150	10 bar		316 - 350	16 bar
151 - 180	11 bar		351 - 400	17 bar
181 - 215	12 bar		401 - 430	18 bar
216 - 250	13 bar		431 - 460	19 bar
251 - 280	14 bar		461 - 480	20 bar
281 - 315	15 bar		481 - 500	20 bar

1.1.5.4 - Non-return valves fitted to the supply gas hose

A supply hose severed or suddenly depressurized may expose the diver to a depression that can be fatal. For this reason, a non-return valve must be fitted between the side block and the gas supply hose of the umbilical. Note that this valve must be function tested before each dive.
Note that as previously described, the "Ultrajewel 601" and the SEACO valves in the bell are designed to isolate exhaust hose that returns the exhaled gas to the reclaim system in the case of a malfunction or a rupture.



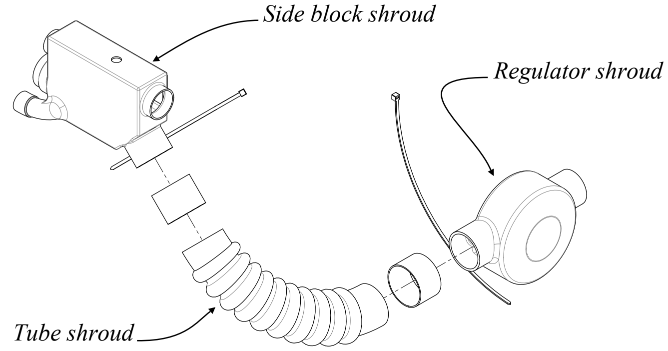
1 - Connector umbilical
2 - Seat
3 - Wiper
4 - O ring
5 - O ring
6 - Poppet valve
7 - Spring
8 - Valve body
9 - O ring

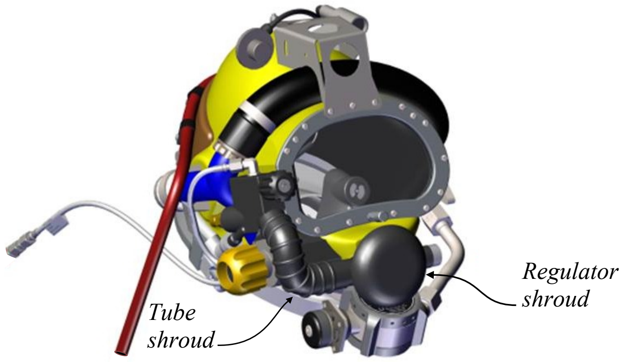
Non- return valves are composed of a poppet valve (see #6), which is pressed to its seat (see #2) by a spring (see #7). This valve is lifted from its seating by the axial force resulting from the pressure of the breathing gas supplied through the umbilical. As a result, when the umbilical is under pressure, the poppet valve is maintained open. If the gas supply is lost, the valve is pushed against its seat by the spring and the gas circuit is closed.

1.1.5.5 - Systems for cold waters

Note that this point has been partially discussed in "Bell internal equipment."
Depending on the area, the water temperature at depth quickly falls below four degrees and may become close to zero degrees. Note that salt water freezes a -2 C°. Regulators are affected by low temperatures, which may result in an affected flowing of gas or a frozen mechanism that stop working. To solve this problem, the manufacturers propose a heating system for the regulator. Professional organizations also recommend this procedure. As an example, IMCA says that a

means of heating the divers inspired gas is necessary if diving at depths below 150 msw. However, depending on the latitude where the dive is carried on, the regulator may have to be heated at a depth close to the surface.
The system consists of a rubber shroud inside which hot water flows. This shroud completely encases the side block, bent tube, and the regulator of the helmet to isolate the hot water flow from the surrounding cold water and so provide efficient gas heating. It is connected to the hot water supply of the diver by a splitter block assembly.





1.1.5.6 - National & international approval and marking

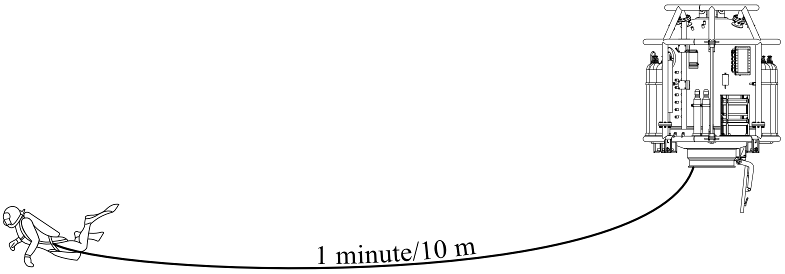
Every device used in a diving system must be certified according to recognized standards.
As an example, the helmets describe in this presentation are certified as PPE devices according to the European Directive 89/686/EEC, which give guidelines and procedures for the certification process of this type of equipment. Note that for this directive, PPE means any device or appliance designed to be worn or held by an individual for protection against one or more health and safety hazards. When the process of certification is successful, a “CE marking” that must be indicated on each device produced is given. As an example, the marking of the Divex Ultrajewel 601 is CE 0088.
Note that the certificate of approval that summarize the process applied and the competent bodies involved must be available and its reference number should be indicated in the brochures supplied with the device.
In addition, Each helmet (or mask) should be indelibly marked with a unique serial number.
All these elements allow establishing whether the helmet conforms to the international and national legislation and also trace its process of certification and fabrication.

1.1.6 - Bailout systems

1.1.6.1 - Purpose

IMCA says that every diver (other than the bellman) must be provided with a reserve supply of breathing gas carried in a bailout system.
NORSOK U100 says that this bailout system should be designed to ensure an easy entrance into the bell and be ergonomically adapted to the primary system. Also, it must be possible to activate it with no more than two operations.

Regarding the bailout endurance, IMCA D 022 says that a calculation should be available showing that the capacity of the cylinder(s) at the depth of diving will allow breathing gas for 1 minute for every 10 metres of umbilical deployed from the diving bell.



Note that NORMAM- 15 limits the umbilical length to 33 metres and the bailout duration to at least 15 minutes during exceptional saturation.
Also, NORSOK standard U 100, which limits the umbilical length to 45 m, says in point 7.8.3 that the bail-out system should provide the diver with gas for 10 min based on an average consumption of 62,5 1/min (at the surface). This consumption value, that should be considered as a minimum, is confirmed by the UK HSE study *"The provision of breathing gas to divers in emergency situations"* which recommends a rate between 50 & 75 litres.

The bailout systems used for saturation operations can be scuba diving cylinders or rebreather apparatus. They should be selected depending on the depth and the distance from the bell to fulfill the requirements indicated above,
Diving cylinders are commonly used as bailout systems for "surface orientated" diving operations. They are often used for shallow saturations.
Rebreather apparatus are used by militaries and experienced recreational divers for diving operations that cannot be organized with standard scuba sets. Note that the systems they used are not adapted to the requirements of commercial diving. Nevertheless, two models of rebreather apparatus have been designed for this purpose by Divex (JFD group): The "Secondary Life Support Mk 4" (SLS Mk4), which is now discontinued and the "Compact Bailout Rebreathing Apparatus" (COBRA) which replaces the SLS Mk4. They are described in the next points with the diving cylinders.

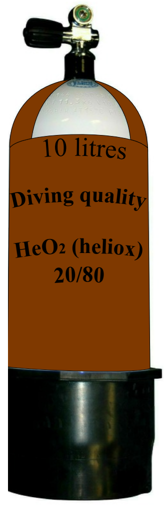
1.1.6.2 - Scuba diving cylinders and 1st stage regulator

The fabrication and the maintenance of scuba diving cylinders are explained in the diving study #2 "Organize the maintenance of diving cylinders". For this reason, these technical aspects are not explained here as they can be found in this study of 98 pages.
Diving from a closed bell imposes the use of cylinders that are not too voluminous to be able to pass through the bottom door. As a result, the bottles used should offer a maximum of gas in a container that has a reduced volume. For this reason, and depending on the size of the bottom door, twin sets composed of bottles of 7, 10 or 12 litres of floodable volume that can be topped up at a pressure up to 300 bar are preferred to mono cylinders of 15, 18 or 20 litres that have a wider diameter, or cylinders limited to 200 or 232 bar.
Note that aluminium cylinders found on the market are generally limited to 200 bar. As a result, composite and steel cylinders which can withstand 300 bar are preferable. The advantage of composite cylinders is their reduced weight and their capacity to withstand extremely high pressures. It is the reason they are used in the space industry. However, the models sold for diving are limited to 300 bar maximum. Their major inconvenience is their limited lifetime and that they are more sensitive to shocks than steel cylinders that can be considered more robust and are cheaper. For these reasons, most contractors often prefer using steel cylinders.

Approximate dimensions and weights of steel cylinders commonly used to compose twin sets

Volume cylinder	*Ø in mm*	*Length in mm*	*Weight in Kg*
7 litres	*140*	*625*	*9.8*
8 litres	*140*	*700*	*10.5*
10 litres	*178*	*600*	*15.1*
12 litres	*178*	*625*	*18.2*

Identification and marking of the cylinders:
Diving cylinders must be colour-coded according to the recommendations of IMCA D 043 that are based on the European standard EN 1089-3. This colour coding is also indicated point 269 of the "code of safety for diving systems 1995" published by the International Maritime Organization (IMO). It is achieved through the use of colour paints.
Also, the information regarding the gas used, the construction and the condition of the cylinder must be always visible.
For these reasons, IMCA says that cylinders used with heliox should be organized as follows:



- The shoulder must be colour coded with white and brown quarters or bands and the body must be brown.
- The words "HeO2" + " heliox" and "diving quality" must be written with the gas percentage by volume, quoting percentage of oxygen first. Also, the floodable volume should be indicated.
- The cylinder serial number should be visible or else stenciled in a visible location on each cylinder. Also, the last test date stamp should be painted over with a small patch distinctive colored paint to aid location. These identification marks must not be hidden by accumulated layers of paint.

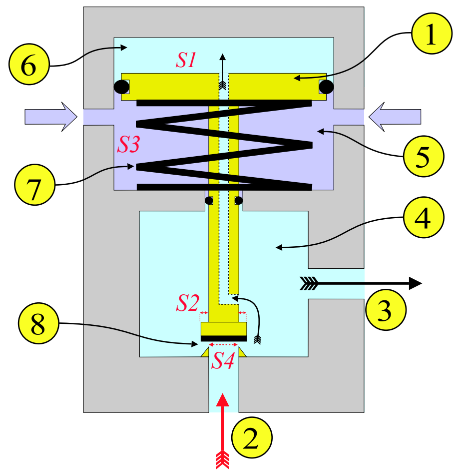
The high-pressure heliox contained in the cylinder must be regulated to a pressure and a flow that are compatible with those of the 2nd stage regulator of the helmet. This is achieved by the 1st stage of a scuba diving regulator that is installed on the bottle and connected to the 2nd stage of the helmet with a dedicated whip. Note that the mechanism used can be based on a piston or a diaphragm. However, it must be suitable for diving in cold water. Also, a balanced type mechanism is highly preferable. The differences between the several mechanisms can be explained as follows:

- A non-balanced first stage piston regulator uses a piston that moves up and down to open or close an injector from which the high-pressure heliox stored in the cylinder flows into a depression chamber. When the planned low-pressure is reached the piston closes the high-pressure injector and the gas is distributed to the 2nd stage regulator. It opens again when the pressure in this chamber drops. Note that this piston is composed of a thick plate that is continued by a hollow shaft through which the gas flows from the depression chamber to the top chamber where the pressure pushes the piston to the bottom. With this system, the opening of the valve partially depends on the high pressure. As a result, if the high-pressure decreases, the pressure opening the valve diminishes as well and breathing becomes more and more difficult as the pressure in the cylinder decreases.

Forces operating the system:

Closing	*- Low pressure x Surface piston (S 1)* *- Low pressure x Surface valve around the tail (S 2)*
Opening	*- Hydrostatic pressure at depth x surface piston (S 3)* *- Spring in wet chamber* *- High pressure x surface valve (S 4)*

1 - Piston
2 - High Pressure inlet
3 - Low Pressure outlet
4 - Depression chamber HP - LP
5 - Hydrostatic pressure chamber
6 - Top-side LP chamber
7 - Spring
8 - Valve + seat

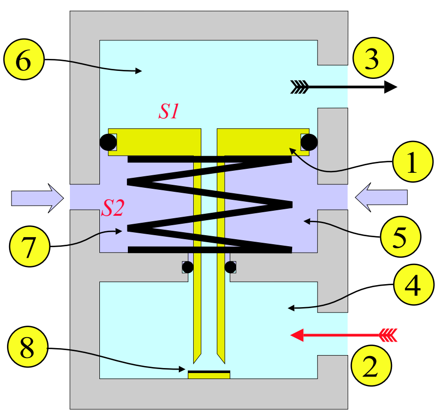


- A balanced piston regulator uses the same basic mechanism as above. However, the forces are organized in such a manner that there is no intervention of the high pressure in the opening of the regulator. As a result, the opening and closure depend only on the low pressure and the effort to inspire is always the same.

Forces operating the system:

Closing	*- Low pressure x Surface piston (S 1)*
Opening	*- Hydrostatic pressure at depth x surface piston (S 2)* *- Spring in wet chamber*

1 - Piston
2 - High Pressure inlet
3 - Low Pressure outlet
4 - Depression chamber HP - LP
5 - Hydrostatic pressure chamber
6 - Top-side LP chamber
7 - Spring
8 - Valve + seat

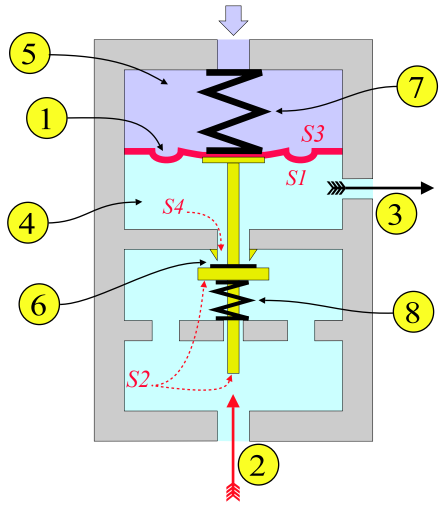


- Non-balanced diaphragm first stages use a thick rubber or composite membrane to which the force from the hydrostatic pressure is added to the strength of the spring situated in the wet chamber to open the valve between the high-pressure and low-pressure chambers. The valve is closed by the combined action of a return spring and the high-pressure that pushes on the bottom surface of the valve. With this design, the high-pressure acts on the closure of the valve. As a result, when the pressure from the bottle decreases, more gas can pass into the depression chamber. Thus the opening of the valve becomes more comfortable, and the regulator delivers more gas. Also, note that this design is slightly more complicated as with piston systems, as there are more parts involved.

Forces operating the system:

Closing	*- Low-pressure x surface membrane (S 1)* *- Return spring* *- Surface bottom valve (S 2) x high-pressure*
Opening	*- Hydrostatic pressure at depth x surface diaphragm (S 3)* *- Spring in wet chamber* *- Surface bottom of the valve (S 4) x low-pressure*

1 - Membrane *5 - Hydrostatic pressure chamber*
2 - High Pressure inlet *6 - Tail + valve assembly*
3 - Low Pressure outlet *7 - Spring in wet chamber*
4 - Depression chamber HP - LP *8 - Return spring*

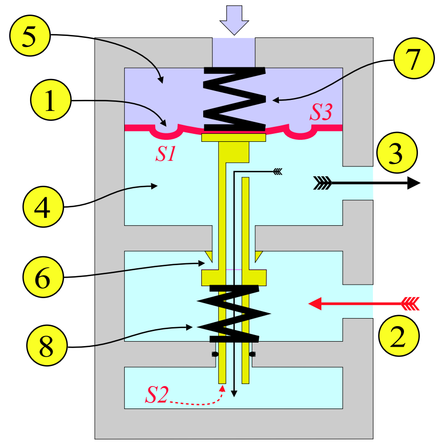


- Balanced diaphragm regulators are designed with the same basic principle to work as described above. However, the forces are organized in such a manner that there is no intervention of the high pressure in the closing of the regulator. As a result, the opening and closure depend only on the low pressure and the efforts of the diver to inspire are always the same. Note that in this case the tail of the valve is hollow.

Forces operating the system:

Closing	*- Low-pressure x surface membrane (S 1)* *- Return spring* *- Surface S 2 in the equilibration chamber*
Opening	*- Hydrostatic pressure at depth x surface diaphragm (S 3)* *- Spring in wet chamber*

1 - Membrane *5 - Hydrostatic pressure chamber*
2 - High Pressure inlet *6 - Tail + valve assembly*
3 - Low Pressure outlet *7 - Spring in wet chamber*
4 - Depression chamber HP - LP *8 - Return spring*



- Regarding the advantages and disadvantages of the mechanical systems described, piston regulators are reputed robust and simple. However, they are often considered less efficient than those designed with a diaphragm in cold waters as they may become more rapidly frozen, which may result in an uncontrolled free-flowing. For this reason, diaphragm systems are often preferred for these conditions. As an example, experimentations in icy conditions conducted by the US Navy in 2008 were performed with only balanced diaphragm design regulators. Note that US Navy recommends using cold water kits consisting of silicone oil and an environmental diaphragm in water temperatures below 38 ºF (3.3 ºC).

Another point to consider when selecting the 1st stage regulator is its ability to work with heliox as some models that are originally designed for air may leak if used with heliox. Also, note that only threaded type bottle connections (commonly called DIN connections by divers) can withstand a pressure of 300 bar. For more information regarding this point, refer to the study CCO Ltd “Organize the maintenance of diving cylinders”.

As a conclusion, scuba diving cylinders are reliable systems of bailouts. However, they limit the operations to shallow depths only. As an example, a set 2 x 7 litres / 300 bar allows less than 6 minutes breathing time at 100 m. Also, the gas they provide is at the temperature of the surrounding that may be cold. Because hypothermia is six times faster with heliox than air, that leaves a limited time for the diver to return to the bell before being affected in such conditions.
Note that the procedure to calculate the diving duration offered by bottles is as follows:

1) Find the pressure available = Pressure bottle - absolute pressure bottom - working pressure regulator
2) Find the volume of gas available = Floodable volume x Available pressure
3) Find the breath duration offered by the cylinders = Available volume / (62.5 x absolute pressure)

1.1.6.3 - DIVEX Secondary Life Support Mk 4" (SLS Mk4) system

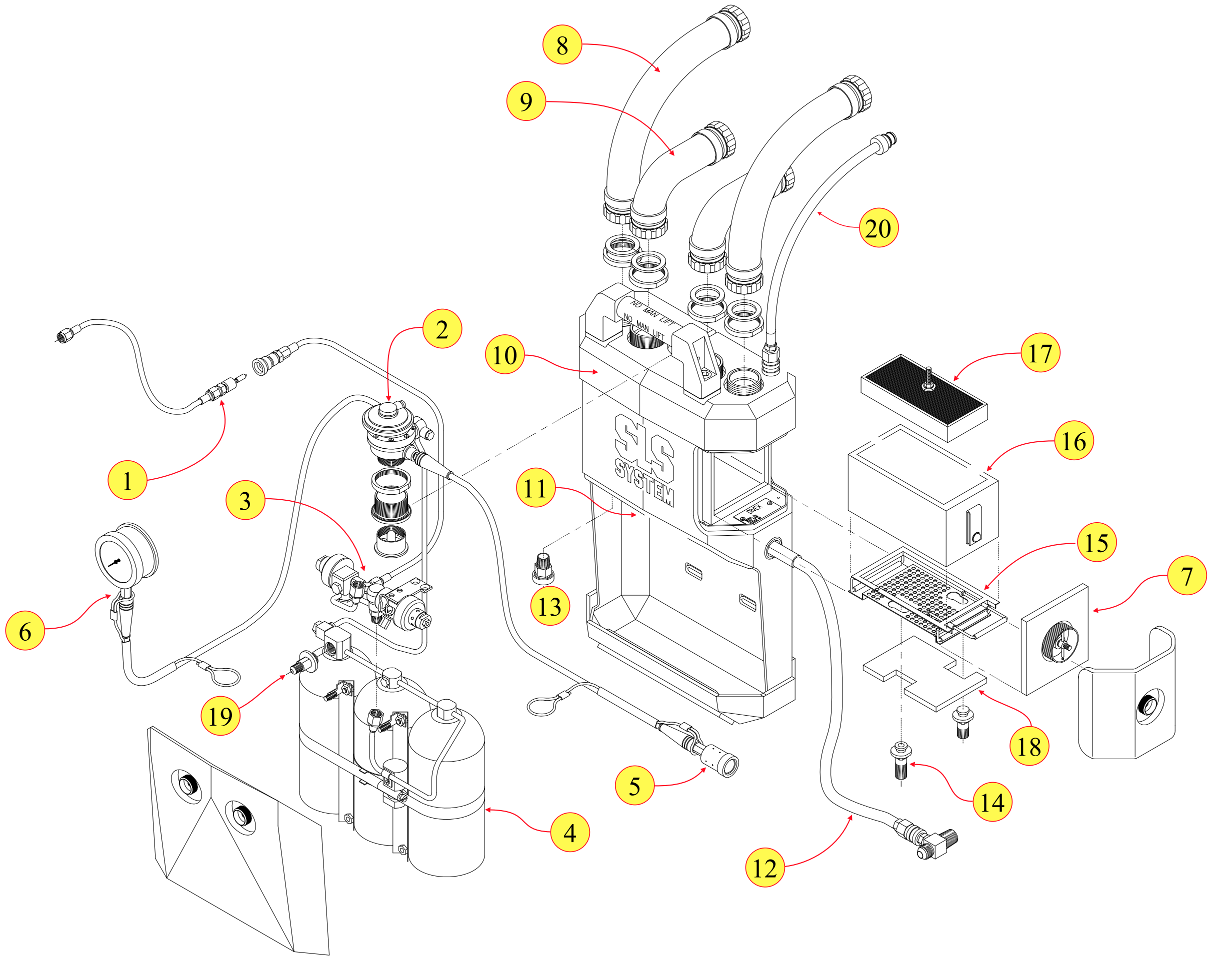
The Secondary Life Support (SLS) is a semi-closed circuit breathing apparatus designed during the eighties and nineties which allows sufficient time to return to the bell at depths deeper than 350 msw in the case that the diver's breathing and hot water supplies are severed. Note that this model is discontinued. As a result, it will be removed from service gradually. However, it will be in use as long as spare parts will be available, which is the reason it cannot be ignored. Also, the description of this rebreather of the previous generation highlights the advantages of the new COBRA system.

The system is composed of a backpack that is connected to a specific helmet.
The operational principle of the system is basically that of a conventional semi-closed circuit breathing apparatus, in which the exhaled gas is captured in counterlungs and is then re-breathed by the diver, after removal of the carbon dioxide (CO_2), and the replacement of the oxygen consumed.
The "backpack" consists of:

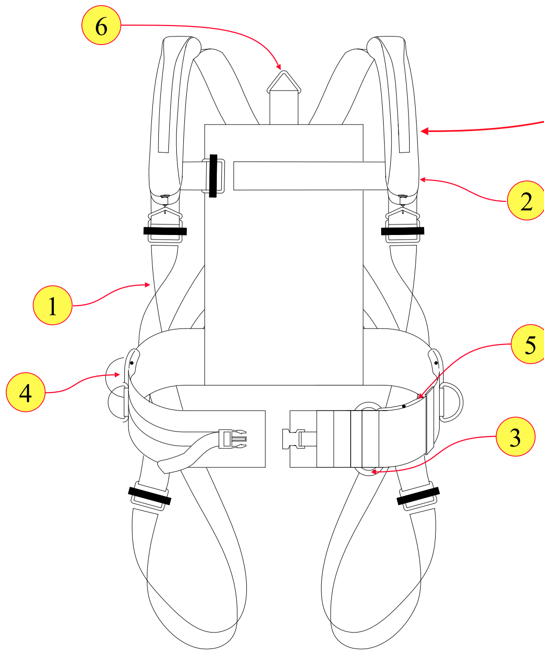
1 - The main housing containing a gas injection system, a CO_2 scrubber canister and a thermal regenerator. Also, the SLS Backpack harness has the counterlungs fitted to its shoulder straps.

2 - The gas injection system is composed of three (3) heliox cylinders with a charging point, burst disc, two stage regulator, injection orifice, single stage regulator, demand regulator and a overpressure indicator. Note that the percentage of oxygen of the breathing gas stored in these cylinders depends on the diving depth planned.

3 - The CO_2 scrubber canister provides a chemical absorbent bed for the removal of the carbon dioxide. A thermal regenerator temporarily stores the heat within the breathing gas in order to avoid losing it to the water as the breathing gas passes into the flexible bags (the counterlungs).



1 - Gas supply from helmet	*6 - Pressure gauge*	*11 - Gas system housing*	*16 - Sodalime canister*
2 - Demand valve	*7 - Lid screw assembly*	*12 - Hot water inlet hose*	*17 - Thermal regenerator*
3 - HP & LP regulators	*8 - Inhale / exhale hose*	*13 - Hot water relief valve*	*18 - moisture absorbent pad*
4 - Gas storage bottle	*9 - Counterlung hose*	*14 - Gas supply penetrator*	*19 - Charging point*
5 - Overpressure indicator	*10 - Hot water housing*	*15 - Canister loading system*	*20 - Hot water to helmet shroud*



1 - Harness

2 - Counterlung in its enclosure (see the photos above)

3 - Actuation sleeve & cable assembly

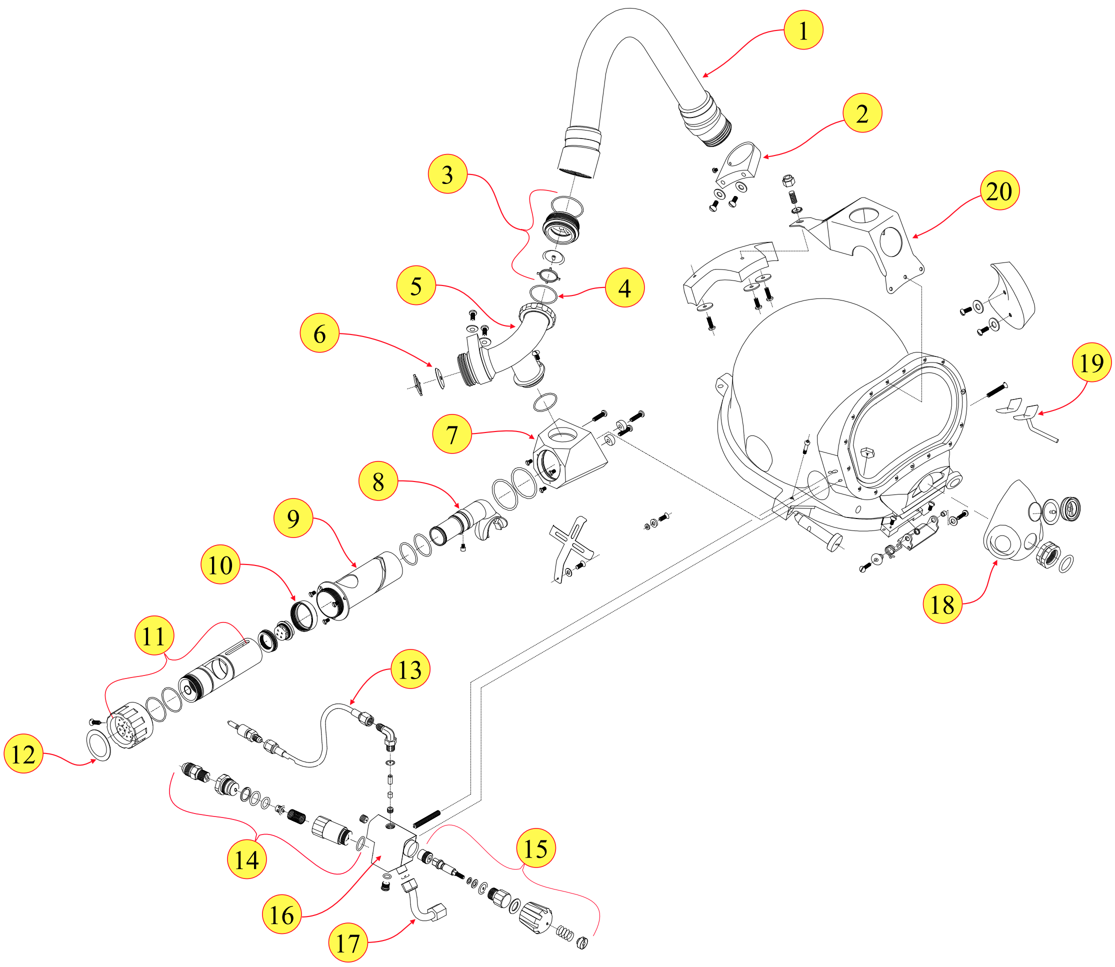
4 - Weight pocket

5 - Handle retaining band

6 - Rescue lifting point

7 - Cable wiper sleeve

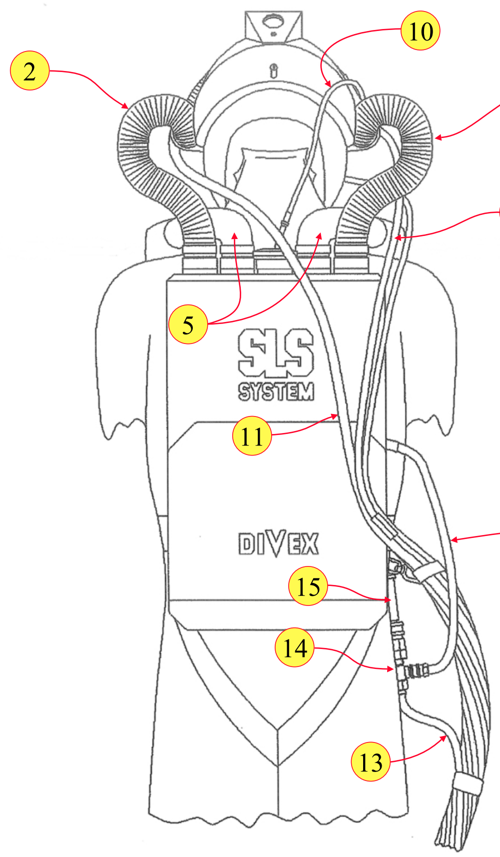
The helmet is based on the Divex “Ultrajewel 601” to which the inlet and exhaust hoses from the backpack assembly are connected. The interface assembly contains a mouthpiece that is stowed retracted out of the divers way during the normal operations. In this case, the diver breathes normally in the oral-nasal mask. When activating the bailout system this mouthpiece is rotated into the helmet oral-nasal mask, and the diver bites it to breathe with his mouth as with a scuba regulator or a snorkel.

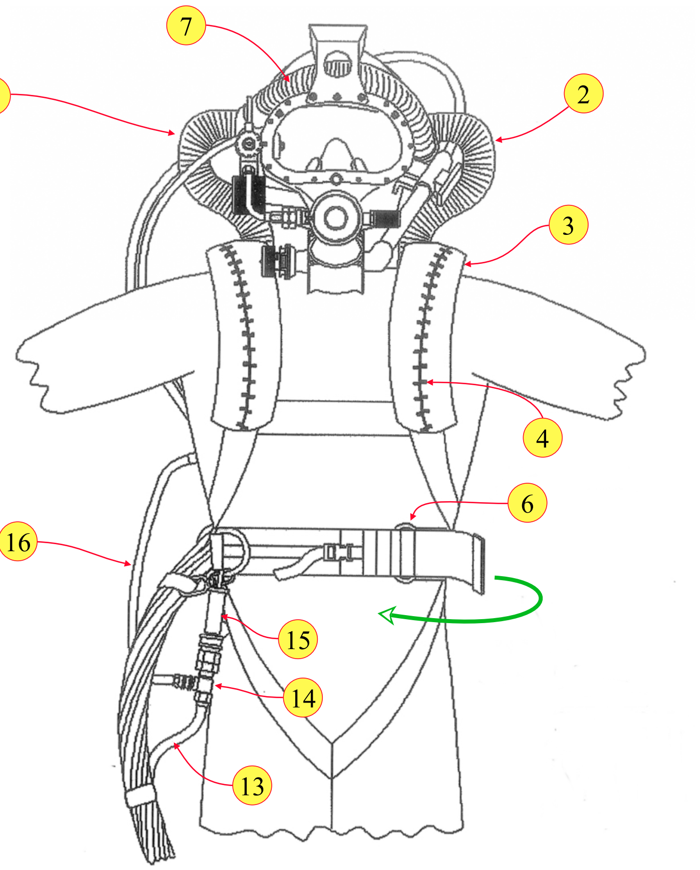


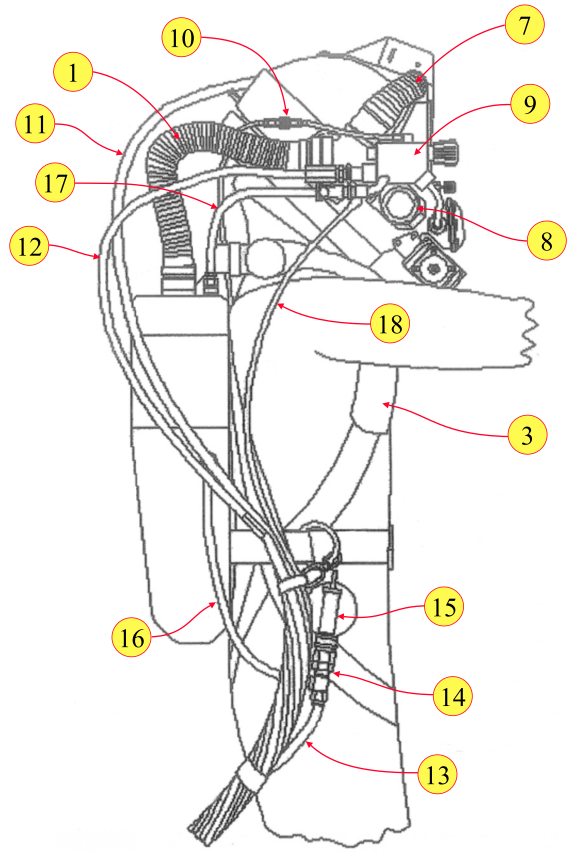
1 - Helmet hose assembly	*6 - Flap valve + circlip*	*11 - Sleeve centre*	*16 - Side block*
2 - Support hose assembly	*7 - Main body*	*12 - Mushroom*	*17 - bend tube to regulator*
3 - Exhale flap valve assembly	*8 - Mouth piece*	*13 - SLS gas supply hose*	*18 - Oral nasal mask assembly*
4 - O ring	*9 - Outer sleeve*	*14 - Non return valve*	*19 - Nose block device*
5 - Y piece assembly	*10 - Retaining ring*	*15 - Free flow valve*	*20 - Handle*

Note that the following supplies from the bell are necessary to allow the system to be ready for use:

- A gas supply hose is connected to the side block of the helmet *(see #10 below)* from which heliox is supplied to a single stage regulator in the backpack. The function of this regulator is to maintain a slight positive pressure inside the SLS system while it is in its standby mode to protect it from water flooding.
- Also, the hot water flowing from the surface to the diver's suit is diverted to the hot water housing of the backpack through a splitter block *(see #14 below)*. The function of this connection is to fill the hot water housing of the backpack and warm the soda lime enough to enable the required chemical reaction that is necessary to absorb the CO_2 when the system is activated. The hot water continues to flow from the hot water housing to the shroud of the regulator through a hose connected to it *(see #17 below)*.







1 - Exhale hose

2 - Inhale hose

3 - Counterlung

4 - Lacing counterlung

5 - Hoses counterlungs

6 - Handle actuation system

7 - Helmet hose

8 - Mouthpiece handle

9 - Shroud side block

10 - SLS supply (quick connect)

11 - Reclaim hose

12 - Gas supply

13 - Hot water supply

14 - Splitter block

15 - Hot water supply suit

16 - Hot water supply SLS

17 - Hot water supply shroud

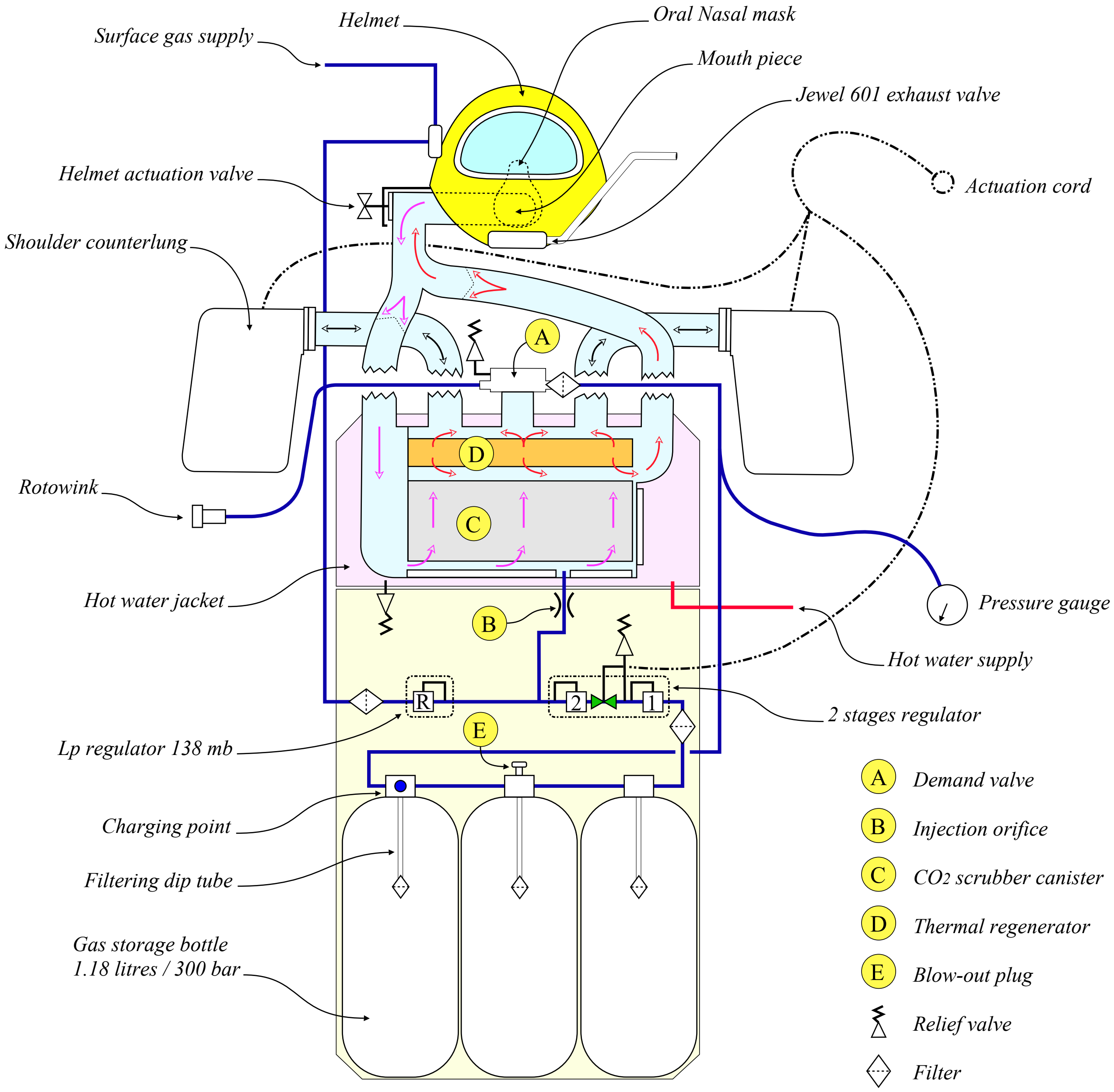
18 - Communications

The activation of the system requires two actions:

1. The interface valve on the right hand side of the helmet *(#8 in the drawing previous page)* has to be rotated through 180º, to push the mouthpiece into the oral-nasal mask where the diver can bite onto it to breath.
2. The actuation handle situated near the buckle of the belt of the harness (see # 6) has to be pulled as for a parachute to deploy the counterlungs, that are packed in their enclosures that protect them from damage, and pull a spool valve which switches on the gas bleed for make-up gas. This handle is protected by a flap.

When the system is activated:

1. The exhaled gas passes via the diver's mouthpiece through the helmet interface assembly and is directed by the check valves through an insulated hose to the backpack. It then passes through the CO_2 scrubber canister and up through the thermal regenerator into the counterlungs. The thermal regenerator removes and stores the heat from the warm gas.
2. Because the counterlungs are tightly packed, there is very little gas available for the diver to inhale after activation. For this reason, a demand valve *(see "A" below)* situated on top of the backpack supplies the gas for the first breath. Then, when the counterlungs are filled, the system functions in its semi-closed circuit mode. As the diver inhales, the new cold gas passes back through the thermal regenerator and picks up the stored heat. The gas then passes up through a second insulated hose assembly and back into the diver's mouthpiece via the helmet interface assembly.
3. The oxygen make-up is provided by means of a constant bleed of oxygen-rich gas from the three cylinders located at the base of the Backpack. This gas bleed mixes with the exhaled gas at the inlet to the CO_2 scrubber to maintain a safe oxygen partial pressure at all times. This rich gas is supplied from the gas cylinders through a two-stage regulator to the injection orifice which regulates the flow rate.
4. As already indicated, the water ingress into the SLS system in standby mode is prevented by pressurising the breathing circuit using a single stage regulator that is set up at 138 mb above ambient pressure and is connected to the side block of the helmet. An indicator of Rotowink type which changes from green to red if a significant loss of pressure occurs is fitted to the system to alert the diver in the case of loss of pressure.



Note that the Secondary Life Support (SLS) uses only mechanical systems and that there is no electronic module for the control of the partial pressure of the gas and the dosage of the oxygen in the breathing circuit as it is the case with a lot of new generation rebreathers where the diluent gas and pure oxygen are stored in separate cylinders from which they are dosed according to the needs.
Thus, as already indicated in the previous description of the system, an "appropriate mix" that must be calculated for the planned diving depth using the table displayed below is stored in the three 1.18 litres / 300 bar gas bottles, from which it is dosed into the breathing circuit through a two-stage regulator and an injector. For this reason, Divex says that it is of ultimate importance to fully empty the bottles before charging the new planned mix to avoid creating an unsuitable gas.

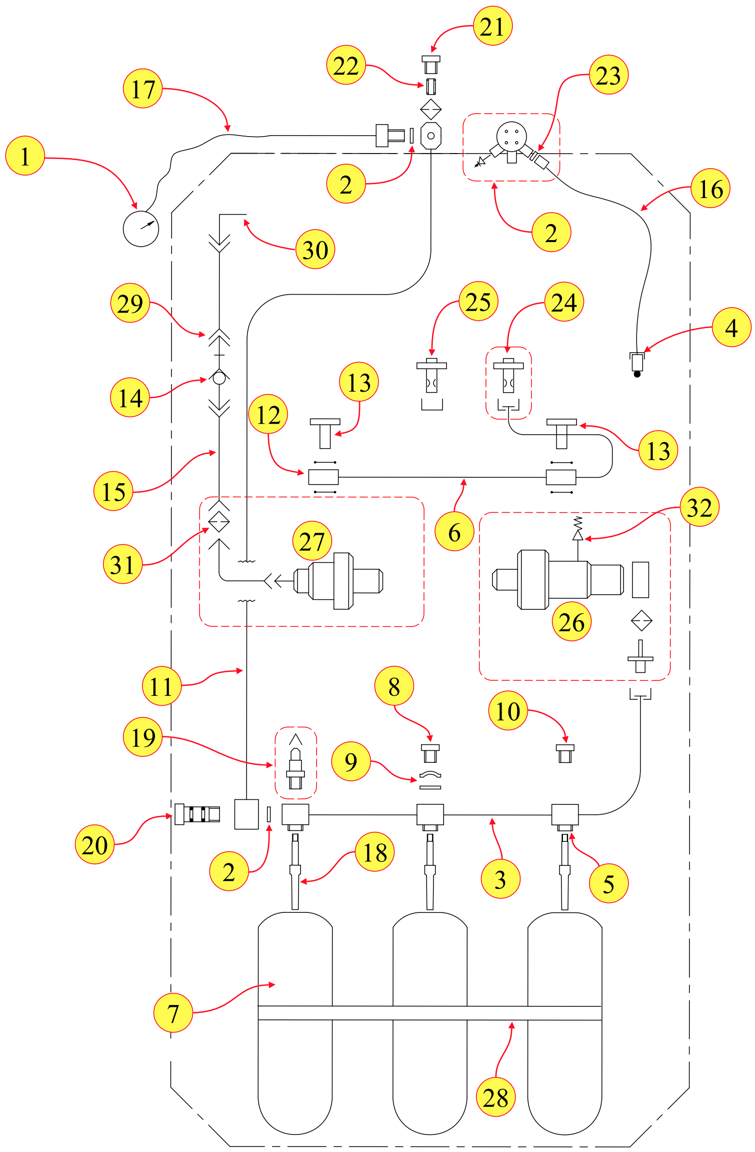
Diver excursion depth	Minimum oxygen percentage	Maximum oxygen percentage	Diver excursion depth	Minimum oxygen percentage	Maximum oxygen percentage
10	39	99	190	8.2	11.4
20	28.5	69	200	8	11
30	23.5	52	210	7.8	10.4
40	20	42	220	7.6	10
50	17.8	35.5	230	7.3	9.7
60	15.7	31	240	7.1	9.3
70	14.4	27	250	6.9	8.9
80	13.4	24	260	6.8	8.7
90	12.4	21.9	270	6.65	8.4
100	11.6	20	280	6.5	8.15
110	11	18.4	290	6.4	8
120	10.5	17	300	6.2	7.7
130	10.2	15.9	310	6.1	7.5
140	9.8	15	320	6	7.3
150	9.5	14	330	5.8	7.1
160	9.1	13.2	340	5.75	6.9
170	8.8	12.5	350	5.6	6.8
180	8.4	11.9	360	5.55	6.6

Example of a mix selection using this table:
Divers are stored at a depth of 190 m and an excursion is planned between 195 - 205 msw. The bell is planned to be stored at 190 msw:

- At 190 msw a heliox mix containing between 8.2 and 11.4% oxygen should be used.
- Find a mix that allows excursions within the planned depth range and includes a safety factor to allow excursions outside the basic depth range:
  - Note that the middle value between 11.4% & 8.2 % is 9.8%. Thus, a richer mix should favor upward excursions and a poorer mix downward excursions.
  - If a mix 9.7% is available onboard the vessel, we can see that this mix allows a maximum downward excursion to 230 msw and a maximum upward excursion above 150 msw (in fact it can be used up to 143 msw). As these depths are beyond the planned working depth range, the mix selected is suitable.

Diver excursion depth	Minimum oxygen percentage	Maximum oxygen percentage	Diver excursion depth	Minimum oxygen percentage	Maximum oxygen percentage
140 (143 m)	9.8	15	190	8.2 ← 9.7%	→ 11.4
150	9.5	14	200	8	11
160	9.1	13.2	210	7.8	10.4
170	8.8	12.5	220	7.6	10
180	8.4	11.9	230	7.3	9.7

Note that these gas cylinders *(see #7 in the scheme below)* are equipped with dip tubes *(see #18)* that protect the pipework from corrosion and thus avoids blocking the gas flow. Also, burst disks *(see #9)* are fitted to protect the system from over-pressurization. These cylinders are linked together though a manifold *(see #3)* and a retainer assembly *(see # 28)* they are filled through a charging point which is installed in the left-hand cylinder fitting *(see #19)*. It has a built-in check valve to allow easy filling and a sintered filter element to protect the check valve seat from damage during charging.



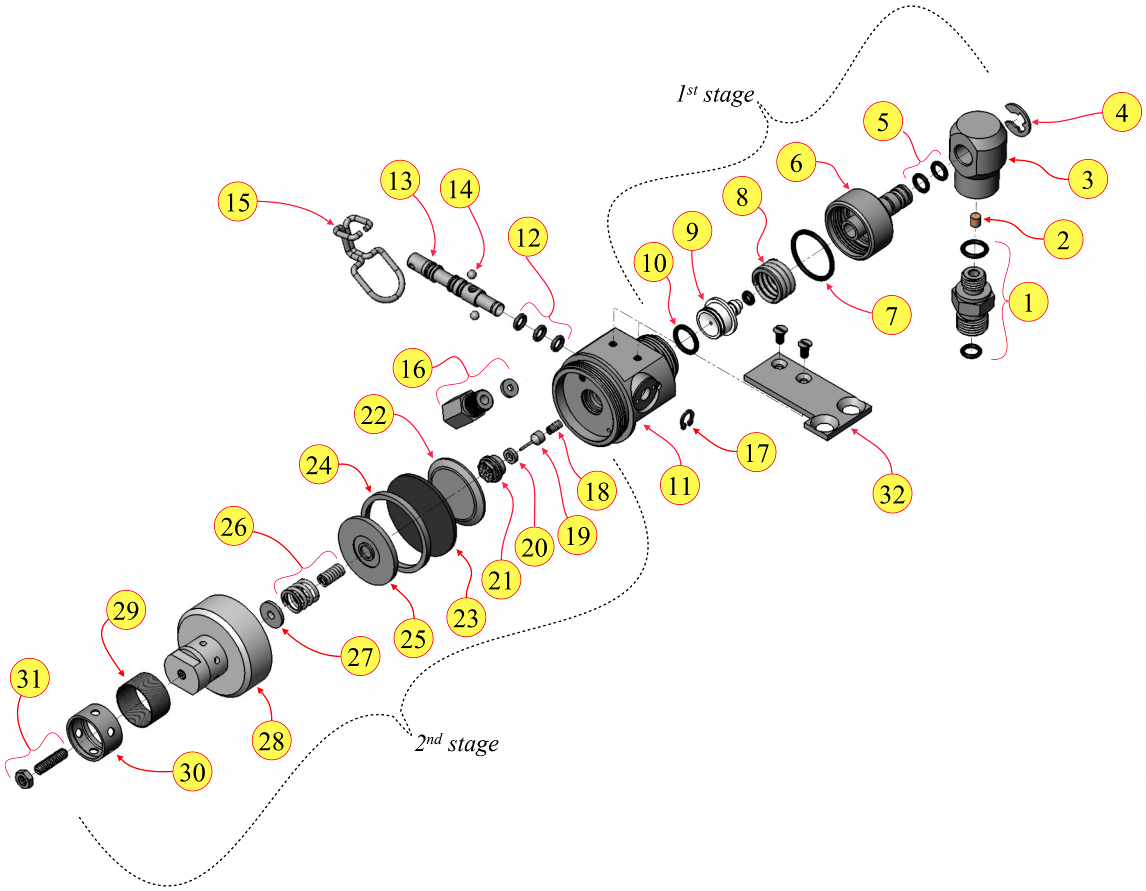
1 - Content gauge (+ O ring)	*9 - Bursting disk + seat*	*17 - Whip gauge*	*25 penetrator blank*
2 - Demand regulator	*10 - Plug + O ring*	*18 - Filtering dip tube*	*26 - Two stage regulator*
3 - Bottle manifold	*11 - Regulator pipework*	*19 - Charging fitting + cap*	*27 - Single stage regulator*
4 - Rotowink	*12 - Sintered element*	*20 - Manifold banjo bolt*	*28 - Bottle retainer assembly*
5 - O ring	*13 - Regulator connection bolt*	*21 - Blanking plug + O ring*	*29 - Connector relief valve*
6 - Regulator pipework	*14 - Non return valve*	*22 - Spring*	*30 - Connection to helmet*
7 - Gas cylinder	*15 - Whip regulator*	*23 - Valve seat regulator*	*31 - Filter*
8 - Blanking plug	*16 - Whip Rotowink*	*24 - Penetrator*	*32 - Relief valve*

The gas from the storage cylinders flows to the two stages regulator *(see # 32 above)* through the manifold *(see #3)*. The regulator is protected from the impurities that may have passed into the pipework by a sintered bronze filter. It is connected to the piping by a banjo fitting *(see #3 in the drawing next page)*.

- The first stage piston provides regulation of the inter-stage gas pressure to approximately 15 bar. This piston is initially raised from its seat by the spring *(see #8 next page)*. Gas flows past the seat and then along the hole in centre of the piston into the chamber to the left of the piston. The pressure in this chamber rises until it is sufficient to overcome the force exerted by the spring. The piston then moves across to seal the regulator port.
- The spool valve *(see #13 on the drawing next page)* is fitted to the inter-stage. The function of this device is that When the SLS System is in its stand-by mode, the spool isolates the first stage from the second stage of the

regulator. It is moved from the closed to the open position when the actuation cable *(connected to the handle)* is pulled. A bullet on the end of the cable contacts the two ball bearings *(see #14)* in the centre of the spool, drawing the valve to the open position. The ball bearings then drop out of the way allowing the bullet to pass through and away up the cable sheath.

- The second stage of the regulator is a diaphragm type. The pin *(see #19 below)* is held off the seat by the diaphragm *(see #23)*, and the support plate (see #22) under the action of the spring (*see #18*). As the pressure in the space to the right of the diaphragm increases, the diaphragm and hence the pin moves to the left, sealing off the seat fully at the pre-set outlet pressure. The outlet pressure is adjusted by varying the tension of the spring by slackening the locknut *(see #31)* and adjusting its screw *(see #31)* until the desired outlet pressure of 1 bar above ambient is achieved.

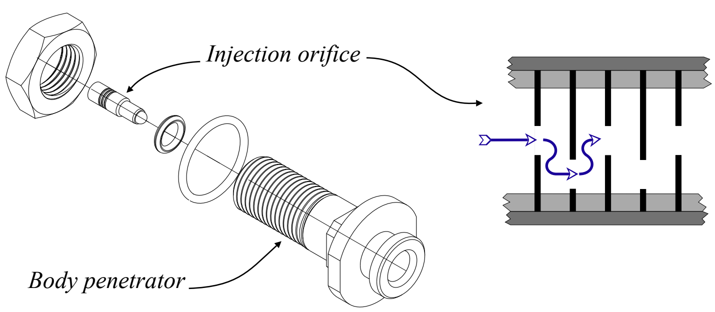


1 - Connector + O rings	*9 - Piston + Seat*	*17 - Cir-clip*	*25 - Support plate (springs)*
2 - Bronze filter	*10 - O ring*	*18 - Compression spring*	*26 - Springs*
3 - Inlet banjo fitting	*11 - Body*	*19 - Valve pin*	*27 - Adjustment plate (springs)*
4 - Cir-clip	*12 - O rings*	*20 - Valve seat*	*28 - End cap*
5 - O rings	*13 - Valve shuttle*	*21 - Valve seat retainer*	*29 - Regulator mesh*
6 - End cap	*14 - Ball bearing*	*22 - Plate diaphragm support*	*30 - Cap sleeve*
7 - O ring	*15 - Load ring*	*23 - Diaphragm*	*31 - Screw + nut*
8 - Compression spring	*16 - Relief valve + gasket*	*24 - Slip ring*	*32 - Mounting plate*

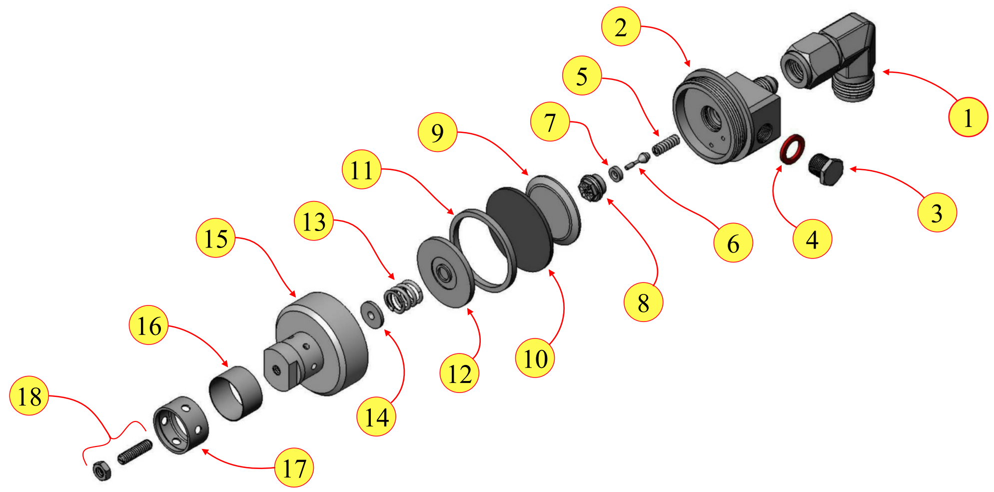
The gas is then supplied to the injection orifice located within the penetrator *(see # 24 in the general drawing in the previous page)* from which it then passes into the breathing circuit at the bottom of the CO_2 scrubber housing.

The injection orifice contains a group of orifices in series with the flow path making many 90º changes in flow direction. The combined effect is to allow the system to contain much larger holes than there would be for a single orifice with the same resistance. This arrangement is designed to reduce blockage.

Note that one penetrator is blank *(see # 25 in the general drawing in the previous page)* and is used as a locating pin for the scrubber lift mechanism.

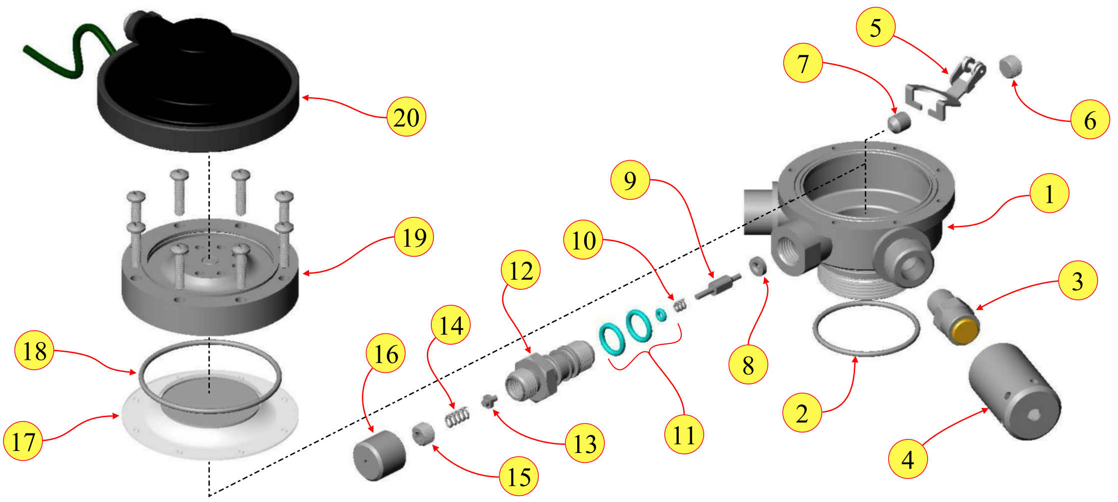


As already indicated in the previous descriptions, the single stage regulator (*see #27 in the general drawing two pages before*) which is supplied with gas from the helmet site block to which it is connected maintains a pressure of 1.38 mb over ambient pressure inside the system at all operating depths while it is in its standby mode to prevent water ingress. Also, it is designed to cope with the diver's upward and downward excursions at a rate of 22 msw / minute maximum.
This regulator is of a diaphragm type which is similar to the second stage of the two-stage regulator.
The valve pin *(see #6 below)* is held off the valve seat *(see #7)* by the diaphragm *(see #10)* and the support plate *(see #12)*, under the action of the spring *(see #13)*. As the pressure in the space to the right of the diaphragm increases the diaphragm and hence the valve pin moves to the left sealing off the valve seat fully at the set outlet pressure.
The outlet pressure is adjusted by varying the spring *(see #5)* tension by slackening the locknut and adjusting its screw *(see #18)* until the desired pressure of 1.38 mb is reached.



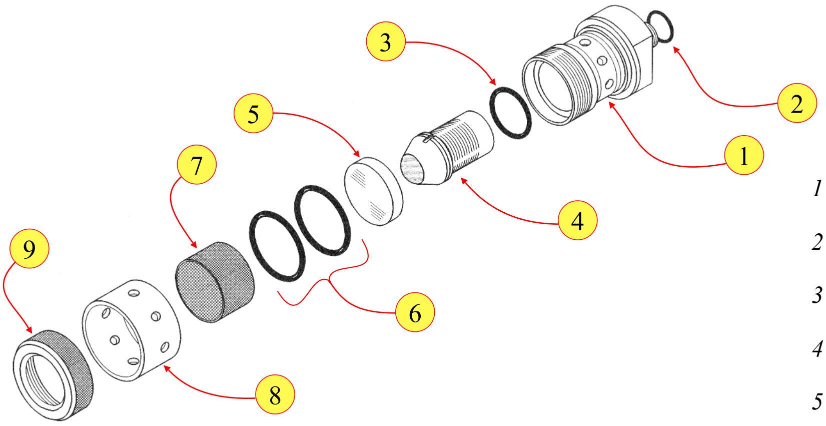
1 - Elbow swivel	*6 - Valve pin*	*11 - Slip ring*	*16 - Slip ring*
2 - Body	*7 - Valve seat*	*12 - Support plate (spring)*	*17 - Cap sleeve*
3 - Plug	*8 - Retainer valve seat*	*13 - Spring membrane*	*18 - Screw + nut*
4 - O ring	*9 - Plate diaphragm support*	*14 - Adjustment plate (spring)*	
5 - Spring	*10 - Diaphragm*	*15 - End cap*	

The demand regulator *(see #2 in the general drawing)* that supplies gas to the system for the 1st breath, and compensates the system in gas volume during any descent while the system is activated, is designed to flow gas only when it is subjected to a depression of 25,5 to 26.5 millibar to prevent the system from passing gas when it is not required.
This regulator is similar to a conventional demand regulator but differs in that it is designed to function with gas supply pressures ranging up to 300 bar so that it does not require first stage pressure regulation.

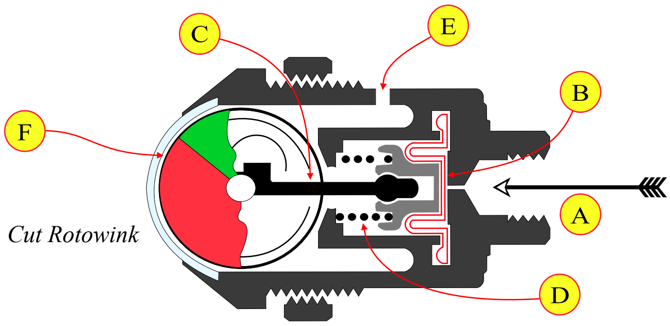


1 - Body	*6 - Set-screw*	*11 - O rings*	*16 - Cap*
2 - O ring	*7 - Demand valve shuttle*	*12 - Seat retainer*	*17 - Diaphragm*
3 - Relief valve	*8 - Valve seat*	*13 - Spring pad*	*18 - O ring*
4 - Vent cap relief valve	*9 - Valve pin*	*14 - Spring*	*19 - Lid sub-assembly*
5 - Lever	*10 - Spring*	*15 - Valve adjustment screw*	*20 - Protection cover assembly*

The high-pressure gas from the cylinders enters the demand regulator through a banjo fitting. We can observe that the gas supply pressure acts on the pin *(see #9 in the drawing on the previous page)* at the O-ring *(see #11)* and, over the same area, at the valve seat *(see #8)*. As a result, we can say that the valve pin *(see #9)* is pressure balanced. That means that the regulator supplies gas at the same negative pressure setting over a wide range of gas supply pressures.
The valve is normally held closed by the spring (see #14). When the pressure acting to the diaphragm (see #17) becomes sufficiently great for the lever fork (see #17) to overcome the spring (see #14) the lever fork pushes the valve pin allowing new gas to flow into the system.
An overpressure valve *(see #3)* that is factory set is fitted to ensure that during the standby mode the internal pressure of the system does not exceed 172 bar. As a result, the internal pressure within the SLS system will vary between the single stage regulator set pressure of 138 millibars and the overpressure valve set pressure of 172 millibars as the diver's ambient pressure will change during the upward or downward excursions.
As indicated previously, a pressure indicator of Rotowink type which changes from green to red if a significant loss of pressure occurs is fitted to the system *(see the drawing below)*. It is installed in a robust metal housing which is allowed to flood in order to reference the ambient water pressure. A fine mesh screen is fitted to prevent the ingress of dirt to its internal parts exposed to the water.



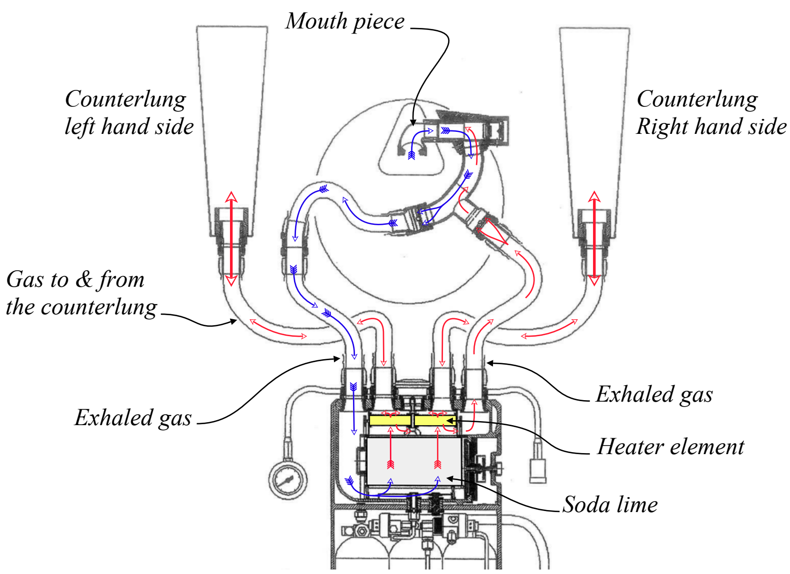
1 - Body
2 - O ring
3 - O ring
4 - Rotowink
5 - Lens
6 - O rings
7 - Mesh
8 - Mesh retainer sleeve
9 - Top cap



Cut Rotowink

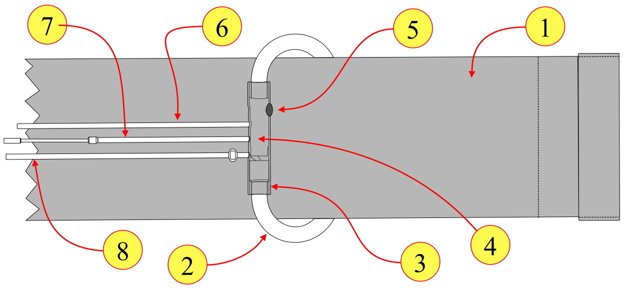
A - Gas pressure
B - Membrane
C - Connecting rod
D - Spring
E - Opening to ambient
F - Rotating indicator

Another difference the SLS Mk4 has with the last generation rebreathers used by militaries and trained scuba divers is that the counterlungs of most of these new systems are organized in such a way that one unit collects the exhaled gas and the second unit is filled with the renewed gas to inhale. Thus, one counterlung is before the cartridge of soda lime and the 2nd after it. Opposite to this design, the counterlungs of the SLS Mk4 are working together and are situated after the CO2 absorber. Also, they are connected by separate hoses and are not along with the main respiratory hoses. As a result, four breathing hoses are installed on the backpack instead of two with the last generation rebreathers.



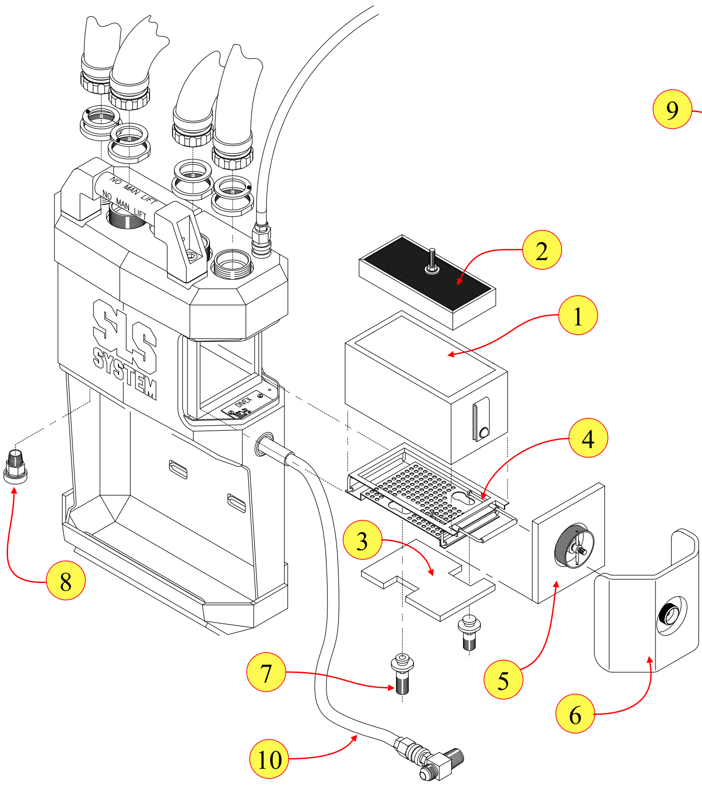
Also, as the SLS is designed to be used only in an emergency, the counterlungs must be protected from rubbing and shocks that may damage them. It is the reason they are packed in robust enclosures.
These enclosures are maintained closed by a series of Teflon lined loops through which the two nylon actuation cables are passed. This design allows the actuation cables sliding easily when they are pulled out by the handle. As a result, the enclosures fall open, and the counterlungs deploy ready for use.
Note that it is of ultimate importance that the cables are entirely removed from the rings to have a correct opening of the enclosures.

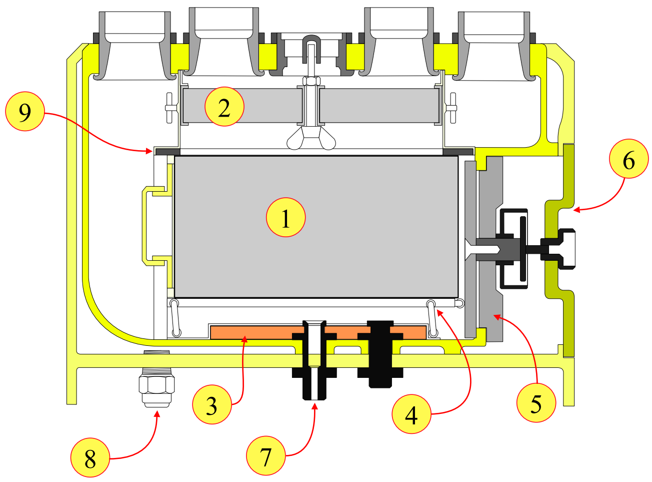
Note that the lengths of the actuation cables which are connected to the actuation handle must be adjusted in such a way that the two-stages regulator and the counterlungs are actuated simultaneously (see the drawing below). This handle is protected by a flap which is terminated by a red colour band *(see item "A" on the photos below)*



1 - Webbing
2 - Actuation handle
3 - Handle sleeve
4 - Cable holder
5 - Screw
6 - Cable actuation counterlung
7- Cable actuation regulator
8 - Cable actuation counterlung

The refillable scrubber canister assembly *(See #1 below)* is a rectangular box which contains 125 gramme of soda lime that allows absorbing CO_2 for 30 minutes maximum *(see the endurance table on the next page)*. It is inserted into the back pack through a waterproof lateral door *(see #5 & #6)* and is pressed against its gaskets by a lift mechanism *(see #4)*.
Note that this opening allows accessing the thermal regenerator and the absorbent sponge *(see #3)* which collects moisture resulting from condensation and breathing.





1 - Scrubber canister
2 - Thermal regenerator
3 - Absorbent sponge
4 - Lift mechanism
5 - Waterproof door
6 - External door
7 - Injector
8 - Relief valve
9 - Gasket
10 - Hot water inlet

The preparation of the SLS Mk4 requires some precautions. Also, Some preventive maintenance has to be performed to ensure that the system is always ready for use.

- The procedure and safety precautions for charging the bottles are those used with quads and scuba cylinders. Also, as previously indicated, Divex says that they must be emptied before filling them again.

- The determination of the mix to be used should be done according to the table and method explained previously. Also, the endurance of the system depends on the pressure of heliox stored in the bottles and the duration of the CO_2 absorbent, which is 30 minutes maximum. As a result, Divex says that there is no advantage in charging the cylinders to their maximum pressure (300 bar) for shallow dives. The table below can be used to select the pressure necessary for the planned depth of intervention:

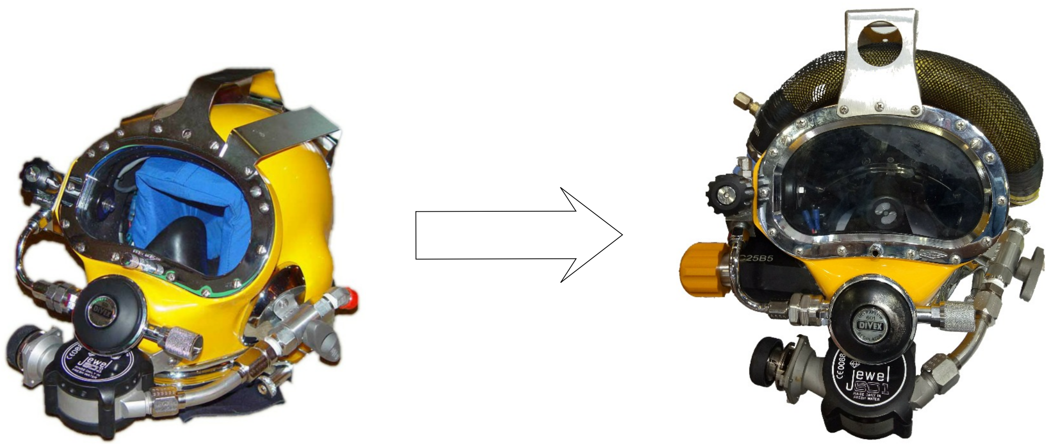
Depth	***Charging pressure***	***Duration (minutes)***	***Depth***	***Charging pressure***	***Duration (minutes)***
50 msw	*300 bar* *	*30 min* *	*200 msw*	*150 bar*	*10 min*
50 msw	*175 bar*	*30 min*	*250 msw*	*300 bar*	*19.5 min*
50 msw	*100 bar*	*17 min*	*250 msw*	*200 bar*	*12.5 min*
100 msw	*300 bar* *	*30 min* *	*300 msw*	*300 bar*	*17.5 min*
100 msw	*250 bar*	*30 min*	*300 msw*	*200 bar*	*11 min*
100 msw	*100 bar*	*12 min*	*350 msw*	*300 bar*	*16 min*
150 msw	*300 bar*	*28 min*	*350 msw*	*200 bar*	*10 min*
150 msw	*150 bar*	*14 min*	*400 msw*	*300 bar*	*13.5 bar*
200 msw	*300 bar*	*22 min*	*400 msw*	*250 bar*	*11 min*
*Note: The values with an asterisk * are limited to 30 minutes due to the scrubber canister duration.*					

- The manufacturer recommends replacing the scrubber canister every 24 hours even though the system has not been actuated. The reason is that there is possible aggregation (sticking together) of the soda-lime granules within the moist bell environment.
- Precautions are indicated by the manufacturer for the compression and decompression of this item. It is to prevent the external pressure damage to the o rings of the pipework, the cylinders, and other items composing the SLS Mk4 system:
  - The SLS system backpack must be disconnected from the helmet prior to locking it in or out of a chamber complex or prior to compression or de-compression of a diving bell or a chamber with the SLS system inside.
  - The gas cylinders must be charged prior to the compression of the backpack

Of course, the SLS system is designed for one use only. For this reason, it must be fully reconditioned after any actuation. This reconditioning includes the change of the soda-lime and a detailed inspection of all the components.
Note that the procedures for the maintenance and inspection of this equipment can be found on the manufacturer's website at the following address: https://www.jfdglobal.com/

1.1.6.4 - COBRA (Compact Bailout Rebreathing Apparatus)

The COBRA (Compact Bailout Rebreathing Apparatus) is the new system from DIVEX that replaces the SLS Mk4. It provides better ergonomics, allows more time to return to the bell, and can be used at depths up to 450 msw in seas at temperatures between -1 Cº and + 34 Cº.
This device, that is based on the same concept as its predecessor, is composed of a backpack that is connected to a specific helmet with the similar operational principle of a conventional semi-closed circuit breathing apparatus, in which the exhaled gas is captured in counterlungs and is then re-breathed by the diver, after removal of the carbon dioxide (CO_2), and injection of fresh heliox to maintain a mix adapted to the depth of the diver. Note that, as with the SLS Mk4, the helmet is originally a conventional Divex "Ultrajewel 601" to which the necessary elements for the rebreather are adapted *(see below and in point 2.3.6.1)*.

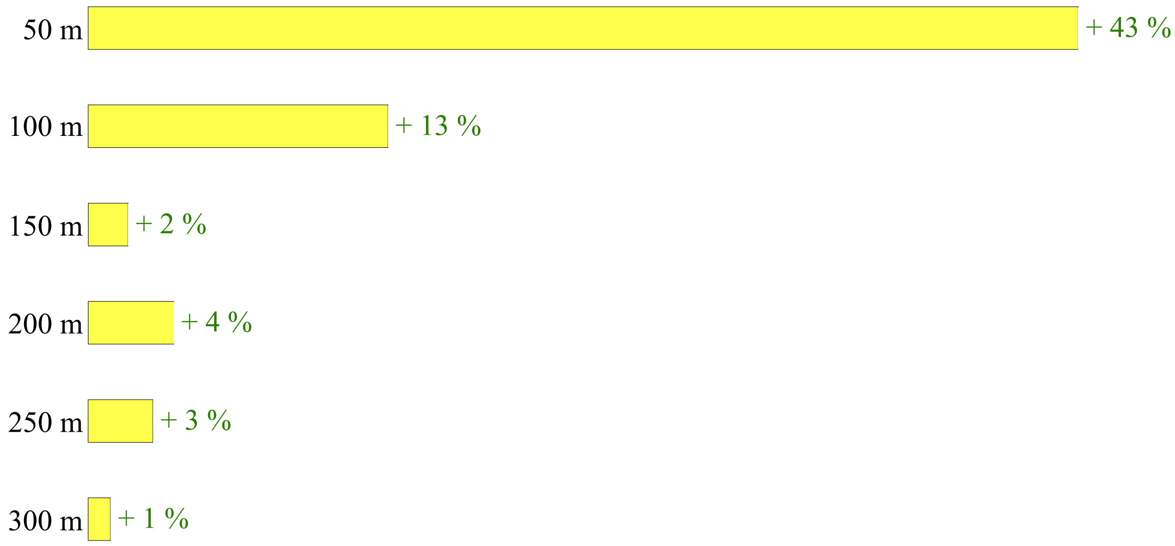


Similarly to the SLS 4, the “backpack” consists of the main housing containing the gas injection system, the CO_2 scrubber canister and the thermal regenerator that temporarily stores the heat within the breathing gas to avoid losing it to the water as the breathing gas passes into the counterlungs.
These modules have been improved, so the operations to change the soda lime of the scrubber are much simple. Also, the feeding of the positive pressure that maintain the breathing loop integrity when the rebreather is offline to allow for the first breath at activation is increased, which allows for a more rapid descent.
A major difference with the SLS Mk 4 is that the counterlungs are encapsulated inside the main housing instead of being on the harness straps. This configuration protects them better against potential damages than the flexible external protectors of the SLS Mk 4. Also, their deployment is now automatic, so the diver does not have to pull an actuation handle to open their enclosure as with the previous model. As a result, the activation of the system is performed with only the rotation of the dedicated handle of the helmet that deploys the mouthpiece at the same time it opens the gas circuit. Note that this configuration also eliminates the two big shoulder counterlungs hoses, so the mobility of the diver is improved.

The gas injection system is composed of two composite or steel gas storage cylinders that supply the 1st & 2nd stages of the regulator, the injection orifice, and the demand valve. As with the SLS Mk 4, the system is provided with a “Rotowink type” pressure indicator, which changes from green to red if a significant loss of pressure occurs. There is no electronic component in place to calculate and dose the mix, such as those found in modern exploration rebreathers used by militaries and sportive divers. Instead, the appropriate percentage of oxygen of the breathing gas is calculated by the technician in charge according to the planned depth of excursions and stored in the cylinders before the dive. So, this system, which is designed to be available at all times within the excursions limits planned for the dive, is similar to the one used with the SLS Mk4. However, the cylinders are installed on each side of the gas injection and reclaim modules instead of underneath them with the SLS Mk4.

Another improvement is that this new system can be activated and deactivated as required. That allows the diver to perform pre-dive function tests as with the gas cylinder of an open circuit bailout. Also, the weight of the system, which is calculated to be neutral in the water, is 26 kg in air. So, it is lighter than the twin-set bottles 10 litres commonly used, and sufficiently compact to be appropriately stored in the bell.

According to the data from DIVEX, the comparison of the possible breathing duration of the COBRA with those of the SLS Mk4 demonstrates improvements at all depths at the following approximate percentages:



In conclusion, this new system of bailout erases the majority of the inconveniences of the SLS Mk 4 without losing its advantages. It provides an increased safety level to the diver and should be adopted for all dives below 50 m and in cold waters.

Note:
Courses regarding the use and the maintenance of this system are organized in the several subsidiaries JFD and can be booked at this address: https://www.jfdglobal.com/services/training-services/course-booking/

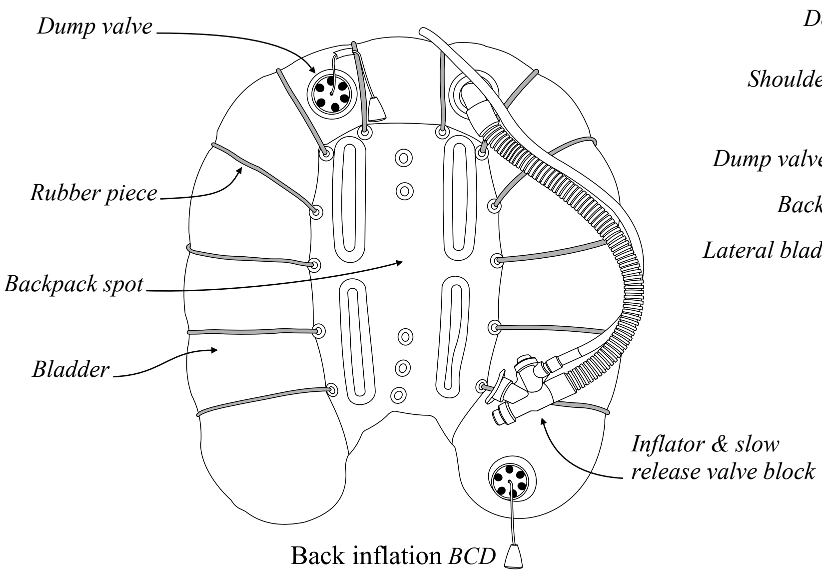
1.1.7 - Buoyancy Control Devices (BCDs)

Recreational scuba divers and militaries commonly use buoyancy control devices. However, they are still not always adopted for saturation, and surface orientated commercial diving operations, despite some noticeable progress.
It is important to note that these tools give the possibility to set a neutral buoyancy allowing the diver not to drop and easily control his depth when performing excursions that are not on the seabed. Also, they can be helpful in the case of the recovery of an unconscious or injured diver. It must be remembered that in the case of a team of three divers, recover a casualty who is not in a condition to move by himself with only the help of the umbilical that is pulled from the bell is a difficult task, even though the rescue diver and the bellman are active and experienced. Also, in the case that the team in the bell is limited to two persons, the rescuer intervening in the water is the bellman, and there is nobody in the bell to pull the umbilicals. For these reasons, we can say that these devices are beneficial and should be part of the tools available to the diver when it is possible to implement them.

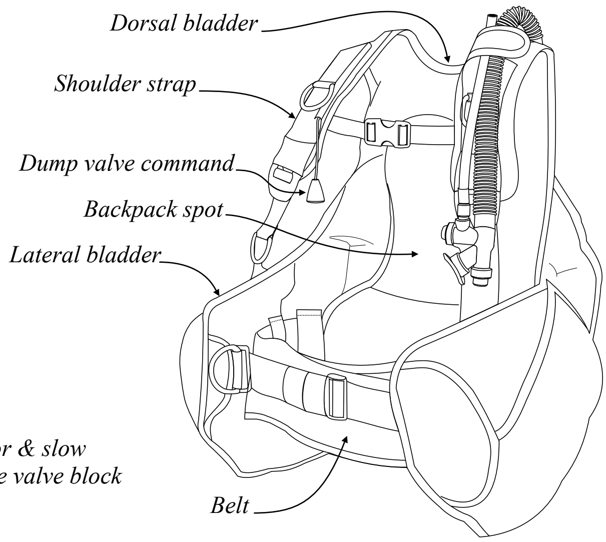
1.1.7.1 - Description

They are composed of a bladder or a sealed bag where the gas is injected through an inflator which is connected to a low-pressure gas supply of a 1st stage regulator connected to a cylinder or situated on the side block of the helmet. The gas trapped in the bladder is released using quick release valves (dump valves) and slow release valves that are used to control the buoyancy. They can be classified into two main families:

- “Stabilizing jackets”, also called “vest BCDs,” are buoyancy control devices that are shaped as a vest. With this design, the trapped gas is distributed around the belly, the torso, the back, and the shoulders. They are generally fitted with adjustable straps. This repartition of the gas makes them very safe when they are fully inflated at the surface as the body of the diver is kept vertical. However, note that these devices will never be used at the surface during saturation diving operations.
- “Back inflation buoyancy control devices”, which are also called "Wings," are installed around the backpack, thus are inflated in back of the diver and may be fitted with rubber bands that retract them when they are not in use. These models are often used by sportive scuba divers practicing deep incursions with extra cylinders as some models can provide lift capacities above 40 kg. However, large volume bladders are unnecessary for saturation divers as, due to the supply from the umbilical and the proximity of the bell, they do not need to carry these cumbersome extra gas bottles.



Back inflation *BCD*



Stabilizing jacket

1.1.7.2 - Precautions to be in place for the implementation of BCDs

- Formation of the divers:

Buoyancy Control Devices are dangerous tools when the divers have not been trained to use them, which may be the case with some commercial divers. Note that there is no IMCA module for the use of BCDs, and even though the procedures for the implementation of such items or inflated dry suits is taught in a lot of diving schools, several experiences show that it is not the case of all schools. For this reason, the diving superintendent must ensure that the divers have had such training. That can be done through the control of certificates or a test. Note that the following documents, but not limited to, can be considered a proof of competence:

- The logbook of the diver should normally record the formations the diver has received. Also, the suits and buoyancy control devices used during the projects should be indicated.
- Military or sportive diving certificates or licenses may prove that the diver is familiar with buoyancy control devices. Note that regarding this point the description of the formation undertaken should be provided.

If there is no evidence that the diver is familiar with buoyancy control devices, he cannot be authorized to dive with such equipment.
Of course, the company can implement a test or a formation. However, that should not be organized without the support of a recognized diving school and diving instructors.

- Selection of the model:

There are a lot of models of Buoyancy Control Device. However, most of them are initially designed for sportive or military divers, and may not be suitable for commercial saturation diving. For this reason, a lot of precautions should be in place when selecting the model. Also, the selection of the BCD should be made by experienced divers and diving supervisors. The people in charge of choosing such devices should focus on the following elements, but not limited to:

- The BCD must not disturb the use of other safety devices such as bailout systems (bottles or rebreathers).
- There must not be conflicts with the hoses and wires of the helmet, the attachment of the umbilical, and the hot water connection and manifold.
- The device should be fitted with dump valves and a slow release valve which are situated in the upper parts of the bladder. Their commands must be readily accessible. Note that the inflator is often fitted at the end of a ringed hose with the slow release valve *(see the drawing on the previous page)*. This hose should be arranged in such a way that it does not conflict with another equipment and is readily accessible at all times. If it is not the case, it should be replaced by an inflator similar to those used with dry suits (*see # 1 on the photo to the side)*. Also, if the BCD is fitted with an optional bottom dump valve, it should be situated in a convenient place and the person selecting the equipment must ensure that it cannot be opened unexpectedly. Thus, if this extra valve can be the source of a safety problem, it should be removed.
- BCDs used for commercial diving must be made of materials that are strong enough not to be damaged during working operations in an aggressive surrounding.

- The buoyancy control device should not deprive the diver of breathing gas if his bailout system is activated. For this reason, it is preferable to supply it from one or two separate dedicated small bottle(s) as it is the case with a lot of military models.

BCDs mounted on twin bottles sets used for shallow saturation diving in one of the bells of UDS Lichtenstein

- Pre-dive checks and maintenance:

BCDs are safety equipment that must be checked before each dive. For convenience, these checks may have to be performed by the technicians outside the bell:

- Webbing, cloth, and sewing threads should be in perfect condition without noticeable wear or scratch.
- The bladder and valves should be tested for leaks, and defective spares should be replaced. Note that most manufacturers say the lifetime of a bladder is approximately 10 years from the date of manufacturing.
- The inflator should be easy to trigger and should immediately return to the closed position when released.
- Note that the small bottles and their regulators may have been flooded. For this reason, they must be frequently visually inspected. They should be removed from service and adequately tested and refurbished if corrosion is detected. Note that these bottles must not be filled inside the saturation system.

Preventive maintenance should be performed:

- The BCD should be rinsed with fresh water internally and externally after every dive.
  Regarding the internal parts of the BCD, the seawater that is inside the bladder should be removed and replaced by approximately two litres of fresh water and the BCD should then be inflated and shaken to rinse it appropriately. This fresh water is then removed. Note that this operation can be repeated several times.

- Note that a Buoyancy Control Device (BCD) transferred from the saturation system through the tool transfer lock should be emptied; otherwise, it will be fully inflated when it arrives at the surface. A precaution to avoid this is to remove one dump valve.
- Pre-project training may be organized in a swimming pool that is filled with chlorinated water. For such a case, manufacturers recommend to thoroughly rinse the BCD, as repeated exposure in such water can damage the construction materials used.
- A buoyancy control device that must be stored should be dried externally and internally. A natural process of drying is recommended not to damage it. Also, manufacturers recommend to store it partially inflated.

1.1.8 - Knifes, fins, weight belt, and small equipment

Only devices from recognized manufacturers are considered suitable.

1.1.8.1 - Knife

The diver must have a knife that is designed to cut ropes, fishing lines, and textile slings.

- The blade that is suitable for this purpose has a specific profile and is sufficiently long (16 to 20 cm) to cut big ropes.
- This blade must be strong enough to not break during normal use. It should be made of specific stainless steel that does not corrode.
- The knife is secured in its sheath that is designed to secure it and easily release it.
- The diver must ensure that it is easily accessible. A small coiled lanyard should be installed to avoid losing it.
- The knife must be tested for efficiency before starting the bell run.
- Note that despite precautions, knives are often lost during diving operations. For this reason, a spare unit should be in the bell and several replacements must be available in the onboard store.

1.1.8.2 - Fins

Fins must be worn for all jobs that are not on the seabed. They should always be available in the bell even though the task is planned to be performed on the seabed and that the diver logically prefers using boots, as they can be useful in the case of an emergency or if the diver needs them due to the conditions encountered. The following elements should be taken into account when selecting them:

- Fins designed for diving operations from closed bells should be made of durable materials and not be too long to allow easy deployment of the diver, not take too much space in the bell, and not to disturb him during the work.
- Open heel fins are generally preferred as they can be worn on booties and are adjustable. However, the shoe size must not be too large and fit the feet of the diver. If it is not the case, the diver does not swim comfortably and may lose them.
- Note that despite numerous new models that are proposed for the market, fins used for commercial diving have not really evolved for more than fifty years. As an example, the model in the photo at the side is still one of the most used and was first commercialized under the name “Jetfin” in 1964. This model is made of rubber and appreciated for its durability despite its heavy weight and its reduced output compared to more modern models.

Fins should be inspected before each bell run:

- Note that rubber straps are fragile and often need to be changed. For this reason, spare straps must be available in the bell.
- Also, buckles may be damaged and should be carefully checked:
  - Metal buckles are robust. However, they may distort with time, or the rubber parts in which they are inserted may tear when they become too old.
  - Plastic fasteners are often mounted on pivots that are molded in the mass of the fin and that may become quickly worn to retain them in position. When such a problem happens, the fins cannot be repaired and should be scrapped. That explains the reason old models such as the one in the photo are still successful.
- Note that rubber loses its capabilities over time. As a result, items made of rubber stored for too long a time become sticky and lose their elasticity and thus may tear easily. Of course, the effects of the sun and the salt speed up this process. Nevertheless, it will happen to items ideally maintained and stored. Products such as talc powder slightly slow down such the process.
- Fins may be lost by divers even though they are in good condition. For this reason, there must be a replacement pair in the bell and several spare units onboard the vessel.

1.1.8.3 - Buoyancy control weights

Depending on whether the diver works on the seabed or not and is equipped with a buoyancy control device, weights should be used to adjust his buoyancy. A balanced buoyancy is ideal when the diver is working above the floor and needs to swim. However, remember that a saturation diver who becomes positively buoyant is exposed to an uncontrolled ascent, and so is in danger.
These weights of one or two kilograms and sometimes one pound can be molded lead blocks or granules in sealed bags. They can be put on a specific belt made of textile or rubber, or clipped to the harness of the diver, or inserted into dedicated pockets of the harness or the buoyancy control device. Note that in the old time weights could be trapezoidal medals installed at chest level. However, this system seems to no longer be used for saturation diving.

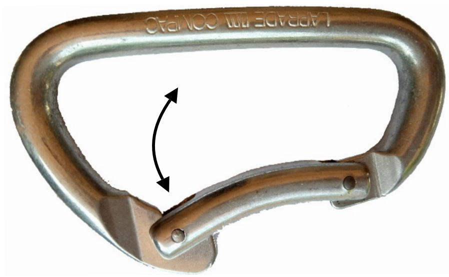
Belts are still used for scuba and commercial surface oriented diving as, depending on the job undertaken, they may have some advantages.

However, they are not the best option for saturation diving and teams still using them are very rare.
If this option is selected, the belt must be robust enough not to be torn during a dive, designed not to be opened (lost) unexpectedly, and be adjusted in such a way that it cannot slide. Specific buckles that can be quickly closed and opened are proposed by manufacturers. Nevertheless, classical pin buckles are still the most selected and the preferable option.
The weights that are installed on the belt must be measurable and secured on it in such a way that they cannot be lost.
Belts are not complex items. However, when preparing the dive, the diver should focus on the sewing or the rivets that secure the buckle and the holes in which the pin of the buckle is inserted. Also, as explained previously, rubber does not keep its capabilities over time and may become stiff and fragile.

As a result of this discussion, weights secured in dedicated secured pockets of the harness seems the most comfortable and safest solution. Thus, the preferable option for saturation diving.

1.1.8.3 - Rescue Lanyard

A lanyard that is designed to secure an injured or an unconscious diver to the rescue diver should be provided to each diver. The rescue lanyard should be a strong polyester rope (approximately 1 cm diameter) with a spliced eye at each end or a similar small soft sling of approximately 1 m long with a carabineer is ready for use in each eye.
Climbing type carabineers similar to the model below, which is designed to be quickly inserted and remain always closed as a result of its particular shape, are the best option for this essential safety tool.



1.1.8.4 - Compass

With the progress of survey systems, divers are guided to the target using beacons. However a compass is a good help to follow or report a direction. These instruments should be able to withstand the pressures attained in saturation. For this reason, liquid filled compasses are recommended.
Note that a lot of diving compasses designed for recreational scuba divers are originally designed for depths above 100 metres.

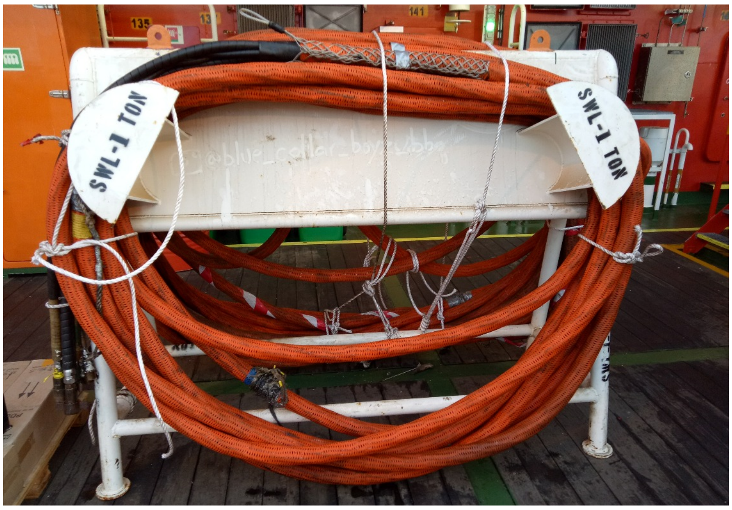
1.1.9 - Main bell umbilical

1.1.9.1 - Description

The main bell umbilical is an essential part through which the following functions are transferred to and from the bell:

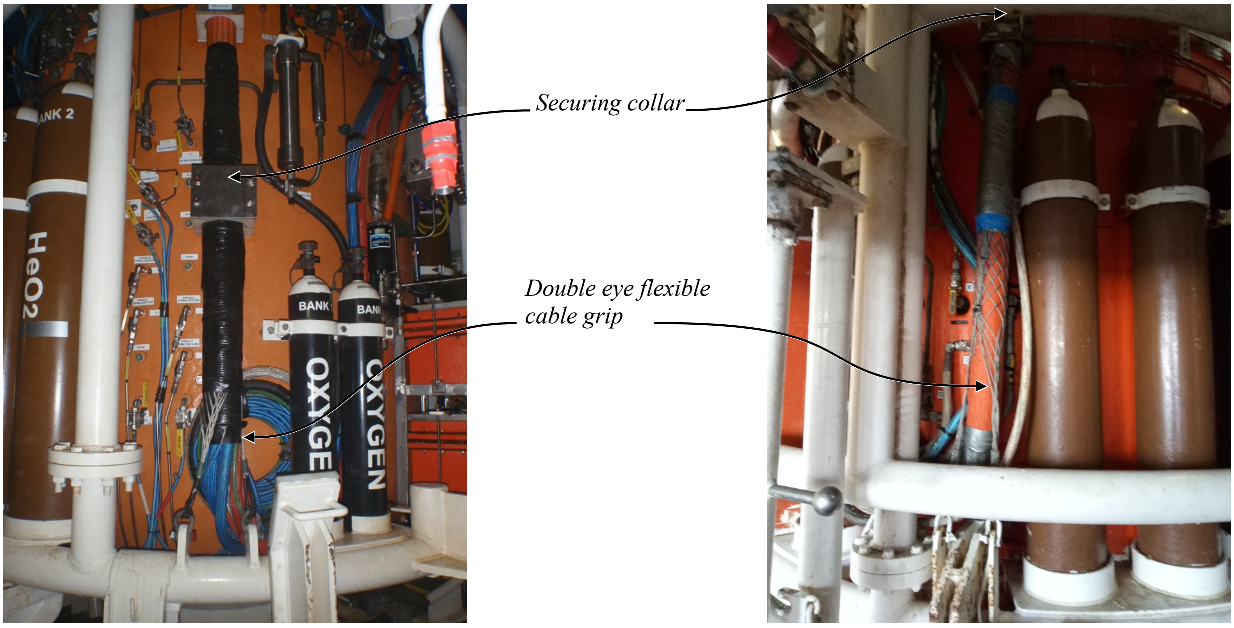
- Gas supplies and exhausts:
  - Bell pressurization and exhaust
  - Diver #1 & #2 gas supply
  - Bellman/Standby diver (diver #3) gas supply
  - Divers' gas reclaim exhaust
- Depth, atmosphere control, & temperature control
  - Depth external bell & diver #3
  - Depth internal bell
  - Depth diver #1
  - Depth diver #2
  - Analysis bell
  - Hot water supply
- Electrical supplies
  - External lights
  - Internal lights
  - Scrubber
  - Diver #1 hat light
  - Diver #2 hat light
  - Diver #1 camera
  - Diver #2 camera
  - Bell internal camera
  - Bell external cameras
  - Sensors divers' monitoring system
  - Hypergas analyser (hydrocarbons analyser)
  - Onboard batteries & through water comms battery
- Video, sensors, & communication signals
  - Diver #1 video signal
  - Diver #2 video signal
  - Signals sensors divers monitoring systems
  - External bottom camera signal
  - External topside camera signal
  - Internal camera signal
  - Sound powered phone communications
  - Microphone diver #1 signal
  - Earphone diver #1 signal
  - Microphone diver #2 signal
  - Earphone diver #2 signal
  - Microphone standby diver (diver #3) signal
  - Earphone standby diver (diver #3) signal
  - Microphone bell intercom signal
  - Earphone bell intercom signal
  - Hypergas analyser signal

Wires and hoses are maintained together by a polyethylene braided sock that protect them from shocks and abrasion. The hoses are made of rubber and high-performance thermoplastic polymers. Similar materials are used to isolate the electrical and communication wires.

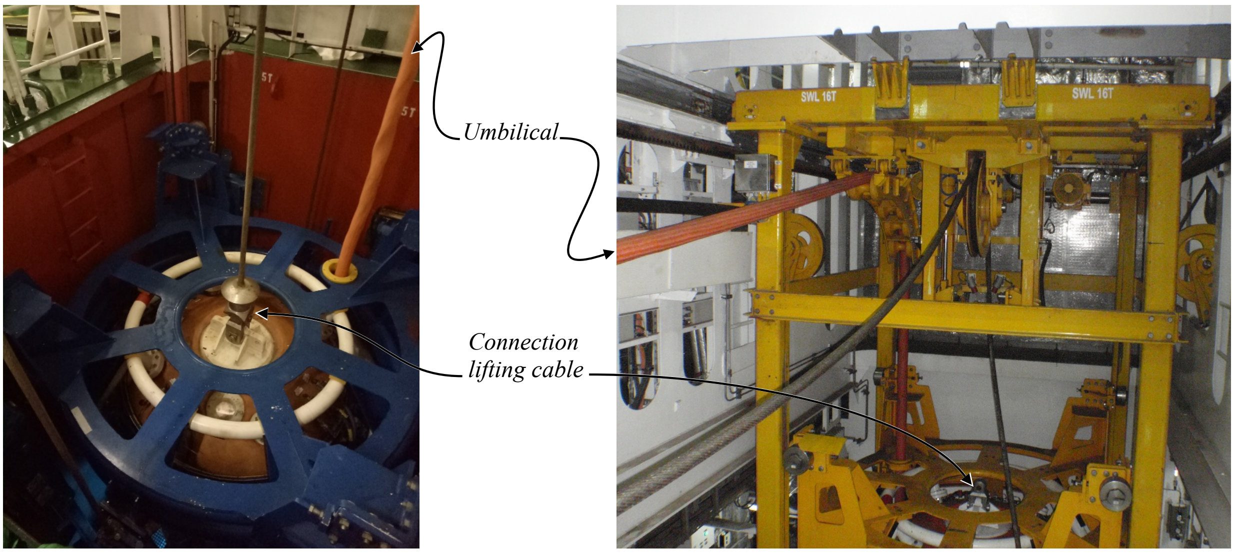


1.1.9.2 - Installation and protection

IMCA D 024 says that The umbilical must be securely attached to the bell by means of a strength member or strain relief fitting so that neither the individual components or any bell penetrations are subject to load. The leads of the hoses and cables at the bell end should be arranged to avoid chafing or kinking.
To fulfill this requirement, most umbilicals of modern systems are secured to the protection frame of the bell by double eye flexible cable grips. Note that in the examples below each umbilical is attached to the bottom frame and also secured along with the bell by dedicated metallic collars. As a result, the hoses and wires moving out the polyethylene braided sock are protected from tractions that may damage them. Also, the connecting wires and hoses are secured along with the wall of the bell and have sufficient ample curves to protect them from kinking. Note that contacts with obstacles should be absorbed by the protection frame of the bell that is arranged at a sufficient distance to ensure that wires and hoses should not be affected by shocks, chafing, and other damages resulting from such undesirable events.



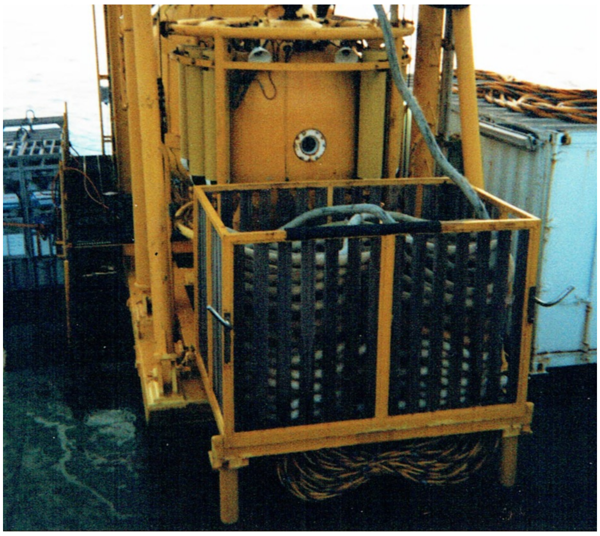
The external braided sheath of the umbilical can be damaged by frequent rubbing with the lifting and guide cables. Also, it can become very dirty as these cables are coated with a layer of grease that protects them from corrosion. To protect the umbilical and avoid conflicts with the lifting cables during the deployment and the recovery of the bell, the manufacturers of the last generation systems secure them to the side of the bell and as far away as possible from any cable. Also, they provide dynamic tensioning systems that permanently recover the excess of slack of the umbilical. As a result, the umbilical is kept in perfect condition.



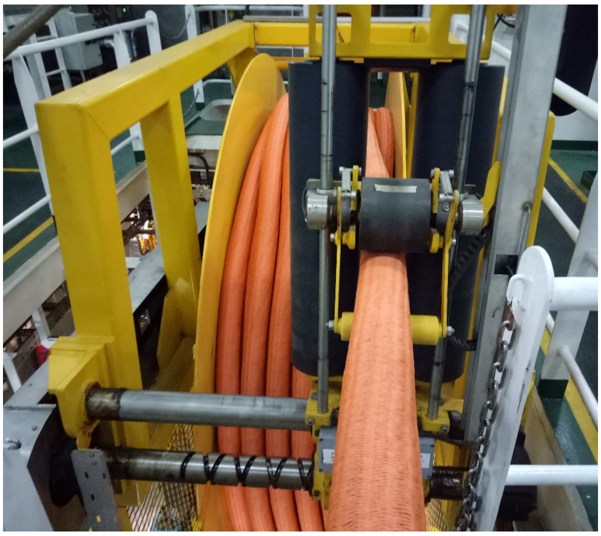
Note that the umbilicals of some systems from the previous generation are sometimes connected to a pad-eye that is welded on the top of the bell and close to the lifting point of the pressure vessel. Also, they are not equipped with dynamic tensioning systems. That results in umbilicals with sometimes an excessive slack that are rubbing with the cables and are made dirty by the grease that protects these cables. To avoid having too much slack in the water with such systems a solution frequently used is to fasten the umbilical along with the lifting cable by the means of whips. The distance between the whips depends on parameters such as the underwater currents and whether the surface support uses a dynamic positioning system.

Old systems are designed with umbilicals that are recovered and deployed by rollers and manually stored in a rectangular or a rounded basket. The manual storage of such an umbilical is a strenuous task that employs at least two people.

Modern systems are designed with a winch that coils the umbilical ideally and deploys it at the speed of the cable winches. The winch is also a part of the dynamic tensioning system. Note that IMCA says that it should be fitted with a mechanical braking system to stop the umbilical paying out under load when the winch motor is in use (over-running), in neutral, or at rest.



Umbilical basket (old generation systems)



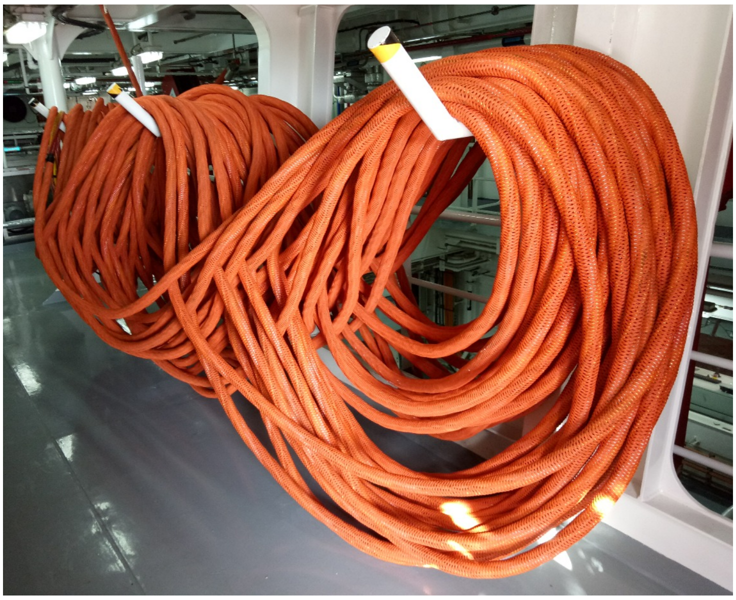
Umbilical winch (Last generation systems)

1.1.9.3 - Bell recovery using the umbilical.

IMCA D 024 says: *The umbilical should only be used as a means of secondary recovery if it is specifically designed for that purpose. If so, it must be tested in line with the requirements in the handling system section.*
The capabilities of the umbilical to withstand a load must be documented by the manufacturer and never be exceeded. Note that umbilicals designed to lift the bell in the air are very rare. Nevertheless, the majority of the umbilicals in service are sufficiently strong to pull the bell to the proximity of the surface where it can be then connected to a lifting gear.
However, this option must never be used without explicit confirmation from the diving system and umbilical manufacturers and the lifting tests indicated in IMCA D 024.

1.1.9.4 - Emergency umbilical

In the case that the main umbilical has been severed, an emergency umbilical can be connected to reinitiate the essential functions of the bell. Of course, this umbilical is designed for emergency recovery only and cannot be used for normal diving operations.
Note that IMCA D 024 says that it is only an option. As a result, IMCA considers that dives can be undertaken even though this equipment is missing. Nevertheless, serious companies and clients impose an emergency umbilical ready for use on the worksite. As already said, emergency umbilicals are designed to provide at least the functions indicated in point 2.3.2.6. As a reminder, it must be fitted with at least a hot water hose with a connector 3/4" NPT male, and breathing gas hose with a connector 1/2" NPT male. However, most emergency umbilicals are also fitted with a 1/4" hose with a male connector NPT for the internal depth, a power supply line, and a comms line. Also. NORSOK requests an additional 1/4" hose with a male connector NPT for the gas analysis.
IMCA says that this umbilical must be stored in suitable conditions, so on a specific frame from which it can be easily deployed *(see the photo below)*. The tests and certifications to be carried on are the same as for the main bell umbilical.



1.1.9.5 - Maintenance

The bell umbilical and its attachments must always be in perfect condition and checked before and after the dive. Also, IMCA D 024 provides the following guidelines regarding the certification and the audit of such a device:

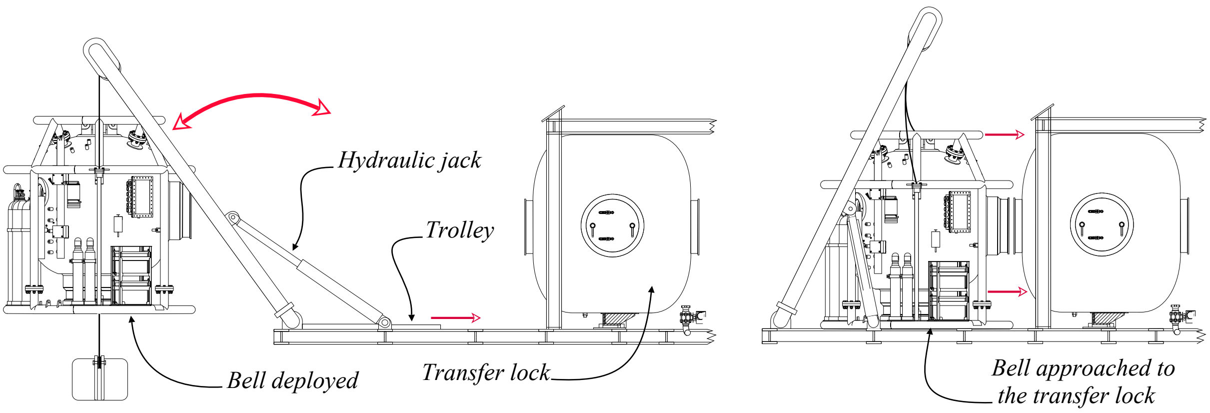
- The continuity and resistance of all cables must be checked every six months. Also, the other electrical components of the umbilical should be examined and function tested at the same time.
- Hose components and their protective devices should be carefully monitored, and function tested every six months. Also, they must be tested to their maximum working pressure every two years. Besides, they must be hydro tested to 1.5 times their maximum working pressure when they are new or as recommended by the manufacturer or the certification body.

1.1.10 - Bell launch and recovery and connecting systems

1.1.10.1 - Kinematics of launch and recovery systems

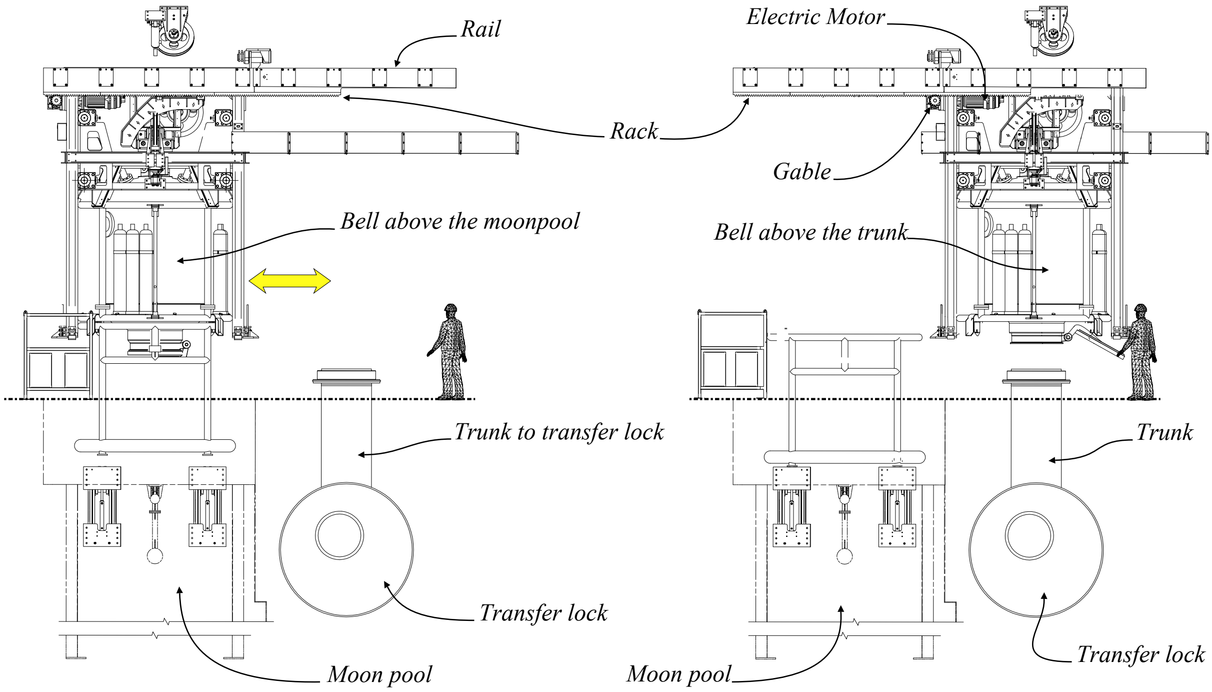
Two main design are commonly found: “A” frames or “trolley systems”.

- “A” frame systems are generally found on portable systems or systems designed with a bell deployed over the side of the vessel. However, it may happen that they are installed over a moon pool. This configuration is also used for the deployment of wet bells, diving baskets, ROVs, and other devices. The winches and the main umbilical reel that can be of complex or straightforward designs are often installed above the chamber to which the bell is connected. The advantages of these systems are their simplicity and robustness. They can be used with bells that connect to the transfer lock by the lateral or bottom door.
  The A-frame is deployed above the sea and returned to the inside of the vessel by strong hydraulic jacks. When the bell connects laterally, a trolley mounted on rollers which are guided by two rails included in the chassis is used for the final approach of the flanges. The procedure to connect the bell laterally to the system consists of lowering the bell on the trolley, then approach it gradually to the flange of the transfer lock. The trolley is generally actuated by a hydraulic jack. The cables and the umbilical are gradually slightly slacked during the approach. Note that on some very old generation systems, there were no trolleys and the bell was resting on skates that were guided and sliding in two slots inserted in the chassis. A winch was used to approach the bell to the transfer lock. It seems that systems with such design are no more manufactured.



As an example of a system designed with A-frame (see #1), the picture above shows a portable saturation system of the previous generation with the bell deployed above the water (see #2). Note that the umbilical is paid-out or recovered by a grooved wheel (See #3) into which the umbilical that is stored by hand in a basket (see #4) is pressed by a roller. Note that a lot of systems similar to this one are still in service.

- A bell traversing trolley system is a self-contained unit, mounted within parallel rails built into the ship’s structure. The trolley moves on the tracks through the action of an electric motor that rotates a gable on a rack *(see the drawing next page).* These systems are more complex than A-frame ones and for this reason, they are not often used with portable systems. They are the preferred ones with built-in saturation systems as they allow a smooth transfer of the bell, and particularly a precise connection of the flanges. As with A frames, they can be used with bell that connects to the system laterally or by the bottom door. The last generation systems are equipped with a computer that controls the disconnection, descent, ascent, and reconnection of the bell.



The photo above shows an example of a system designed with a traversing trolley. Note the rails (see #1) to which the trolley (see #4) is hung. Also, note the rack (see#2) and the gable that moves the trolley along the rails and is motioned by an electric motor (see #3). The Bell is at depth and for this reason the trolley (see #4) is above the moon pool (see #5). The moon pool can be closed using doors that are folded on each side (see #6).

1.1.10.2 - Winches and wires

Most last generation launch and recovery systems are equipped with winches designed to fulfill the following functions:

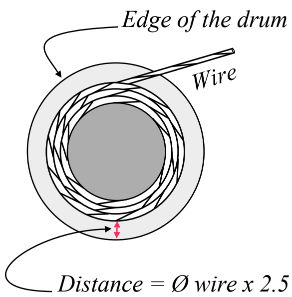
- Lowering and recovery of the bell
- Anti-gyration of the bell
- Secondary recovery
- Umbilical deployment

The lowering and recovery of the bell are performed by the main winch which cable is connected to the center of the bell.

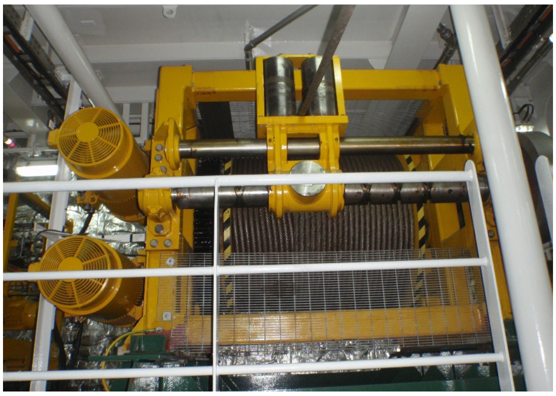
Regarding this winch and the cable used, IMCA says the following:

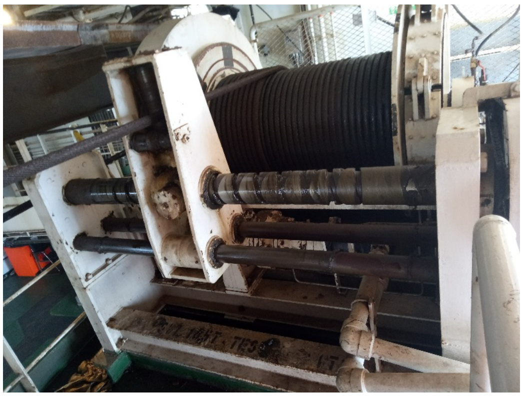
- The winch used must be certified suitable for man-riding and its raise & lower control must be designed to return to the neutral position when it is released by the operator. Also, the raise, neutral, and lower positions must be indicated so the operator knows how to operate the command. Note that regarding this point, modern systems are driven from a separate console which controls are operated electronically.
- An automatic brake which secures the winch when the operating lever is at the neutral position or if there is a loss of power must be in place. Also, a secondary automatic or manually operated braking system must be fitted and ready for use in case the main brake fails.
- Some systems are equipped with a clutch mechanism. There must be a system that prevents this mechanism from becoming disengaged during the operations.
- The winch must be fitted with two independent sources of power. The secondary source must always be available in case of failure of the primary source of power. Also, winches used to lift diving bells, including cursor winches, must be equipped with a main and a secondary motor *(so, two motors as on the photo below)*. IMCA also says that this requirement does not apply to winches used for secondary recovery.

- The winch drum must be able to accept the full length of wire being used. It means that there should be a space between the outside of the top layer of wire and the edge of the drum flange of at least 2.5 times the wire diameter as is that case of the winch below and also explained in the drawing on the side.
  Also, unless access is physically restricted, guards should be fitted to the winch and drum to stop anything (clothing, fingers, etc.) being drawn into the machinery. When the winches are installed at the proximity of other equipment, this requirement is often fulfilled using grating installed all around the winch as on the photos below. Other systems have winches installed on their top with no protection. However, their access is only possible by a ladder or a door.



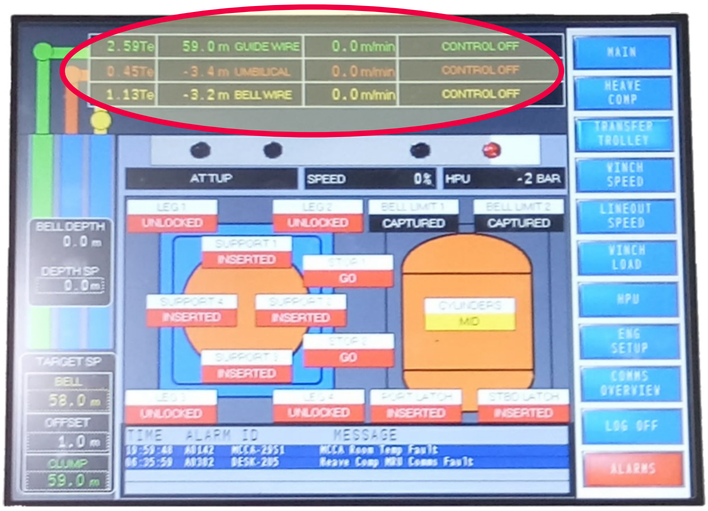
- Arrangements should exist to ensure that the wire being recovered on to any man-riding winch is correctly spooled. In the case of main bell winches this is often by means of a mechanical spooling device *(see below)*.





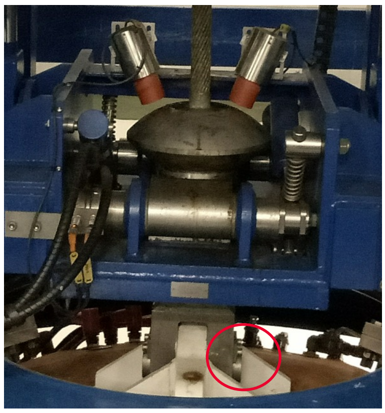
Note: The principle of work of a mechanical spooling system consists of a bidirectional reciprocating screw with two screw threads with opposite rotating directions that are crossing. A trolley equipped with rollers that direct the cable is fitted on this rod. This trolley is guided to a side of the winch by the rotation of the screw. When the side of the winch toward which the trolley is pushed is reached, the rotation of the rod pushes the trolley to the reciprocating thread, and it is moved to the opposite direction. Etc.

- A notice giving the operating instructions for the winch, including the actions necessary if power is lost, must be displayed where the winch operator can see it.
  Also, to avoid paying out umbilical in excess, there must be a device allowing the winch operator to see how much of the main bell lift wire and main bell umbilical have been paid out. It may be by line-out meters *(see on the photo below)* or by marking the bell wire and umbilical at 10 metre intervals or less.



- The winches must be visually examined and function tested at their maximum Safe Working Load (SWL) at least every 6 months. Also, an independent static load test on each brake system at 1.25 times maximum SWL should be performed at the same period.
  In addition, a static load test on each brake system at 1.5 times maximum SWL plus a dynamic test at 1.25 times maximum SWL followed by Non Destructive Evaluation (NDE) of critical areas must be performed every year.
- The lift wire(s) must be non-rotating and the connection of the wire to the bell must be of a suitable type. It should have two retaining means for the removable pin (as an example ,a nut locked with a split pin).





- Unless the wire is to be renewed every 2 years, it should be pressure lubricated every 6 months, at least from the bell back to the maximum depth of immersion in the period. If it has been laid up for a substantial period then it should have been pressure lubricated before lay up.
- There have been a number of problems in the past with high tensile bell wire ropes which appear to lose strength even when properly stored. For this reason, a test to destruction should be carried out when any high tensile bell wire rope is first put into service to establish the actual breaking force of the wire at that time. Provided the test result does not fall below the manufacturer’s Maximum Breaking Force (MBF), future destructive test results should be compared to that original figure (the base value), rather than to any claim (or test certificate provided) by the manufacturer.
  If the test to destruction when the wire is first put into service does indicate a Maximum Breaking Force (MBF) below that of the manufacturer, then the manufacturer’s MBF should always be adopted as the base value against which to monitor future deterioration in breaking force.
  However, if the result falls 10% below the MBF, then the rope should be discarded.
  The sample tested to destruction should prove an adequate safety factor exists. This usually is eight times the safe working load.
- The inspection and maintenance of the cable should be organized as follows:
  - A static test at 1.25 times SWL plus a function test at SWL as an integral part of lifting system and a visual examination of visible sections must be performed at least every six months.

  - A test to destruction to prove an adequate safety factor should be applied to a length of the rope that has been cut (usually, 2 - 3m above the connection to the bell) at least every 12 months.
  - When this test is completed (thus, every 12 months), the technician re-terminate the cable *(see the photo below)*, and a static load test at 1.5 times SWL is performed.

  - As it is necessary to be able to trace the testing history of a main lift wire, all certification, including original manufacturer's certificate, initial test certificate and any annual test certificates should be available for inspection.
- Note from IMCA SEL 022/M 194, section 13:
  There should be an annual removal of a length of wire rope from just beyond the first sheave from the bell termination with the bell below the surface, allowing for swell, to be discarded. A length sufficient to provide test samples for two tensile tests should be cut from the bell end adjacent to the termination. In certain circumstances the competent person may waive the recommendation to cut all the way back to the first sheave. In systems where there is a single vertical fall directly from the winch to the bell it will be necessary to cut right back to the winch.
  A sample should be tested to destruction to verify that the required factor of safety is maintained. Should the test prove unsatisfactory due to problems with test procedures or where the wire rope fails within a length equal to six wire rope diameters (6 d) from the base of the socket or cone, a second test may be carried out.
  This alternative test should not be used as a way of avoiding discard where a valid test is performed which indicates low strength.
  The ultimate strength test to be carried out on a sample from the part subject to the most severe dynamic loading will be used to verify that a factor of safety of 8:1 is still being maintained and if not the wire rope should be discarded. Even if the factor of safety is being maintained but the result falls 10% below the base value adopted following the test carried out when the rope was first put into service, it should be discarded.
  One of the tensile test samples should be dismantled and the internals examined.

IMCA says that there must be a secondary means of recovering the diving bell to the surface, bringing it on board and mating it to the chamber system. This means of recovery must be independent of the main recovery system. Also, IMCA says that this requirement is intended to refer to the means of lifting (wires, lifting gear, winch, etc.). It is not intended to say that a second A-frame, gantry or set of supporting steelwork should be provided.
To answer to this requirement, the secondary recovery of the bell is usually performed by the clump weigh winch which technical requirements are the same as those of the main winch. The only difference is that, as indicated previously, a second motor is not required for the secondary recovery winch. Nevertheless, some manufacturers provide their secondary means of recovery with two motors. It is the case of Parkburn which built-in launch and recovery systems (LARS) of UDS Lichtenstein and Picasso that are taken as references in this description *(see below)*.

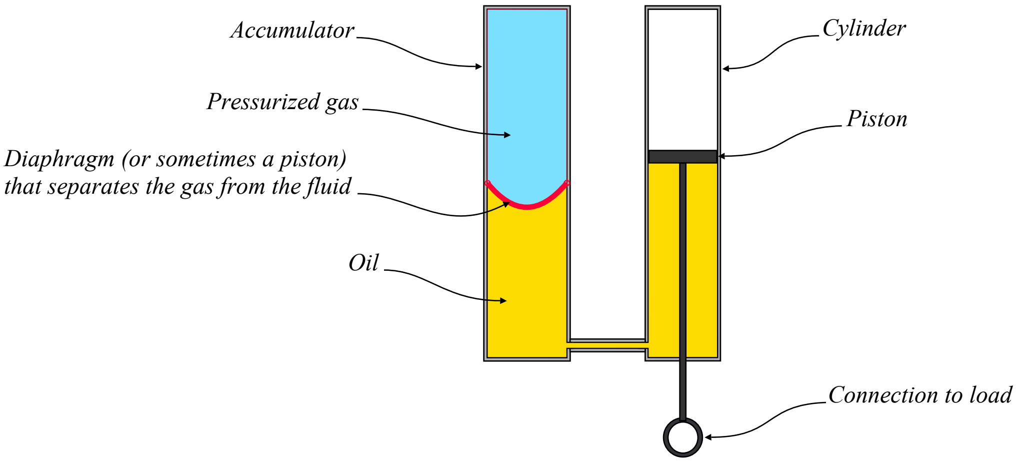
Note that IMCA takes into account the fact that the secondary means of recovery may not be the clump weight system. In this case, it is said that if the winch(es) and the guide wires of the clump weight are not designated as man-riding then they are required only to meet the normal standards for lifting equipment applying at the site.

Umbilical winches must be built with the same requirements as wire winches. Note that nothing is said regarding synchronization with the main winch. However, manufacturers provide this option in addition to the system to avoid paying out umbilical in excess or the opposite. Also, as already discussed in point 2.3.10, IMCA says that the main bell umbilical should not be designated as a secondary means of recovery for the bell unless both it and its handling system are specifically designed for that function.

1.1.10.3 - Heave compensation

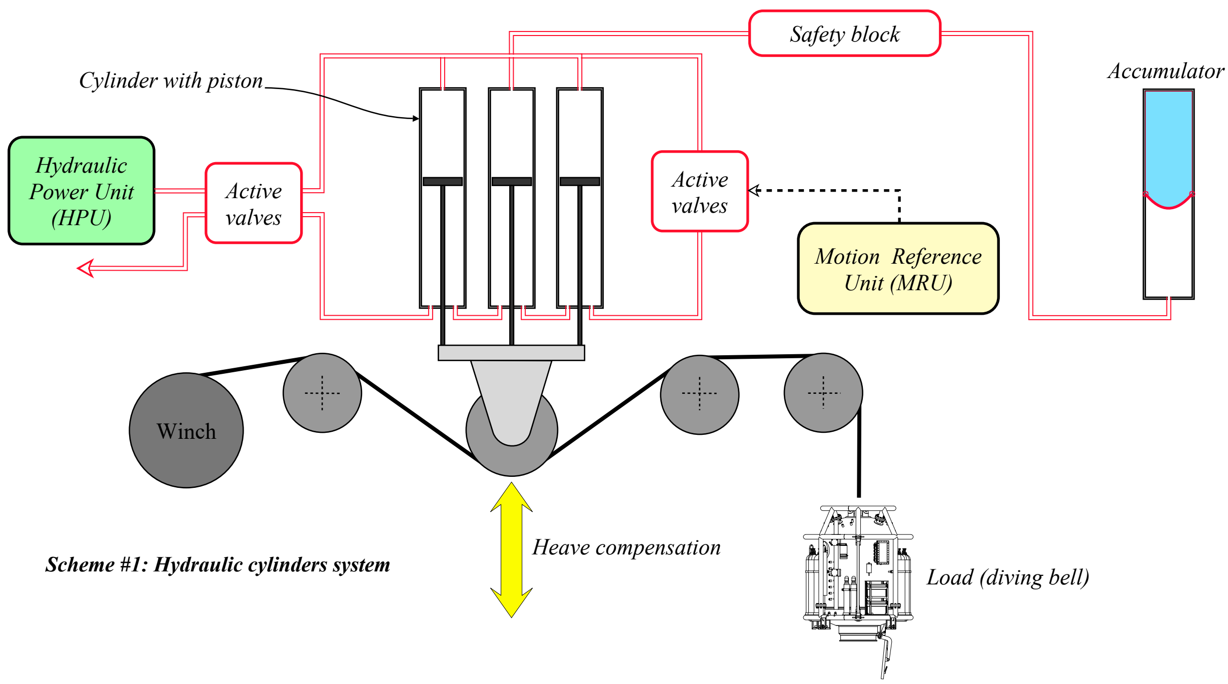
When there is an established swell, the vessel moves up and down, and the bell follows the motions of the ship. As a result, when the bottom door of the bell is opened, and depending on the amplitude of the movement, The ambient pressure changes permanently, which results that the level of the water inside the bell is unstable and that the divers inside the bell are obliged to correct the balance of their ears constantly. Also, entering and leaving the bell is dangerous due to its vertical movements that can be of several metres. To compensate this problem some diving LARS systems are fitted with heave compensators which function to keep the bell motionless, so it is always at the same depth.
Heave compensation systems are usually divided into “Passive Heave Compensation” (PHC) and “Active Heave Compensation” (AHC). However, note that a lot of mechanisms combine the two systems.

Passive Heave Compensation (PHC) systems accumulate the energy of a movement and use it to compensate for the change of position between the vessel and the load underwater. These systems work similarly to shock absorbers and often consists of hydraulic cylinders and gas accumulators that keep the circuit under pressure. Note that their efficiency is limited. Externally, they often consist of cylinders that are connected between the hook of the crane and the load.
As an example, the scheme below shows a hydraulic piston passive heave compensator. With this system, the gas, that is separated from the oil by a reinforced diaphragm, is pressurized to hold the desired load.



Active Heave Compensation (AHC) systems utilize a Motion Reference Unit (MRU), which is an inertial measurement unit with multi-axis motion sensors that actively measures all the movements of the vessel. Based on the data collected, A computer calculates the necessary counter motion of the system and controls it in real time. As a result, the length of the cable is permanently adjusted to counteract the vertical movements of the vessel, and there is no variation of the distance of the bell from the bottom; thus, its depth is kept constant.
The systems that adjust the length of the cable can be based on hydraulic cylinders, and also rotary hydraulic motors or electric motors that directly move the winch.

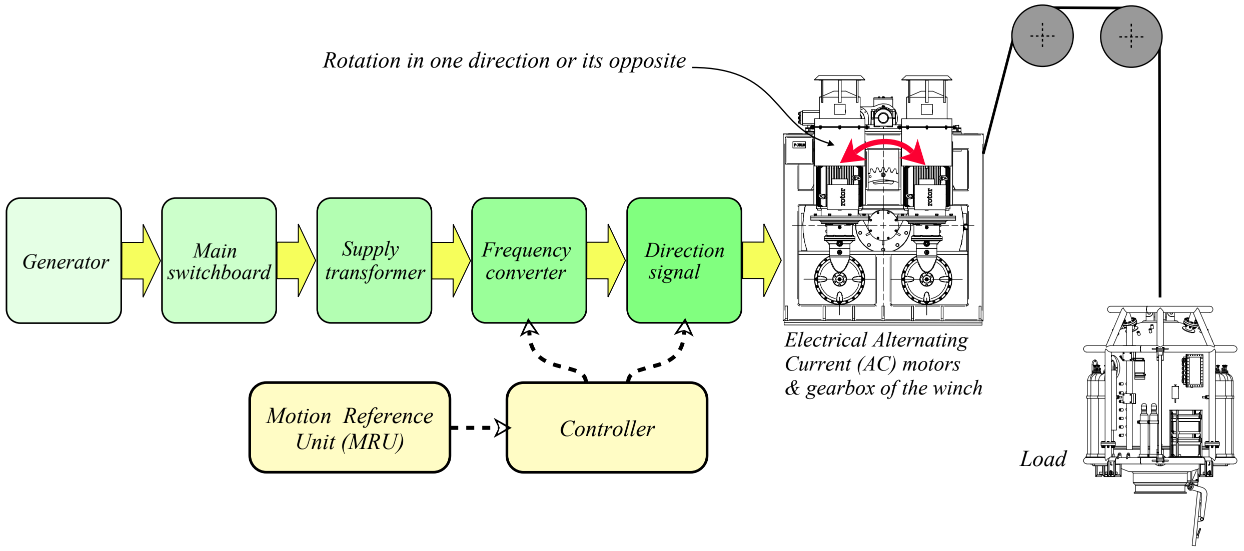
Hydraulic cylinder systems are based on pistons that extend and retract according to the direction of the fluid coming from the Hydraulic Power Unit (HPU) through a series of electronically piloted control valves that direct this fluid according to the orders from the MRU (See scheme #1 below). The cylinders are working independently from the winch, which is usually inactive. They can be installed vertically or horizontally. The function of the accumulator is to maintain a constant pressure in the system.



Scheme #1: Hydraulic cylinders system

Rotary hydraulic systems are based on the same principle as hydraulic cylinders. The difference is that the cylinders are replaced by the motor of the winch that acts in one direction or its opposite in function of the direction of the fluid sent from the HPU through the electronically piloted control valves.

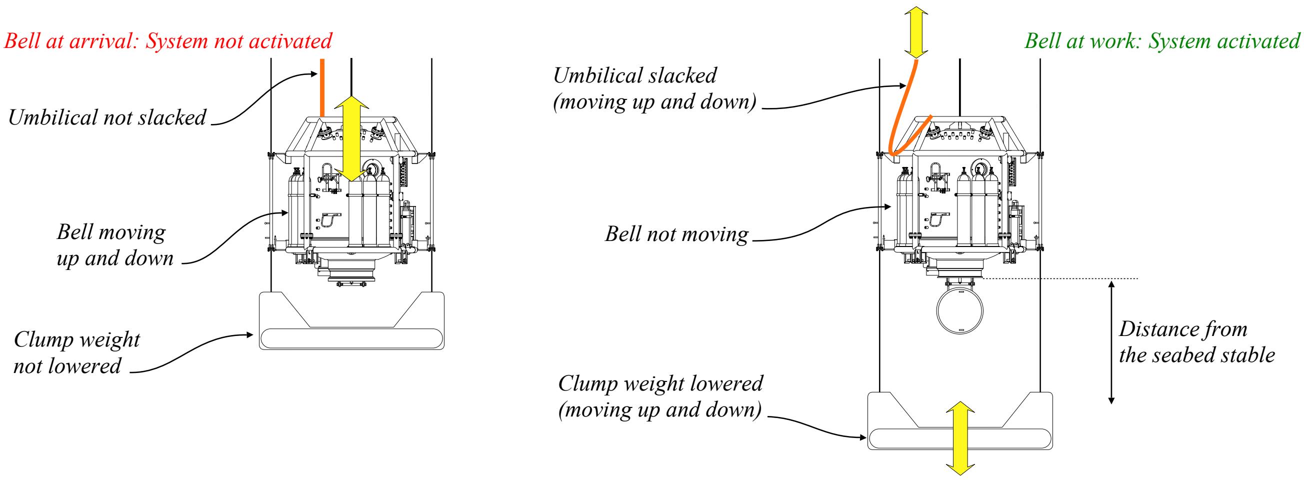
Electrically driven heave compensation systems are often selected due to their high efficiency as well as the fact that they can be easily fed by the generators of the last generation diesel-electric vessels. Also, it is said that they are more silent than other hydraulic systems. In addition, they do not need an oil reservoir and Hydraulic Power Unit (HPU), which may save some space and attract contractors who do not want to deal with oil replacement and potential leaks.
The advantage of electricity is also that it can act directly to the motor and allows the same torque at a slow speed as that at rapid speed. However, the electricity produced by the generators must be adjusted to the needs of the electric motor of the winch. The scheme below shows an example of a chain of conversion of the electrical current produced by the generator and where the motion reference unit (MRU) intervenes to allow heave compensation.



Definitions:

- *An electric switchboard is a device that directs electricity from one or more sources of supply to several smaller regions of usage. It is an assembly of one or more panels, each of which contains switches that allow electricity to be redirected.*
- *A transformer is a device used to change the voltage of an alternating current in one circuit to a different voltage in a second circuit. Transformers consist of a frame-like iron core that has a wire wound around each end. As a current enters the transformer through one of the coils, the magnetic field it produces causes the other coil to pick up the current. If there are more turns on the second coil than on the first coil, the outgoing current will have a higher voltage than the incoming current. This is called a step-up transformer. If there are fewer turns on the second coil than on the first, the outgoing current will have a lower voltage. This is called a step-down transformer.*
- *A frequency converter is a device that converts alternating current (AC) of one frequency to alternating currents of other frequencies. As the speed of an AC motor is dependent on the frequency of the AC power supply changing this frequency allows changing the motor speed. As a result, the rotational speed of the motor can be adjusted using this means instead of using a gearbox, which allows saving energy*

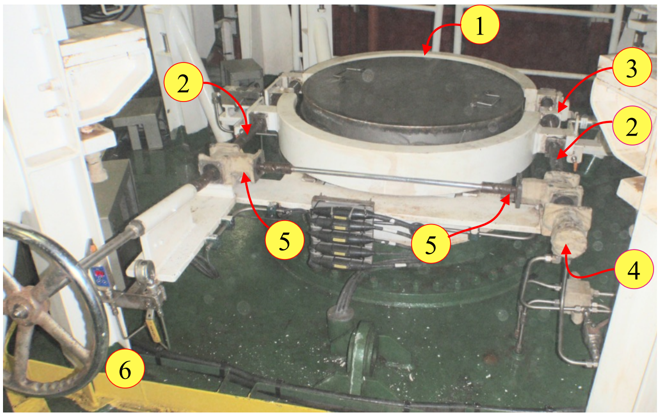
Note that heave compensation systems are designed to be activated only when the bell is at depth and should be deactivated when the bell is recovered to the surface. Also, before starting the system, the operator, must pay out sufficient length of umbilical and lower the clump weight to allow a sufficient distance for the system to work and avoid damaging these elements when they are moving up and down (remember that the bell does not move). New systems perform this operation automatically. Note that some models of clump weights that are designed to allow the divers entering into the bell cannot be used for this purpose with heave compensation systems.

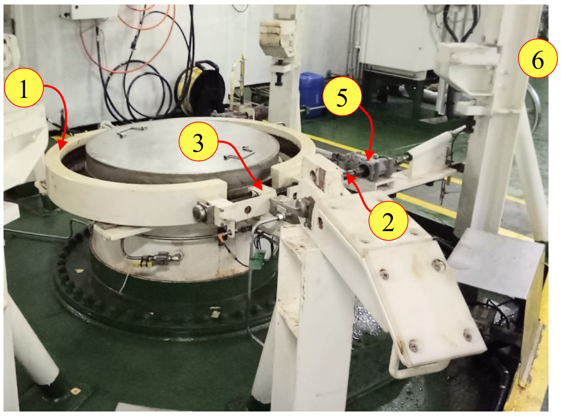


1.1.10.4 - Connection to transfer lock

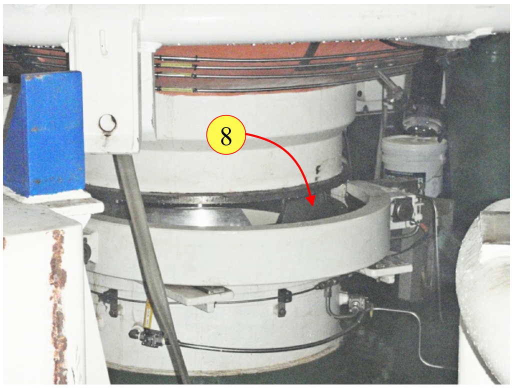
As already indicated, the transfer to or from the transfer lock can be performed through a trunk that is lateral or connected to the bottom opening of the bell.
This connection is of primary importance as if it fails during the transfer under pressure, the divers will be killed as a result of an explosive decompression. Such accident has already happened on Byford Dolphin in 1983 *(see "Explosive decompression accident" in the document "Saturation diving accident")*.
For this reason the connection and disconnection of the bell to the saturation system must be performed with a lot of precaution, and the system must be designed to never open during the transfer under pressure. IMCA D 024 says: *A safety interlock system must be fitted to the clamping mechanism securing the bell to the chamber. This interlock must make it impossible to open the clamp if there is still pressure inside the trunk and impossible to obtain a gas tight seal on the trunk if the clamp is not properly closed.*

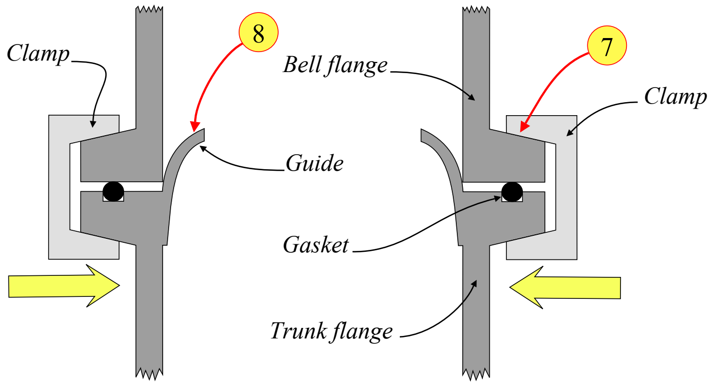
The connecting clamp consists of two half-clamps with internal profiles in bevel *(see #1 below)* that are approached around the flanges by two thread bars *(see #2 below)* secured on their middle at the central axis of the flanges *(see #3)* and designed with threads of opposite direction. As a result, the half-clamps close simultaneously when the bars are rotated in one direction and open when they are rotated in the opposite direction. Note that these bars are actuated by a motor, which can be hydraulic or pneumatic *(see #4)*, and through a series of gears *(see #5)*. Also, a wheel *(see #6)* allows to open or close the clamp manually in the case of a breakdown of the motor.



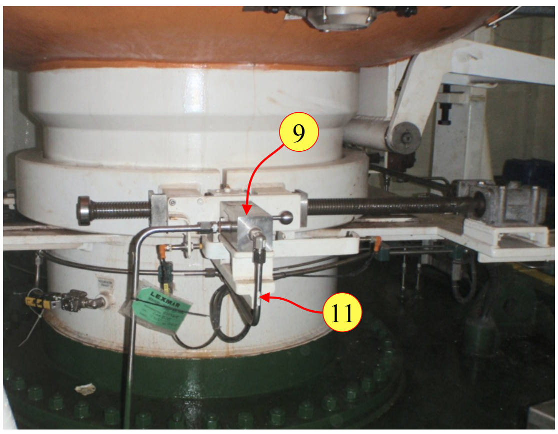


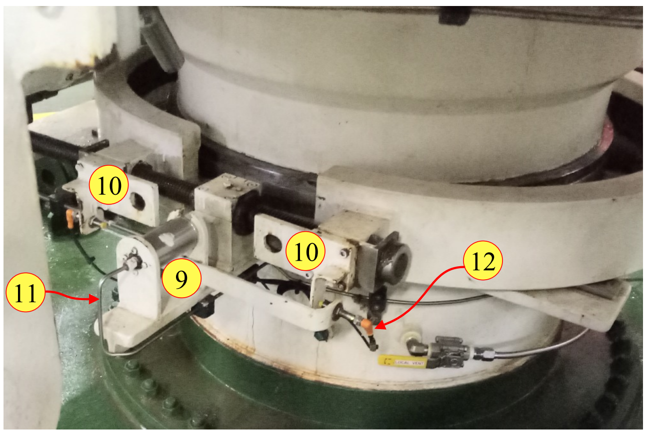
Note that in addition to the profile in bevel *(see #7 in the drawing below)* of the faces that are in contact with the clamp, the flange of the chamber may have a specific profile to guide the flange of the bell exactly to the ideal position *(see #8)*.





When the transfer trunk is under pressure, the clamp is locked by pins that are pushed out of their cylinders *(see #9)* through two overlapping holes *(see #10)* by the pressure established in the trunk. This locking mechanism is connected to the trunk through small pipes *(see #11)*. Springs in the cylinders retract the pins when the pressure in the trunk is released. Sensors are in place when additional electronic safety systems are fitted *(see #12)*. Note that other locking systems exist.



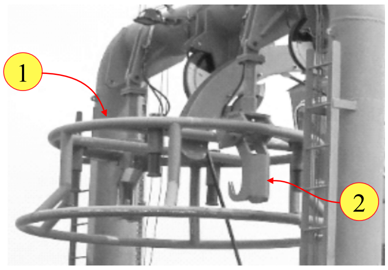


1.1.10.5 - Anti-swinging systems

Depending on the kinematics of the LARS, this part of the mechanism can be more or less complex.

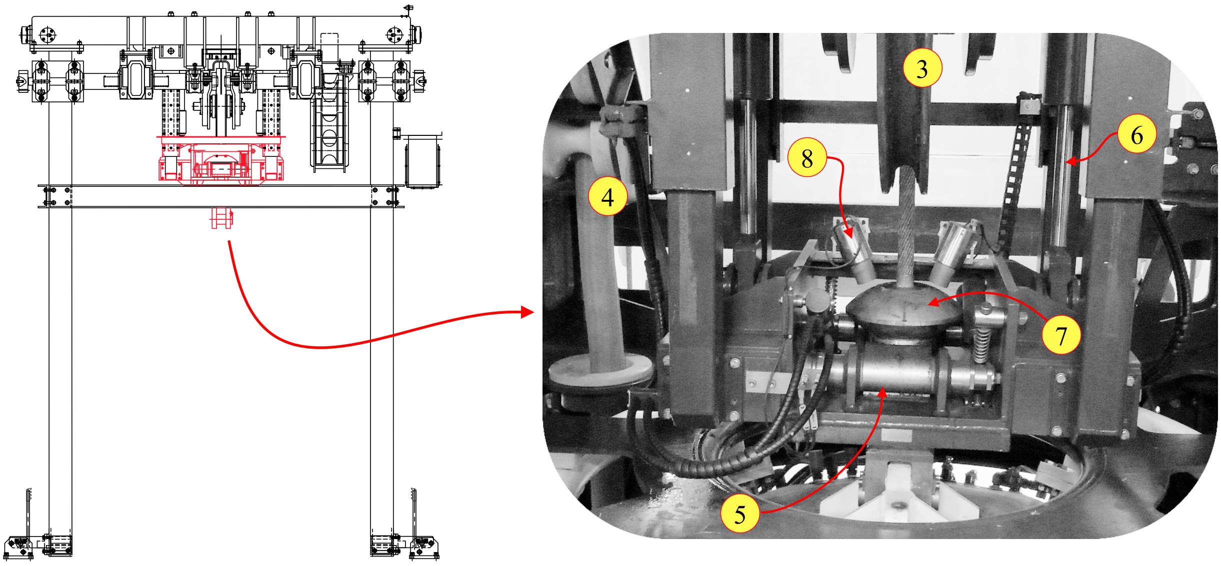
Old systems were not provided with blocking mechanisms and the bell was merely hung to the main hook. As a result, the bell was swinging in any direction and was difficult to control during the launching and the recovery phases.
To correct this problem blocking mechanisms have been fitted at the top of the launch and recovery systems.

With some systems, these mechanisms can be quite simple and may consist of a circular tubular structure which is kept at the top of the frame *(see #1 on the photo)* and is in contact with the top of the guards of the bell.
Two latching hooks *(see #2)* that are locked underneath the topside horizontal tubes of its protector frame secure the bell to the structure during the transfer, which limits its swinging movements and allows slacking the main cable if necessary during the adjustment of the bell above its final lowering point.
To lower the bell, the main cable is recovered in tension to slack the latches that are then opened. When the latches are confirmed opened, the bell is slowly lowered.

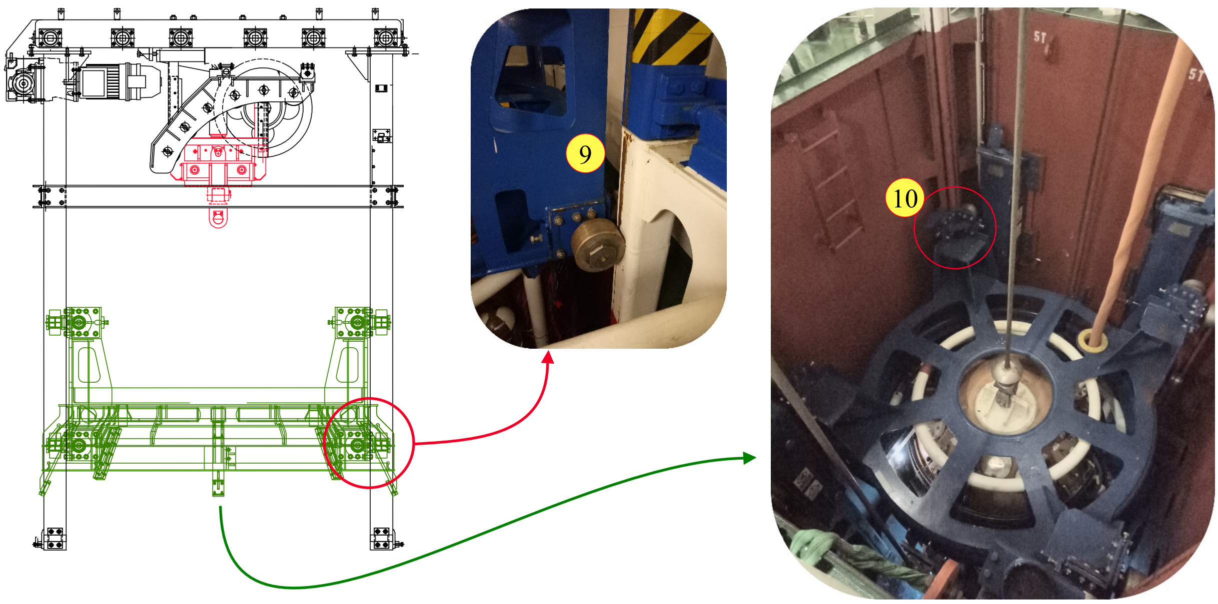


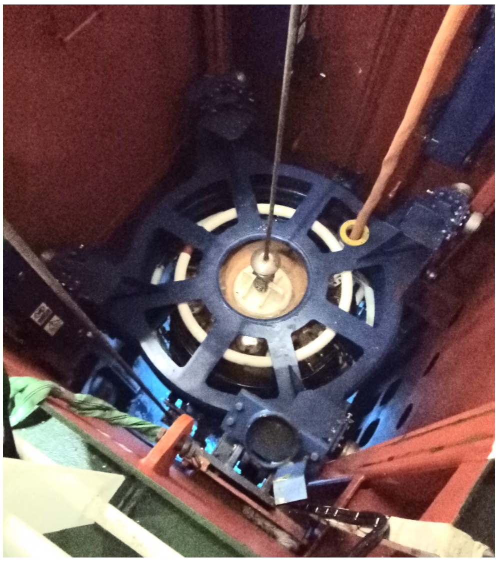
Last generation systems used with built-in trolley are generally much more complex as they are designed to limit any movement of the bell during the transfer to and through the moon pool. An example of such mechanisms are those in place on the LARS system from Parkburn already described previously.
This system is composed of 2 main parts:

- The parts that remain on the trolley: They are the pulleys of the main lifting cable (see #3 below) and the umbilical (see#4), the latching system (see #5), and two cylinders (see #6) that allow lowering and lifting the bell to and from the flange of the entry lock while the latching system secures the bell to the trolley through a blocker with a specific shape installed on the connection to the bell (see #7). Sensors (see #8) are fitted to inform the operator when the bell is fully lifted and hung by the main winch.



- The cursor, a circular piece which purpose is centralizing the the bell during its descent through the moonpool It is fitted with rollers *(see #9 & #10 below)* that perfectly maintain it in the middle of the moon pool during the descent. The cursor stops at the end of the moonpool *(see the photos on the next page)*.

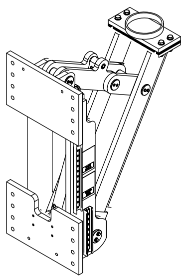




Bell and its cursor in the moonpool

Cursor at the end of the moonpool

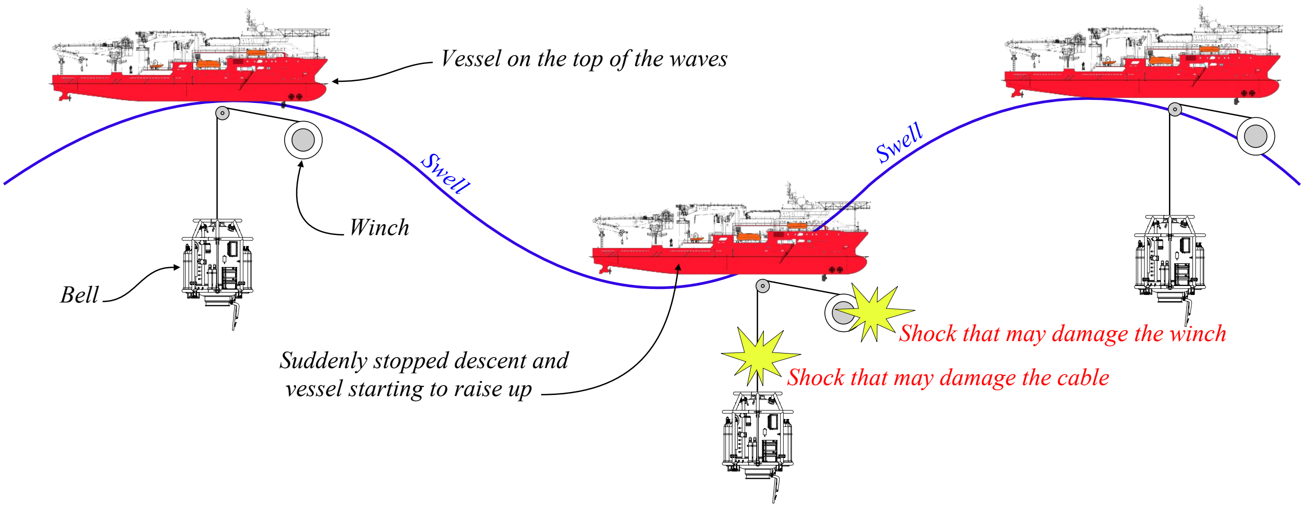
1.1.10.6 - Retaining legs in moonpool



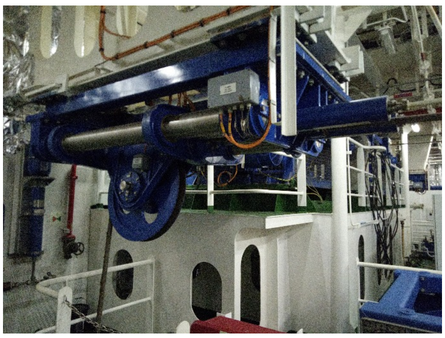
Depending on the design of the system, retractable legs may be installed in the moonpool to secure parts of the system such as clump weight and standoff frame that may be stored there to save some space and have them ready to go as fast as possible.
These legs are articulated structures that are deployed and retracted by hydraulics jacks *(see the drawing aside)* Sensors are normally provided to inform the operator of their position and prevent any lowering operation if they are not fully retracted. They are visible on the photos above where they are in the closed position because the bell is moving down or is at work. They will be deployed only when the bell will be back on deck.
Note that this mechanism is optional and not found on all systems using moonpools.

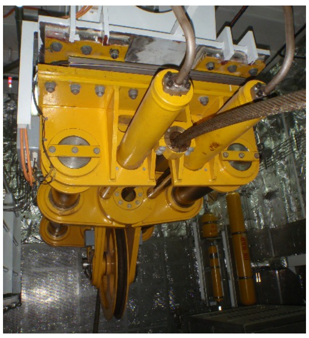
1.1.10.7 - Load limiters

Load limiters use a similar principle as passive load compensators. However, their function is to act as shock absorbers to protect winches and the deployed cables from the shocks resulting from a suddenly stopped motion. Such a situation may happen in the case of a descent suddenly stopped and more often as a result of vertical movements from the vessel heaving in the swell *(See the scheme below)*.

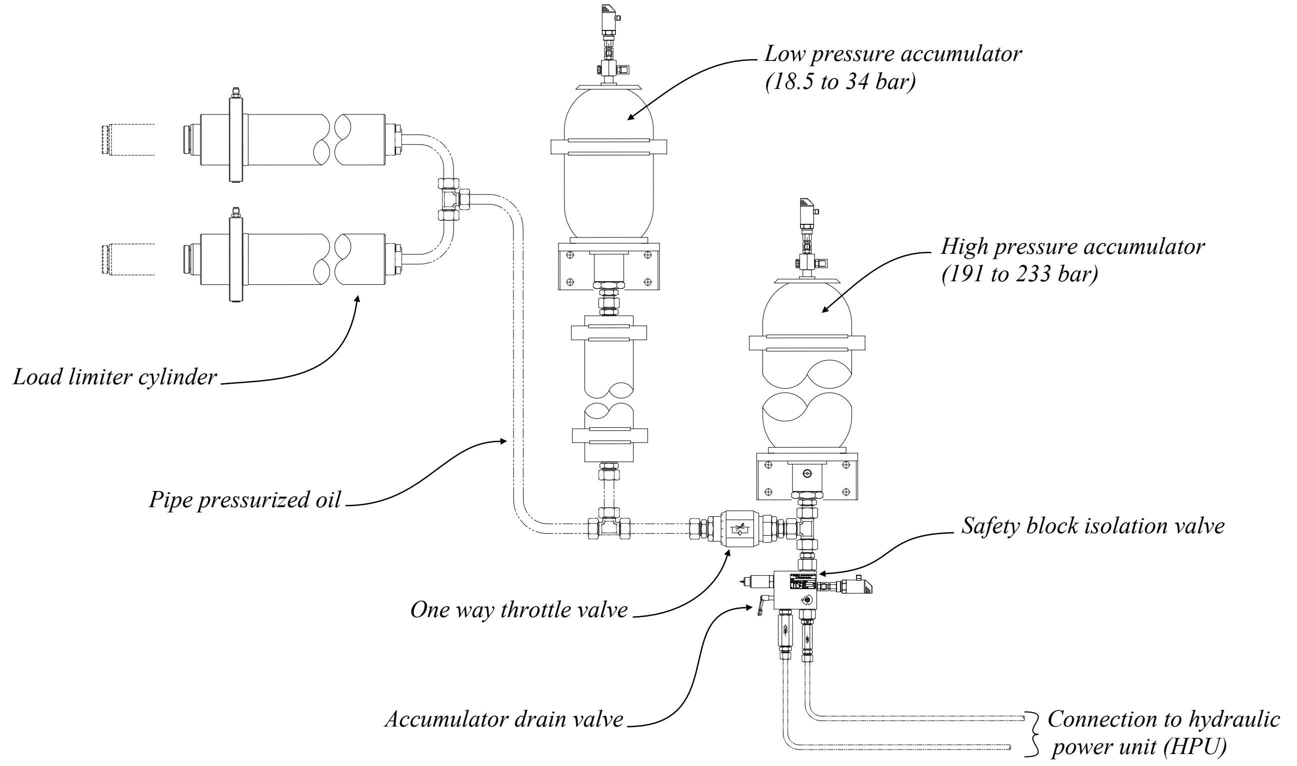


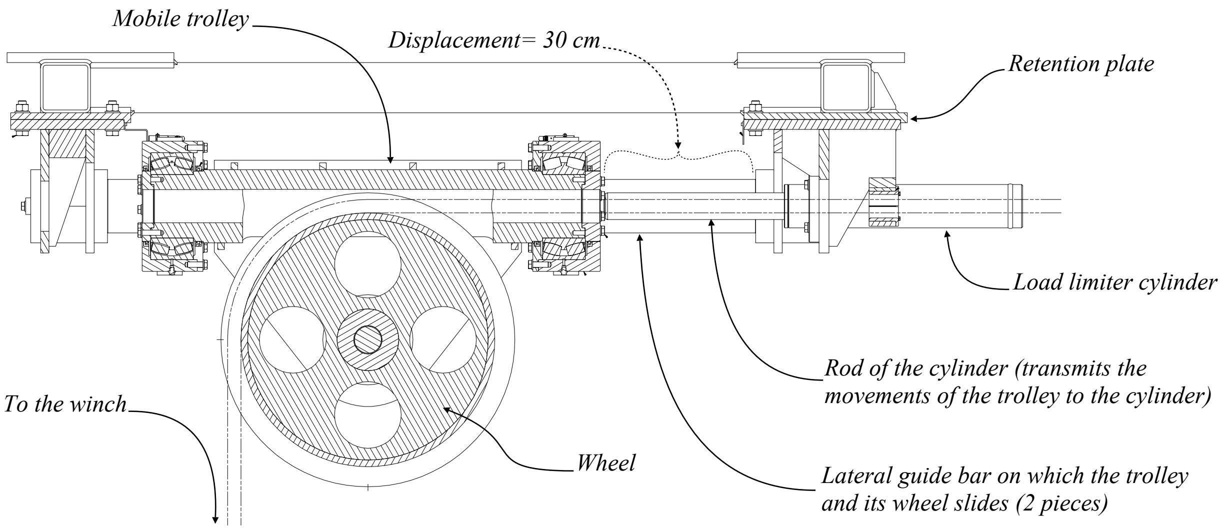
On UDS Lichtenstein and Picasso, load limiters are installed above the winches they protect and are at the same level that the top of the trolley. They are designed to work horizontally with a displacement of 30 cm.





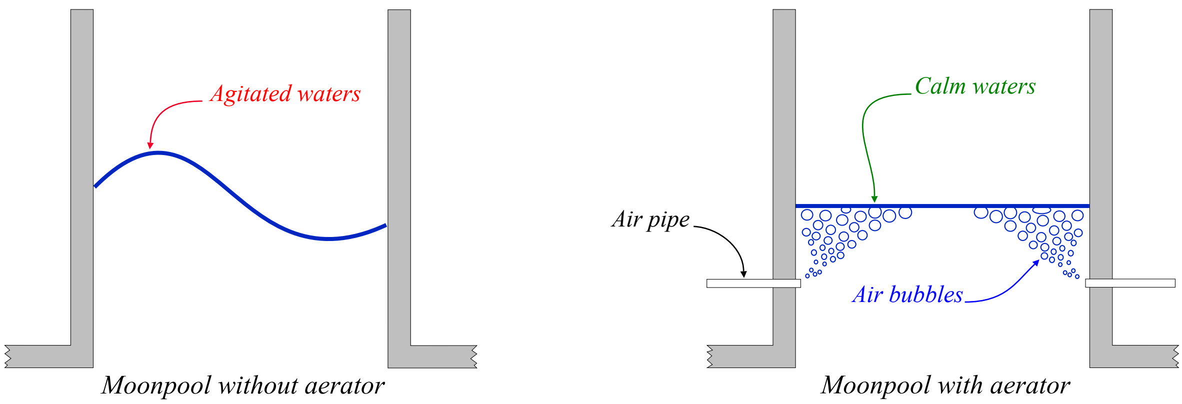
The principle of work of these devices is based on oil-filled cylinders that are maintained under pressure by hydro-pneumatic accumulators similar to those used for passive heave compensation, as previously described in point 2.3.11.3.





1.1.10.8 - Moonpool aerator system

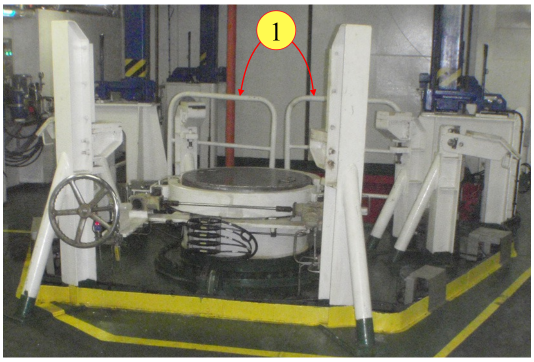
Aeration of the moonpool is a mechanism that is designed to send air into the moonpool to make the water surface inside it calm when the sea conditions become severe and that waves and vortexes form in it due to the vessel movements, which may result in difficult and dangerous launching and recovery of the bell. The principle of the system is based on the fact that when air is blown into the water, the density of the water change which makes the waves break. This mechanism consists of several pipes arranged around the moonpool that blow compressed air into it.
Note that this system is optional. Thus, it is not available on a lot of vessels.



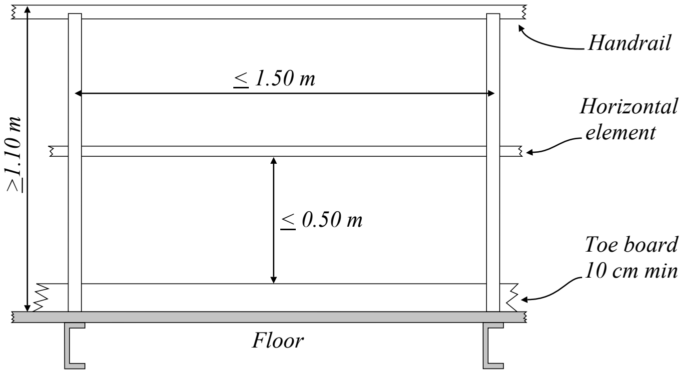
1.1.10.9 - Protections to prevent a man overboard

Barriers should be installed to prevent a man from falling into the sea during the launching operations and when the bell is at depth. These items can be permanently installed or mobile when the opening must be used to transfer the bell to the sea *(see #1 below)*. Note that side protections should at least conform with the requirement from standards similar to EN ISO 14122-3. "*Safety of machinery. Permanent means of access to machinery. Stairs, stepladders and guard-rails"* that requires the following:

- The handrail should have a diameter between 25 and 50 mm.
- The minimum height of the handrail should 1.10 m.
- The distance between the centres of two posts should be 1.50 m or less.
- The distance between each of the horizontal element should not exceed 500 mm.
- Toe boards should have a minimum height of 100 mm and their distance from the walking surface should not exceed 10 mm.



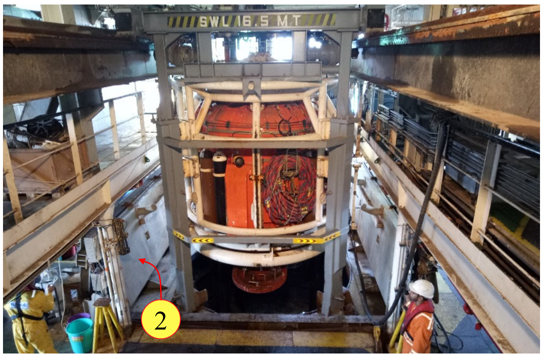
Mobile barriers of the moonpool of UDS Lichtenstein



Barriers are sufficient protections when the dive station is sufficiently high above the sea level. As an example, it is the case of UDS Lichtenstein and Picasso which moonpools openings are at more than 6.5 metres above the sea level. However, in the case of a launching deck that is at 3 metres or less above the sea level, the launching station can be flooded during rough weather conditions and people may be caught by waves when passing at the direct vicinity. For this reason, launching stations situated on the side of the vessel are usually isolated by additional barriers restricting access to them to avoid such an accident.

However, this is difficult to do in the case of a moon pool which opening is on a deck used to transit and perform some maintenance activities. Also, waves coming inside the vessel may damage some equipment. As a response to this problem, manufacturers provide doors that can be closed to isolate the moonpool. It is the case of the system onboard HOSQ Shaddad which is also designed and built by Lexmar *(JFD Group)*.

This closing system consists of four doors that are folded each side of the moon pool when the diving operation is in progress (see #2 below) and that are deployed and secured above the opening, using dedicated jacks (see #3), when the vessel is sailing and during rough weather conditions. That protects the personnel and equipment and gives the possibility to prepare future work and perform maintenance activities during unfavourable weather conditions.



Launching of the bell: Doors folded each side

Doors folded: Note the actuating jack

Doors closing (sliding on the sides of the moonpool)

Doors closed

1.1.10.10 - Control consoles

In this document, a “control console” is a panel accommodating a set of commands for mechanical or electronic equipment that is designed to control the deployment and recovery of the bell from only one location. Its design depends on the complexity of the system it is supposed to manage. As a result, it can be very basic or extremely complex as with some last generation systems such as those designed by Parkburn for UDS Lichtenstein & Picasso.

With old generation systems, the control console consists of a series of bi-directional joystick valves and switches that are grouped on a panel at the direct proximity of the winches. That allows reducing the lengths of pipes and wires and the technician can have a direct view of all elements involved in the launching and recovery of the bell, such as the winches, Hydraulic Power Unit (HPU), bell umbilical, etc.
This panel is fitted with manometers such as oil pressure and temperature and some alarms such as lack of oil in the HPU or too elevated temperature. However, with the majority of such systems, the information provided is at a very minimum, and the operator has reduced tools to diagnose the condition of the system. Also, the distance of wire and umbilical paid out are often calculated using marks on the umbilical and the cables as described by IMCA in point 2.3.11.2.
This panel is generally installed in a small cabin situated in the direct proximity of the bell and above it *(see “A” on the photo below)*, so the operator can manage it at the same time as the other parts of the system involved. Communication to the dive control should be performed through wired hand free connections and radio as a backup.
Such systems are still in use with a lot of saturation systems, which are mainly portable systems. Also, they are sometimes fitted to new fabrications. Their advantage is their robustness and easy maintenance.

The consoles described above are mostly purely mechanical and electrical. Thus, there is no intervention of the electricity to operate a mechanical device and vice versa.
Another type of consoles are those that are based on electro-mechanical systems. Electro-mechanical refers to devices which involve an electrical signal to create mechanical movement or vice versa. As an example, electromagnetic relays, which using a small voltage current allow controlling a more powerful electrical circuit by mechanically switching sets of contacts, and solenoids, by which it can actuate a moving linkage such as an electrically operated valve.
As all their commands are wired, such consoles do not need to be at the vicinity of the elements they control and can be installed in the dive control from which the operator may communicate with the diving supervisor without the need of an intercom. Also, it often installed in a directly adjacent room. Note that when the operator is not in the same room and the direct vicinity of the diving supervisor, hand-free wired communications and a backup radio should be provided.
The room in which the console is usually installed is at bell level or above it. Thus, the operator has a clear view of the bell when he is transferring it. Also, screens showing the strategic points of the LARS, such as the winches and the connecting flange, should be provided in the room.

The panel aside is composed of electrical commands such as:

- *Winch controls*
- *Trolley control*
- *Rams and bell clamp controls*
- *HPU controls*
- *Lock pin controls*

Essential information is provided:

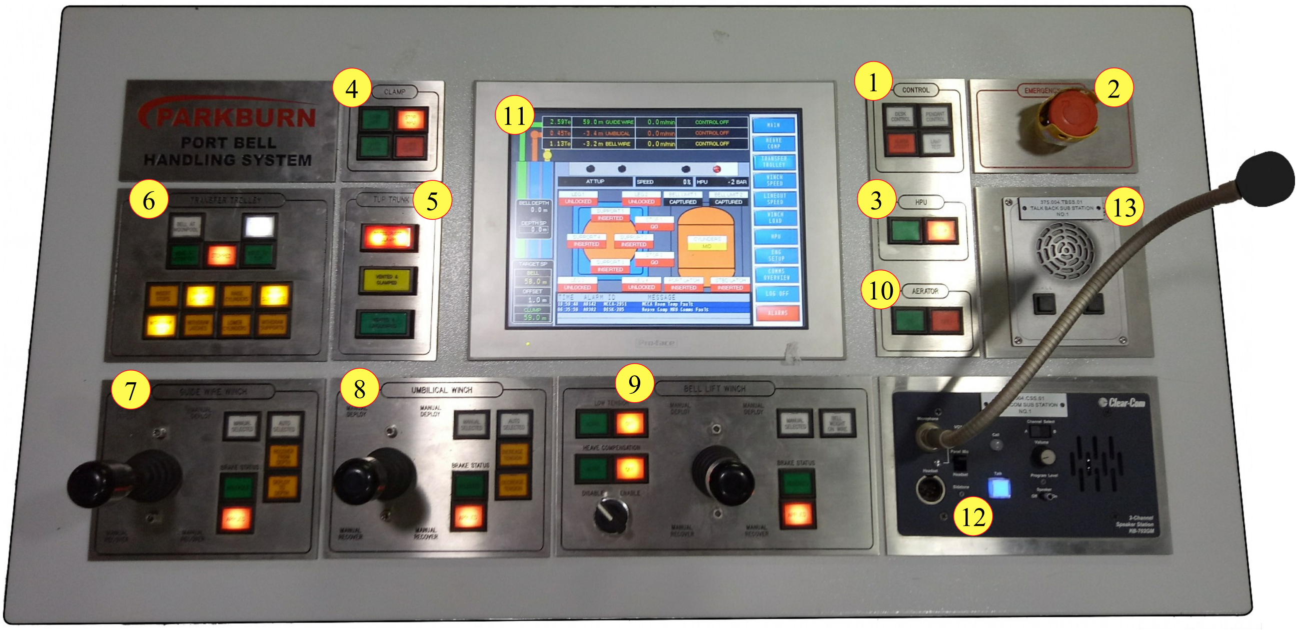
- *Cable and umbilical distance paid out*
- *Bell winch load*
- *Ram pressure*
- *System pressures*
- *Temperatures*
- *Whether the trunk is pressurized*
- *Warnings HPU #1 & #2*

The last generation consoles are still based on electro-mechanical devices. However, they are fitted with a computer terminal where the operator inputs orders which are controlled by the software system prior to be implemented. Also, the computer provides status messages from the essential parts of the system. The communication with the computer is performed through a Human Machine Interface (HMI), which is a touch screen. More traditional electromechanical commands are installed throughout the command panel.
We can imagine that with the progress of the electronics industry, such types of consoles are going to replace those of the previous generations. For this reason, a study of how the software intervenes in the management of the deployment and the recovery of the bell is interesting. The console used for this study is designed by Parkburn and installed on UDS Lichtenstein. Note that other models may be different, but they use similar principles.

- Step 1 - Powering and general description

Powering the Diving Bell Handling Equipment is made through the Motor Control Centres that also feed the Bell Master console. Note that these elements are separated from the console
The Bell master console is started by pressing the pushbutton “desk control” that is situated in the section “Control” of the console, which is at the top of the right-hand side aside from the emergency stop pushbutton *(See #1 on the picture below)*. Note that this master console is composed of several sections that allow controlling automatically or manually all the elements that compose the Launch and Recovery System (LARS). These sections are identified as follows:

- Control *(see #1)*
- Emergency stop *(see #2)*
- Hydraulic Power Unit (HPU) *(see #3)*
- Clamp *(see #4)*
- Transfer Under Pressure (TUP) trunk *(see #5)*
- Transfer trolley *(see #6)*
- Controls guide wire winch *(see #7)*
- Controls umbilical winch *(see #8)*
- Controls Bell lift winch (with the Active Heave Compensation command) *(see #9)*
- Aerator *(see #10)*
- Human Machine Interface (HMI) *(see #11)*
- Main intercom *(see #12)*
- Second intercom *(see #13)*

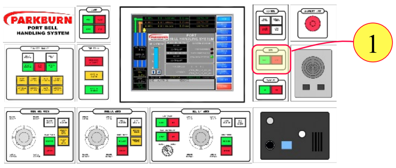


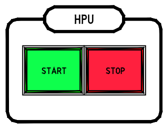
The Master console is designed to centralize all information regarding the status of the Launch and Recovery System. The Human Machine Interface (HMI) *(see #11 above)* provides the following details:

- Whether the system is active
- Status of the heave compensation system
- Condition of the Local Area Network (LAN). Note that a LAN is a computer network that interconnects computers within a closed area such as a boat, a series of offices, or the elements of a dive system.
- Condition of the Electrical supply of the Motor Control Center (MCC) which is an assembly of electric and electronic elements that controls some or all the electrical motors of a system from a central location.
- Condition of the Active Front End (AFE) distribution. An AFE is a rectifier that allows bi-directional power exchange between AC and DC sides. It is also used to minimize the amount of harmonic distortion of the electrical supply.
- Winch status
    - Whether the control is activated and the mode selected (manual or auto.)

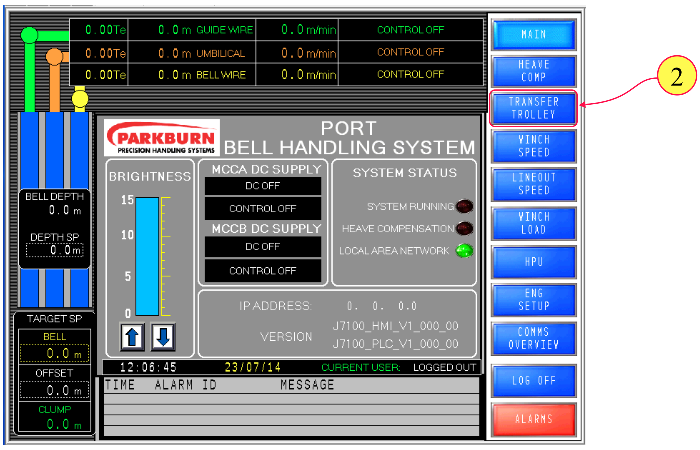
  - Tension mode applied (low or normal)
  - Paying out or picking up wire
  - Details of the emergency stop warnings that are halting the winch
  - Winch's encoder or/and load cells bypassed or not
- Tension applied to the cable of the winch
- Distance of cable out (Line out)
- Speed of cable delivery or recovery
- Position of the bell during the operations
  - At home
  - On the deck
  - In the moonpool
  - In the splash zone
  - At the direct proximity of the cursor
  - Near the ship (within 5 m below the ship)
  - Clear of ship
  - Near the final depth selected
  - At depth

When the master control starts, the computer analyses the status of all the elements that compose the system, and in the case of a problem a message of alert is displayed on the HMI screen.
To continue to activate the LARS system, the operator must start the Hydraulic Power Unit (HPU). This pushbutton is situated in section "HPU," which is just below the section "Control" *(see #1 below)*.



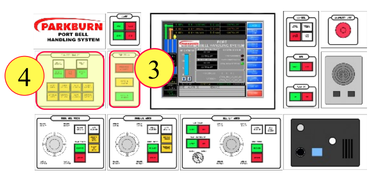


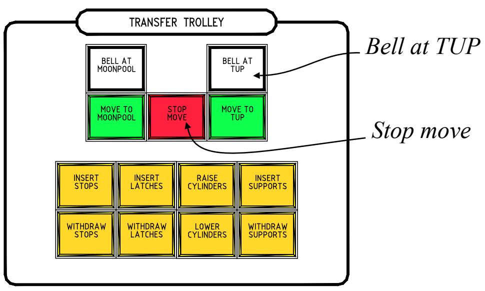
Usually, a message should be displayed on the HMI that reminds the operator that the sea fastenings that secure the LARS must be removed. This removal should have been done manually as with the previous generation LARS.
The status of the HPU can be then displayed on the screen by pressing the menu "HPU" on the right-hand side of the screen. Then the operator can change the display to monitor the transfer trolley. It can be performed by pressing the dedicated touch that is displayed on the right-hand side of the screen *(See #2 below)*.

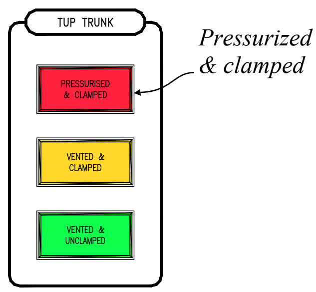


- Step 2 - Transfer Under Pressure (TUP)

When the bell is clamped to the saturation system, and the Transfer Under Pressure (TUP) trunk is pressurized, the light "Pressured & clamped" at the TUP Trunk Control section *(see #3)*, which is at the top of the left-hand side of the panel is illuminated. Also, the light "Bell at TUP" and the pushbutton "Stop move" in the section "Transfer Trolley" beside the section TUP Trunk are illuminated *(see #4)*.
As a result, the bell cannot be disconnected from the system as long as the trunk is pressurized because the sensors prevent any action as long this part of the system is under pressure. Thus the TUP can be performed safely.
Note that this section is provided with two other pushbuttons that are illuminated in green: "Move to up" and "Move to moonpool." A white light is also provided to indicate when the trolley arrives at the moonpool.

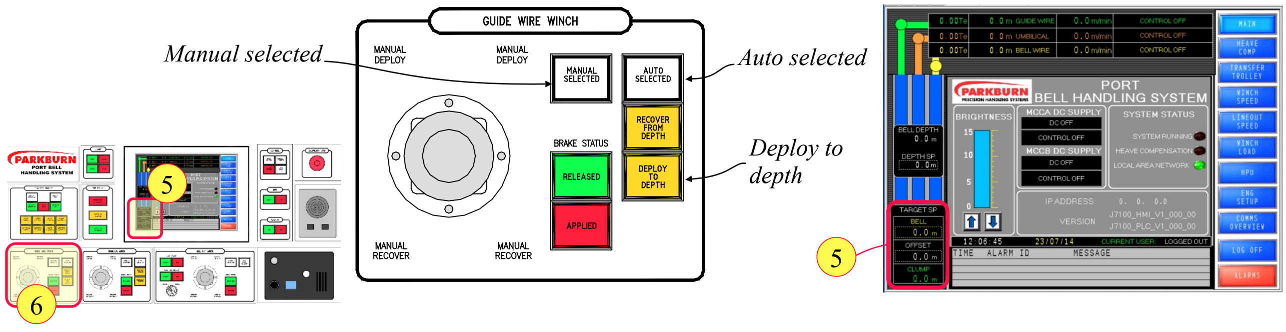


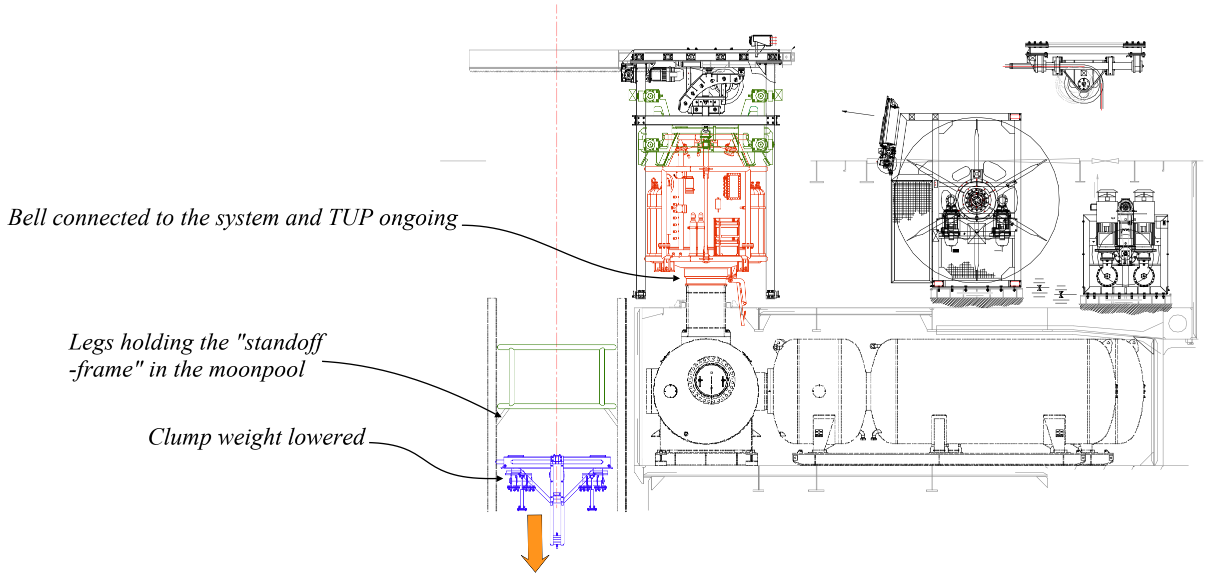




- Step 3 - Clump weight deployment

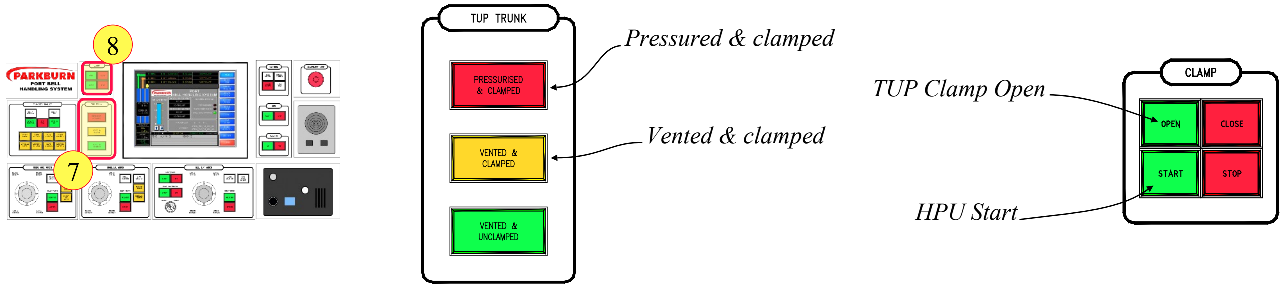
The clump weight must be deployed at depth prior to the remaining operations. If it is not, the software does not allow for continuing the operations.
Before implementing the clump weight and the bell, the operator must set up the required bell depth using the menu “target SP” of the HMI display *(see #5)*.
The clump weight can be deployed automatically or manually:
Using the pushbuttons “Auto selected” & “Deploy to depth” in the section “Guide Wire Winch” *(see #6)* which is on the bottom of the right-hand side of the panel. As a result, the clump weight deploys to the required depth according to the depth previously selected for the bell.
If the operator prefers a manual deployment, the button “Manual selected” should be pressed. In this case, the control of the clump weight is performed using the joystick. However, the winch will automatically stop when the depth previously selected will be reached



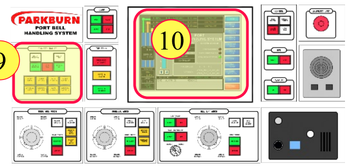


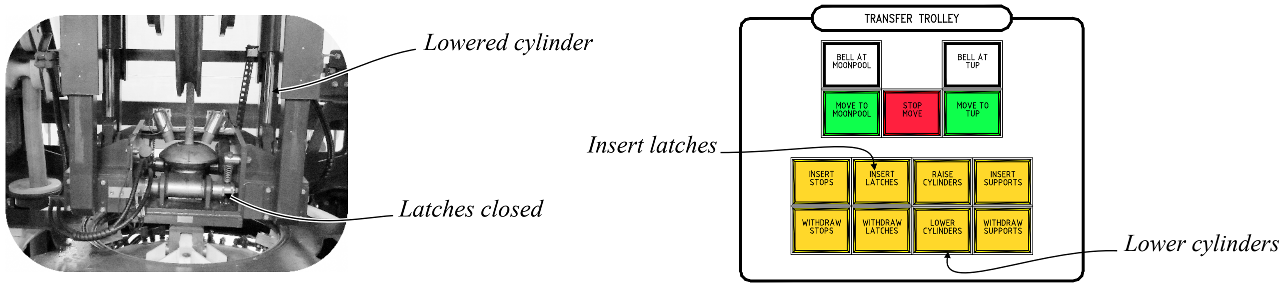
- Step 4 - Disconnection of the bell

As indicated previously, the system prevents the bell from being removed from the trunk as long as the transfer under pressure is ongoing.
When the trunk has been vented, the amber light “vented & Clamped” in the section “TUP trunk” *(see #7)* is illuminated and the red light “Pressured & clamped” is shut down. That indicates that the bell and the transfer lock are secured and that the system allows disconnecting the bell.
That can be done pressing the button “HPU Start” & “TUP Clamp Open” in the section “Clamp” that is situated at the very top of the right-hand side of the console, near the logo Parkburn (see #8).
The TUP clamp opens and the green light “vented & unclamped” opens while the amber light “vented & clamped” shutdown (these lights are in the section “TUP trunk”).

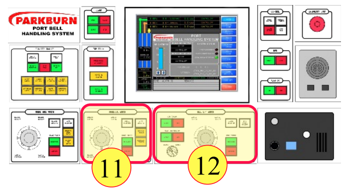


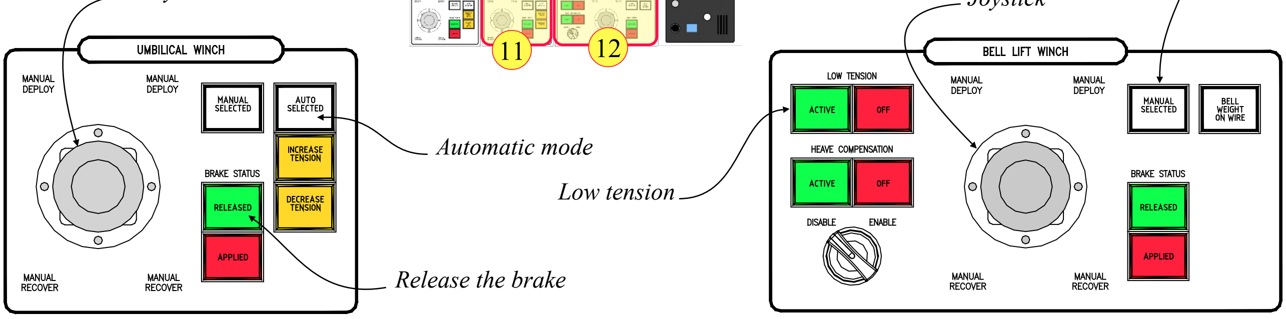
When the TUP clamp is opened, a warning light is illuminated on the HMI screen.
Then, the mating cylinders are lowered to pick up the bell using the pushbutton “lower cylinders” in the section “transfer trolley” *(see # 9)* that is highlighting. Also, a warning is displayed in the trolley status on the HMI *(see #10)*.
The Latches are then inserted using the button “Insert latches”. A confirmation message appears on the HMI screen.



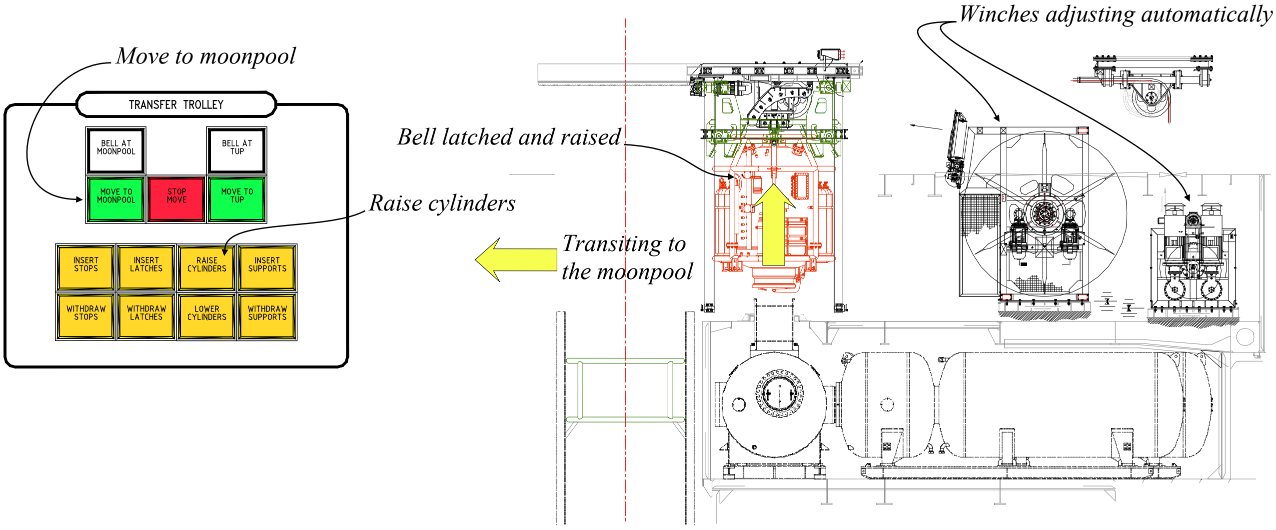


Before raising the bell, the winches of the main cable *(see #11)* and the umbilical *(see #12)* must be implemented. Their commands are fitted with joysticks and are in the sections near the "Guide wire winch". Automatic or manual modes can be selected.
If the mode "automatic" is selected for the umbilical winch, it automatically stabilizes at the preset tension. Note that to allow the winch to establish the pre-set tension, the operator should release the brake by pressing the corresponding green button.
The umbilical winch can also be run in manual mode for maintenance purposes and recovery in the event of an instrumentation fault. In this case, the joystick is used to control it.
To implement the main wire winch, the operator activates the option "Low tension." That allows the movement of the Transfer Trolley. The Bell Winch drives run and hold zero speed at the low tension torque limit.
When this phase is completed, the bell can be raised.

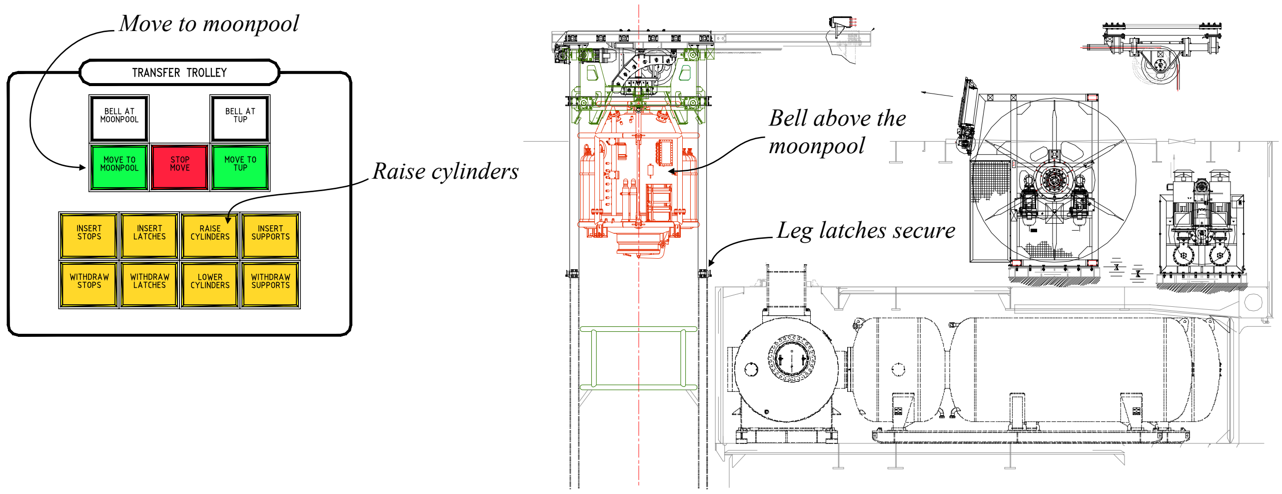




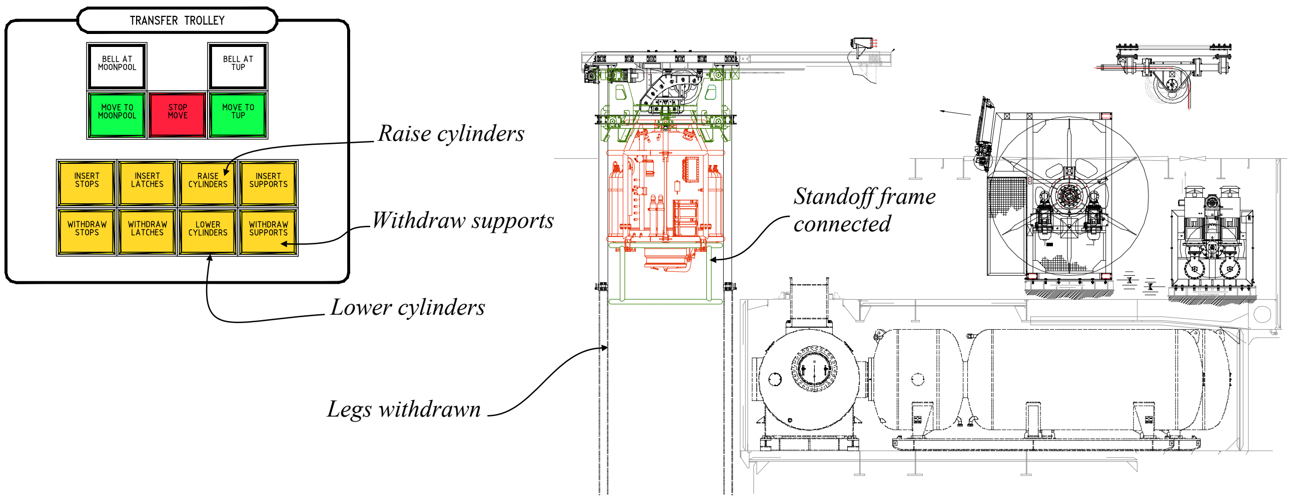
To lift the bell off the connecting flange. The operator must hold the pushbutton "raise cylinders" in the section " transfer trolley." Usually, the main cable winch automatically recovers the excess of slack. The push button is illuminated by a yellow light when the cylinders are fully retracted. Also, that can be visually checked through the window that allow to see the bell and the flanges, and using the corresponding menu on the HMI screen.
When the cylinders are fully retracted, the trolley can automatically move to its final position above the moonpool. To implement this, the operator presses the button "Move to moonpool" in the section "Transfer trolley" and confirms the new status on the HMI screen. Both winches are paying out adequately when the trolley is moving. The button "Move to moonpool" is flashing during the transfer to indicate the operation is ongoing.



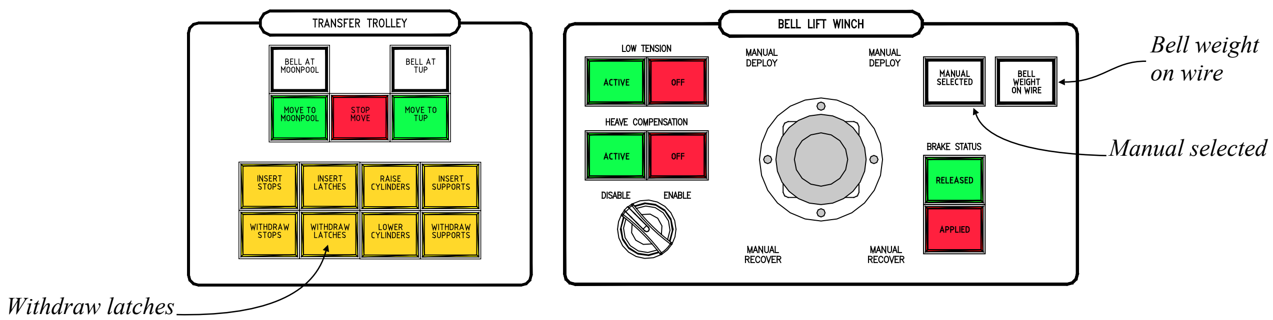
When the trolley reaches the final position, the flashing ceases and the adjacent light "bell at moonpool" flashes.
At this moment the operator locks the trolley in its final position by pressing the buttons "insert lock" and then "move to up" that are in the same section.
During this time, the supporting team manually closes the leg latches of the trolley to ensure that it cannot move back.



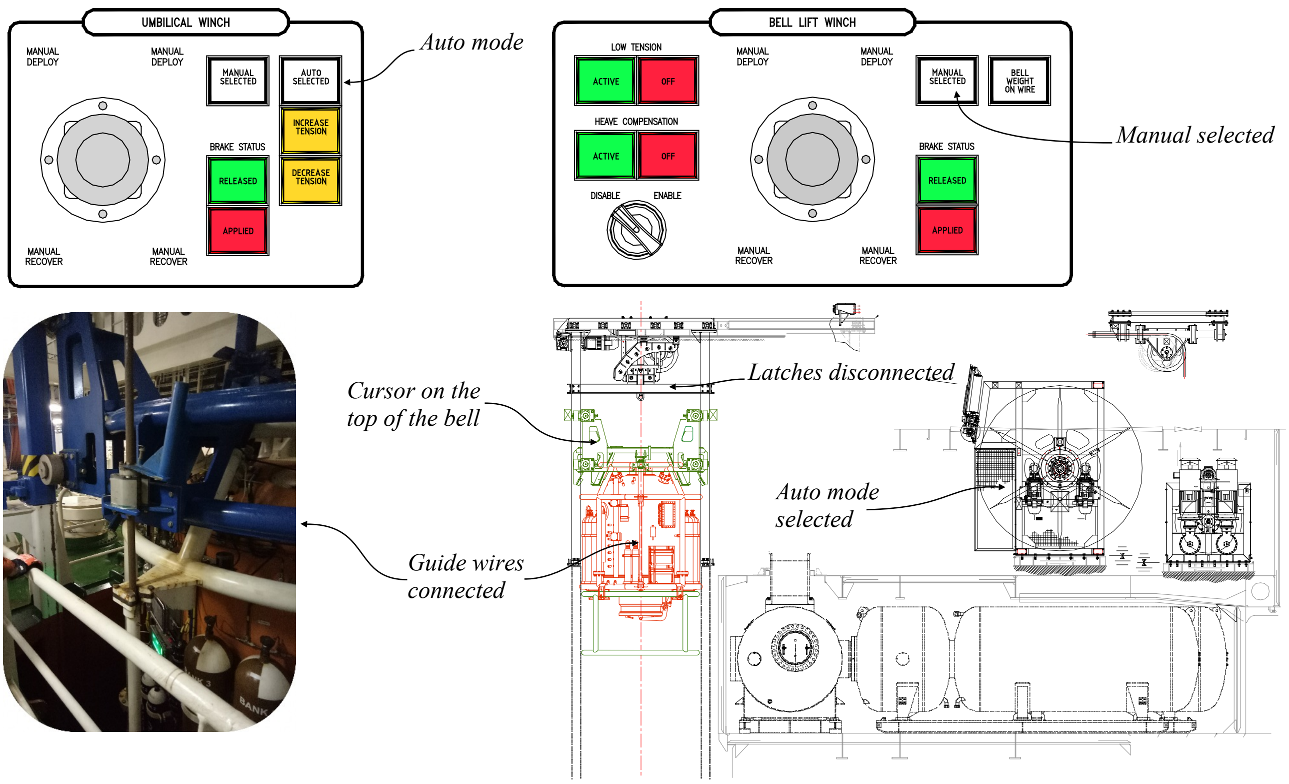
- Step 5 - Preparation above the moonpool and launching
The standoff frame and the cables of the clump weight must be connected before sending the bell to the work site. To do it, the operator pushes and holds the button "Lower cylinders" In the section "Transfer trolley".
When the bell is in contact with the standoff frame, the supporting team inserts the locking pins manually. When the pins are secured, the operator pushes and holds the button "Raise cylinders" (in the same section) to lift the bell and its standoff frame off their support.
During these operations, the slack of the main wire and the umbilical are automatically adjusted.
When the bottom of the standoff frame is off the supports that are deployed in the moon pool to hold the standoff frame can be retracted. That is done by pressing the button "withdraw supports" in the section "Transfer trolley". The button "Lower cylinders" is pressed again to lower the bell to its launch position.



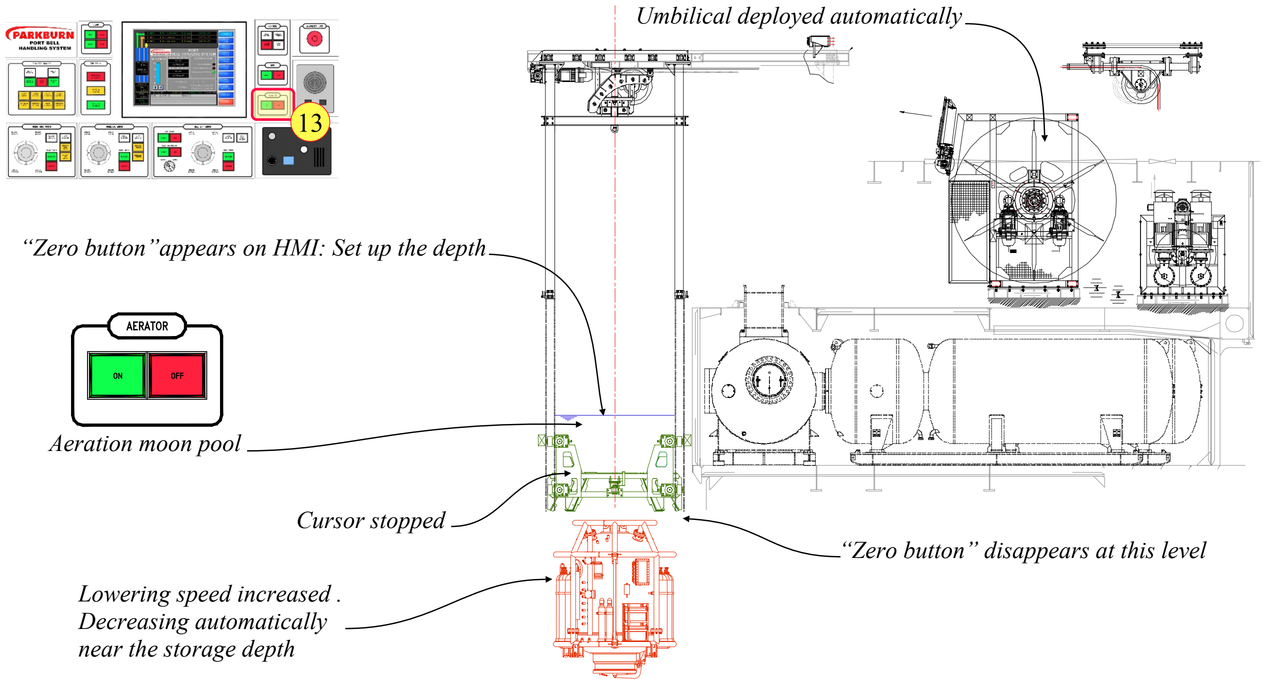
To launch the bell, the operator needs to withdraw the latches. To do it, he presses the button "Manual selected" in the section "Bell lift winch" and then the button beside named "Bell weight on wire".
As a result, the wire winch take up the tension and holds the bell (note that the pushbutton flashes when the operation is in progress).
The joystick is then used to raise the bell until the limit sensors detect it. Note that the bell status is automatically displayed on the HMI screen.
Then, the operator presses the button "Withdraw latches" in the section "Transfer trolley." When the latches are cleared, the new status is confirmed on the HMI screen.



Before lowering the bell, to operator ensures that the umbilical deployment is on “Auto mode.” Then the bell is lowered to the level from where the cables of the clump weight can be connected. At this moment, the wires of the clump weight are manually connected and secured to each side of the bell by the supporting team.
When the cables are confirmed secured, the bell can be lowered manually through the moon pool. It can be achieved by pressing the relevant “manual selected” pushbutton and using the Joystick.



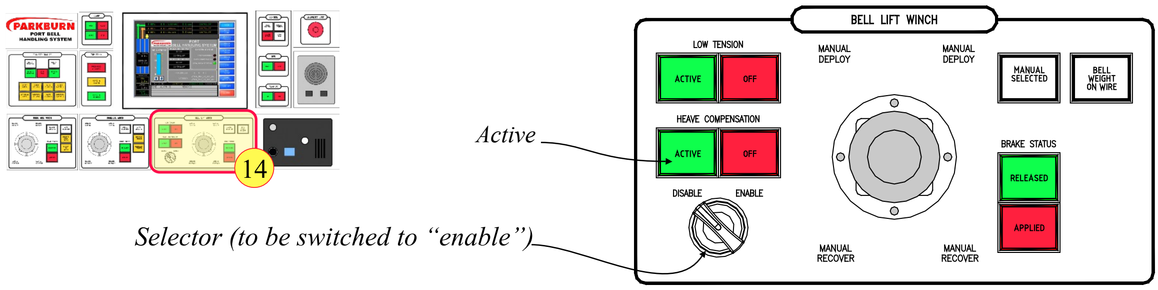
When the bell is in the moonpool, the “zero button” appears on the HMI screen and the operator presses it to set up the depth of the bell when it reaches the surface of the sea. This button then disappears when the bottom of the boat is passed.
If the weather conditions create too many waves and vortex into the moonpool, the aeration can be switched on to create a massive bubbling that will break the waves. This function is available on the right-hand side of the panel, under “Control” and “HPU” *(see # 13)*



Note that the cursor is stopped at the end of the moonpool. Also, if it has been activated, the aeration is stopped when the bell is entirely outside the moonpool.
The lowering speed that was previously slow is then increased. It will decrease again at the proximity of the planned storage depth. Note that the umbilical is deployed automatically with the ideal tension. The speed of the bell, tension of the cable and the depth can be monitored at any time on the HMI screen.
When the bell is at depth, the winch of the deployment cable is shut down by pressing the button “Manual selected.”

- Step 6 - Heave compensation

When the bell is at the storage depth, heave compensation can be activated if necessary. To do it, a selector that is available into the section "Bell lift winch" *(see #14)* must be switched to "enable" and the green button situated above and labeled "Heave compensation active" must be pushed to raise the bell 3m above the initial depth.
Note that the umbilical winch is not activated. As a result that has for effect to create a 3 m loop in the umbilical and add a distance of 3 m between the bell and the clump weight, allowing the movements of the boat without affecting the bell and its umbilical.
When the correct depth has been reached the message "Line out ok for heave compensation" is displayed on the HMI screen. The alternative method proposed by the manufacturer is to lower manually the clump weigh 4 m deeper and pay out manually the corresponding extra umbilical.
On the HMI screen, the menu "Heave comp" provides information regarding the displacements of the bell.
Note that heave compensation cannot be activated at depths shallower than 50 metres. Of course, this function must be deactivated prior to recovering the bell.

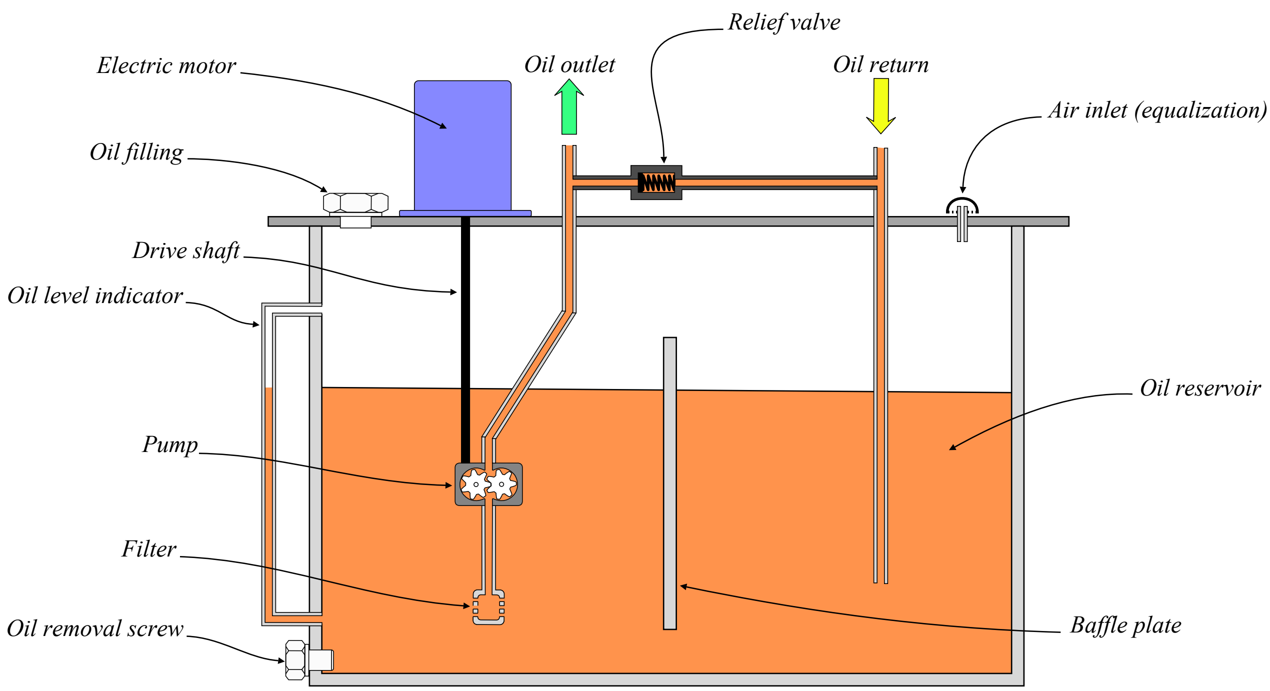


To recover the bell, the inverse process has to be performed.

To conclude on control consoles
The study of the launching process of the bell using a digital console that is described above shows that the operator is obliged to follow the established procedure to launch the bell. As a result, mistakes such as disconnection of the TUP trunk when it is under pressure or a forgotten phase are not possible as the system blocks any further operation as long as the correct procedure is not followed. Thus, we can say that computerized control systems provide additional safety precautions which result that the divers are better protected during the transfers under pressure and the descent and recovery of the bell.
However, the models of consoles from the previous generations are robust and easy to maintain. For these reasons, we can expect to cross them within the next twenty years.
Note that, despite efficient supports from the manufacturers, the major problem of the last generation control consoles is to find technicians who are competent in electronic and computer systems, in addition to the traditional mechanical skills.

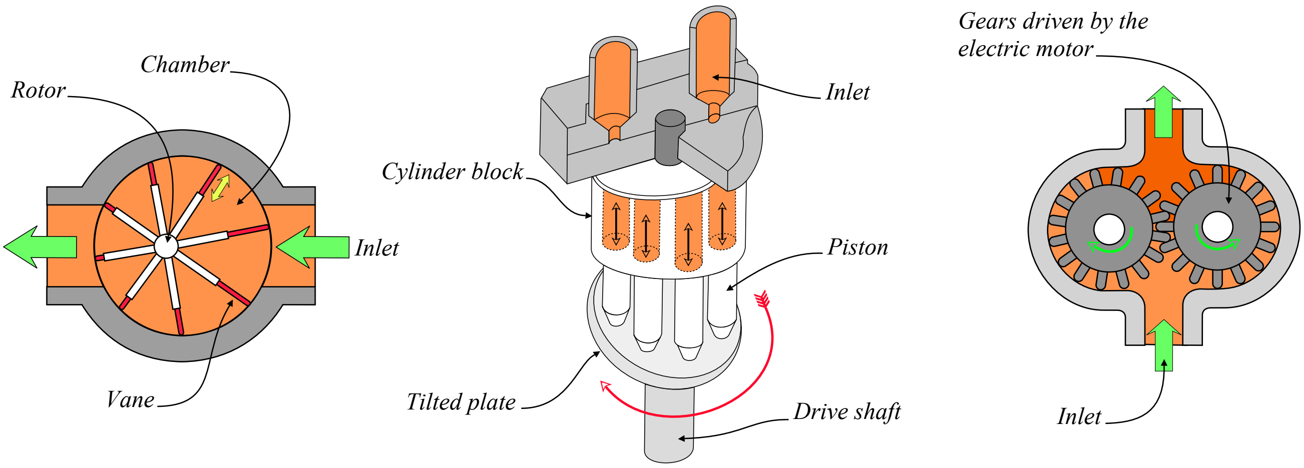
1.1.10.11 - Hydraulic Power Unit (HPU)

Hydraulic jacks and motors cannot be operated if there is no pressure in the circuit that feed tem with oil. It is the function of the Hydraulic Power Unit, also called Hydraulic Power Pack.
The Hydraulic Power Unit is composed of a hydraulic pump that is driven by an electric motor, an oil reservoir, pipework with pressure relief valves and a filter.



The pumps usually used are positive displacement pumps that are sufficiently powerful to power the tools they supply. Three types of pumps are commonly found:

- Gear pumps produce a flow of oil by using the teeth of two meshing gears to move the fluid. They are reputed robust and can transmit high amounts of hydraulic fluid.
- Piston pumps are also used for this purpose. They contain one or more pistons that convert the rotary shaft motion into an axial reciprocating motion. They are composed of a tilted plate that rotates, causing the pistons to move up and down, and thus, take the fluid and expel it each shaft rotation *(See the scheme below)*.
- Vane pumps are also found. They consist of a rotor rotating inside a circular cavity where its center of rotation is eccentric. Several vanes are in place at the periphery of this rotor, creating chambers that vary in volume as the rotor turns. The intake of the pump is where the chambers are the largest. The outlet is where the size of the chambers is smaller.



Vane pump *Piston pump* *Gear pump*

The the oil reservoir is designed to:

- Hold enough fluid to adequately supply the hydraulic system: For this reason, it must have a sufficient volume to supply the elements connected to it and collect the returning fluid from these elements. Note that fluids expanse when they are hot, and this phenomenon must be taken into account when the volume of the tank is calculated.
- Provide communication to the external atmosphere, and sufficient space above the fluid to let the air compressed when it is hot to escape to the atmosphere and vice versa.
- Provide a surface that is large enough to transfer the heat from the fluid to the ambient environment by radiation and convection.
- Avoid fluid turbulence at the pump inlet: It is the function of the “baffle plate” that forces the fluid from the return line to take an indirect path to the pump inlet. The baffle plate also limits the movements of the stored hydraulic oil linked to the sea conditions encountered by the boat.
- Provide a gauge to check the volume of oil, and means of access to top-up it if necessary, and change it when it is too old or dirty.

The filter is usually installed at the pump inlet. Also, a relief valve is usually installed at the pump out let. Note that other relief valves may be provided in the hydraulic circuit

Important note:
The hydraulic power unit of the Launch And Recovery System (LARS) must not be for any other purpose than the supply of the elements of the LARS, and this according to the original design indicated by the manufacturer and agreed by the certification body. So, a separate Hydraulic Power Units must be provided to supply the working tools of the divers.

1.1.10.12 - Maintenance

IMCA D 024 gives the following guidelines regarding the planned audits for the maintenance of the system.

Items	*Visual examination + function test + Load test 1.25 SWL*	*Wire destruction test*	*Load test 1.5 SWL*	*Other*
Relief valve	6 months	2 ½ years		
Pneumatic hoses	6 months	2 years		
Electrical winch testing	6 months			
Communication	6 months			
Emergency breathing apparatus	6 months	2 ½ years	5 years	
Bell clamp safety interlock	6 months	2 years	When installed	
Fire fighting portable system	6 months			Manufacturer specification
Fire fighting fixed system	Visual: 6 months Test: 12 months			Manufacturer specifications
Fire detection	12 months			
LARS overall testing	Static: 6 months Dynamic: 1 year		12 months	1 year: NDE critical areas
Weight of the bell (Outside and in the water)	12 months			
Main winches (function and load test)	6 months		12 months	NDT critical areas: 12 months
Main lift wire	6 months	12 months	12 months	History of certificates must be available
Secondary winch	6 months		12 months	
Secondary lift wire	6 months	12 months	12 months	History of certificates must be available
Lifting attachment points	6 months		12 months	NDT critical areas: 12 months
Cross haul system general			6 months (test in the water)	
Heave compensation	6 months (test at max SWL)	6 months		
Hydraulic systems (general)	Hydraulic systems (Intercooler/heater)	6 months		
Hydraulic oil analysis or replacement				12 months

The pre-operation checks must be performed at least daily during the diving operations. The manufacturer of the system presented (Parkburn) provides the following guidelines that should be followed regardless of the commercial brand of the system used.

- General inspections:

- Ensure that all communication links are operating correctly.
- Ensure that all personnel are aware of the intention to operate the equipment.
- Ensure that all associated equipment is operating correctly.
- Inspect all structures and proprietary items for damage.
- Inspect all fastenings to ensure that all are present and appear to be correctly tightened.
- Ensure that all protective guards are correctly fitted.
- Ensure that all safety devices are operational.
- Ensure that any maintenance authorizations have been completed.
- Ensure that there are no outstanding issues, which could affect the safe operation of the equipment.

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- Ensure that equipment movement paths are clear of all obstructions, and foreign bodies.
- Ensure that the all sea fastenings have been removed.

\- Mechanical system

The following checks should be carried out with the system isolated at main circuit breakers:

- Carry out a visual inspection of the Diving Bell Lift Winch. Ensure all deck mountings are secure and torque loaded. Ensure no debris is present in gear trains. Check that the Lift Winch cable and all terminations are sound and that the wire is secured to the bell. Check that all guards are fitted.
- Carry out a visual inspection of the Guide Wire Winch. Ensure that all deck mountings are secure and torque loaded. Ensure no debris is present in gear trains. Check that the Guide Wire cable passes through all sheaves, clump weight and onto the Moon Pool anchor point. Check that mountings are secure and torque loaded. Check that all guards are fitted.
- Carry out a visual inspection of the Umbilical Winch. Ensure that all deck mountings are secure and torque loaded. Ensure that there is no debris is present in gear trains. Check that the Umbilical cable and all terminations are sound and that the Umbilical cable is securely attached to the Dive Bell. Check that all guards are fitted.
- Carry out a visual inspection of the Trolley and Moon Pool Guide Rails. Check that mechanical stops, locking mechanisms, and proximity sensors are present and sound. Note: if the LARS uses an A-frame, carry out a similar inspection to be sure that the frame can deploy safely. So, the fixations of the structure and the jacks to the frame, and those of the pulleys.

\- Hydraulic system

- Pipework should be safely supported in order to avoid vibration or movement. Fittings are assembly elements and should not be used to support pipework.
- Flexible hydraulic hoses should be long enough for free-movement, but short enough to avoid snagging on other equipment.
- Inspect all hydraulic hoses and pipework for signs of damage.
- Check the integrity of all hydraulic connections.
- Ensure that the system contains hydraulic oil and has been vented.
- Ensure that all accumulators have been pre-charged to the required pressures.

\- Electrical systems

- Inspect all controls and instrument panels for signs of damage.
- Use the Lamp Test facility at the Control Desk to verify that all lamps are operational.
- Check the integrity of all electrical connections.

1.1.11 - Gas reclaim system of the bell

1.1.11.1 - Purpose

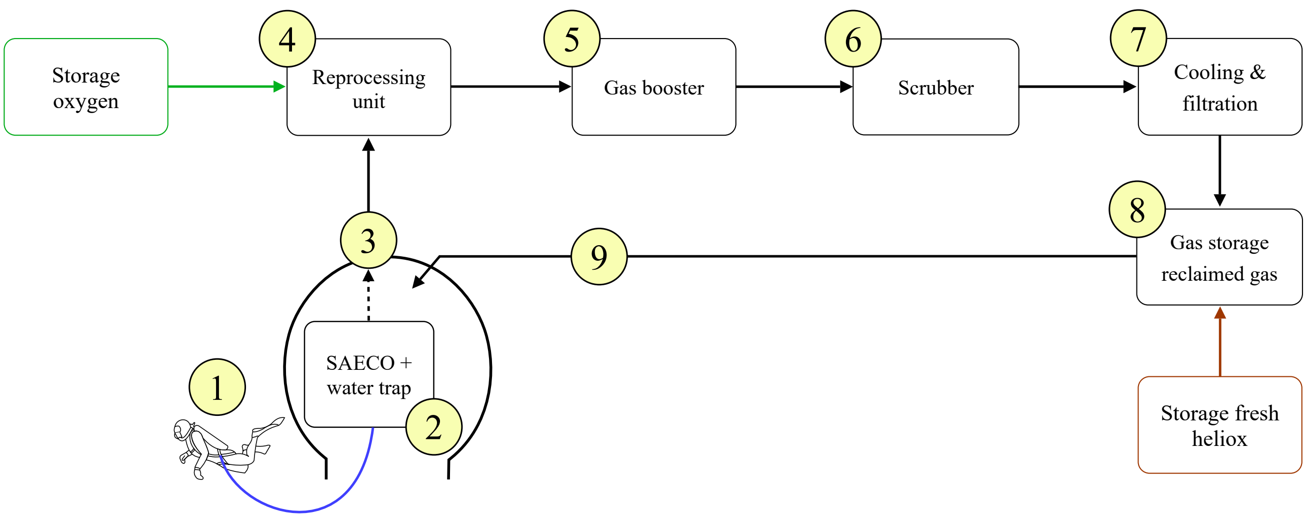
Heliox (He + O_2) is used in saturation as it is the best gas to avoid narcosis and is comfortable to breathe. However, helium is very expensive and cannot be fabricated. For this reason, it is of utmost importance to recycle it. It is the function of the gas reclaim system of the bell which recovers the gas mixture breathed by divers, re-process it and delivers it into the supply system. This system that has been already mentioned in the previous points is a closed circuit that allows recovering up to approximately 90% of the gas injected in the breathing circuit. The 10% loss is the result of helmet and bell flushing and undetectable leaks. Note that the new rules of gas purity require the removal of contaminants.
Also, the reclaim system allows staying a long time at sea as only the oxygen and the helium lost are to be renewed. Without such a system, the vessel is obliged to return to the shore very often as the consumption of gas is multiplied by the depth the divers are living and working. As an example, a diver at work at 60 meter consumes 245 litres per minute, so 14700 l per hour. Thus for a 24 hrs operation with two divers in the water, the consumption can reach 705600 litres per day. As a conclusion, a failure of the reclaim system can affect a project and for this reason, its condition must be monitored. The general layout of the equipment is as follows:

- In the bell

1. Exhaled gas is recovered from the divers through reclaim valves, mounted on helmets. The exhaust umbilicals are connected via SAECO valves (supply actuated exhaust cut-off valves), also called “Pressure Operated Safety” (POS) valves, situated in the bell and which description can be found in point 2.3.2.
2. The gas then passes via a water trap to the exhaust which is maintained at a slight differential pressure by a back pressure regulator (see in point 2.3.2). The bell-man can monitor this pressure on a gauge situated in the bell.
3. The gas is then passed to the surface through a non-return valve and the main umbilical of the bell.

- At the surface

4. The gas enters the reprocessing unit, where it is filtered, stored in receivers, and oxygen is added to make the correct mix.
5. The gas is then passed to an Electric Gas Booster where the pressure is increased.
6. It is then scrubbed to remove the CO_2 and other impurities
7. Then, the gas is dried by cooling and filtered.
8. It is then stored. Eventually, fresh heliox is added to compensate the gas lost during the dive.
9. Then, the gas is passed via the umbilical to the bell gas supply manifold and then to the diver’s regulator.



Some small differences may be found from one system to another. However, the basic concept remains the same. Also, as such systems are complex, it is preferable to describe them in details using existing models as support. For this reason, the model currently in use on UDS Lichtenstein and Picasso which has been designed and built by LEXMAR, a company of JFD group is taken as an example.

1.1.11.2 - Bell Unit

I. As indicated above, the breathed gas of the diver is expelled through the exhaust valve of the helmet that is described in point 2.3.6 and the exhaust hose of the umbilical. This exhaust hose, is connected to the “Supply Actuated Exhaust Cut-Off “ (SAECO) valve, which is also called “Pressure Operated Safety” (POS) valve *(see #1 in the figures A & B on the next page)*. The exhaust hose can be isolated by a ball valve *(see #2)*.
II. The SAECO/POS valves allow the exhaled gas from the diver to return to the surface. Please, remember that this valve is designed to close in the event the supply pressure drops below a pre-set value. This pre-set value is controlled by the back-pressure regulator *(see #3 in the figures A & B on the next page)*
III. The Back Pressure Regulator loader regulates the divers exhaust gas pressure in the umbilical. A valve controls the amount of gas going to the flow meter *(see #4 in the figures A & B)*.

IV. A flow meter controls the amount of gas being tapped off from the divers supply to load the Back Pressure Regulator (BPR) at the desired flow rate (0.5 L/min) to the BPR reference port *(see #5 in the figures A & B)*. That sets the reference pressure for the bell BPR which in turn determines the pressure in the exhaust hose for the diver excursion umbilical and the Bell water trap. A slight flow is required so that the BPR load can be varied to compensate for any required setting changes.

V. The Back Pressure Regulator (BPR) that controls the negative pressure in the exhaust umbilical to the optimum value to give a minimum breathing resistance is fitted with a bleed valve which allows regulating the pressure from the BPR loader *(See #6 in the figure A)*.

VI. A pressure gauge *(see #7 in the figures A & B below)* allows to monitor the pressure in the water trap, which is the same as the pressure umbilical which is the same as the pressure in the exhaust umbilical if the exhaust hose isolating valve and POS valve is open.

VII. The bell exhaust, which can be isolated by a valve *(See #8 in the figures A & B)* allows the gas of the bell to enter in the water trap and being drawn through the Back Pressure Regulator (BPR) to the Reprocessing Unit (TRU), which is situated in the vessel, where it will be recycled.

VIII. The "water trap" collects most of the water present in the gas expelled by the divers *(See #9 in the figures A & B)*. It consists of an acrylic housing, a compound pressure gauge, an overpressure relief valve, a negative pressure relief valve, and drain and isolation valves. It is designed to be drained regularly without affecting the working process of the reclaim system *(see in the figure C)*. This item should be mounted in a prominent position so the bellman can have an unobstructed view and is able to check its status at any time.

IX. From the back pressure regulator, gas passes through hull stop valves *(see #10)*which function is the isolation of the circuit during maintenance or in the case of an emergency. As usual there is one valve inside the bell and a 2nd valve outside the bell.

X. From the hull valves, the gas passes through a check valve *(see #11 in figure A below)* situated at the external of the bell which function is to prevent reverse flow of gas from the bell umbilical into the bell equipment: As an example, when the bell is being depressurized.

XI. Then the expelled gas flows to the external water trap (see #12 below) that collects any additional free water which has not been trapped at the main water trap or condenses when the gas passes from the internal to the external of the bell as a result of its cooling. Water should be anticipated in this filter, so it is essential to drain it when the bell is recovered out of the water.

Figure A

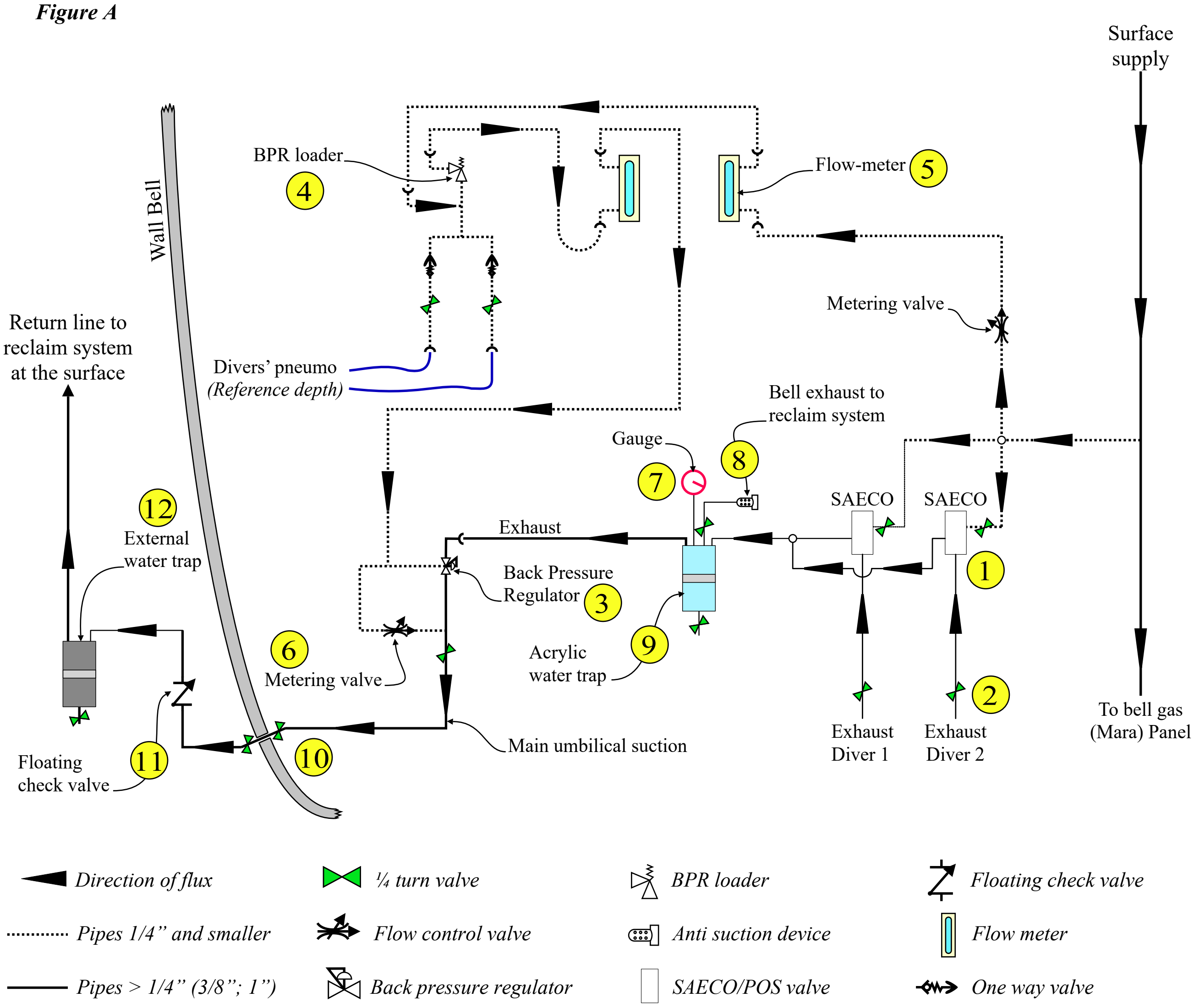


Figure B

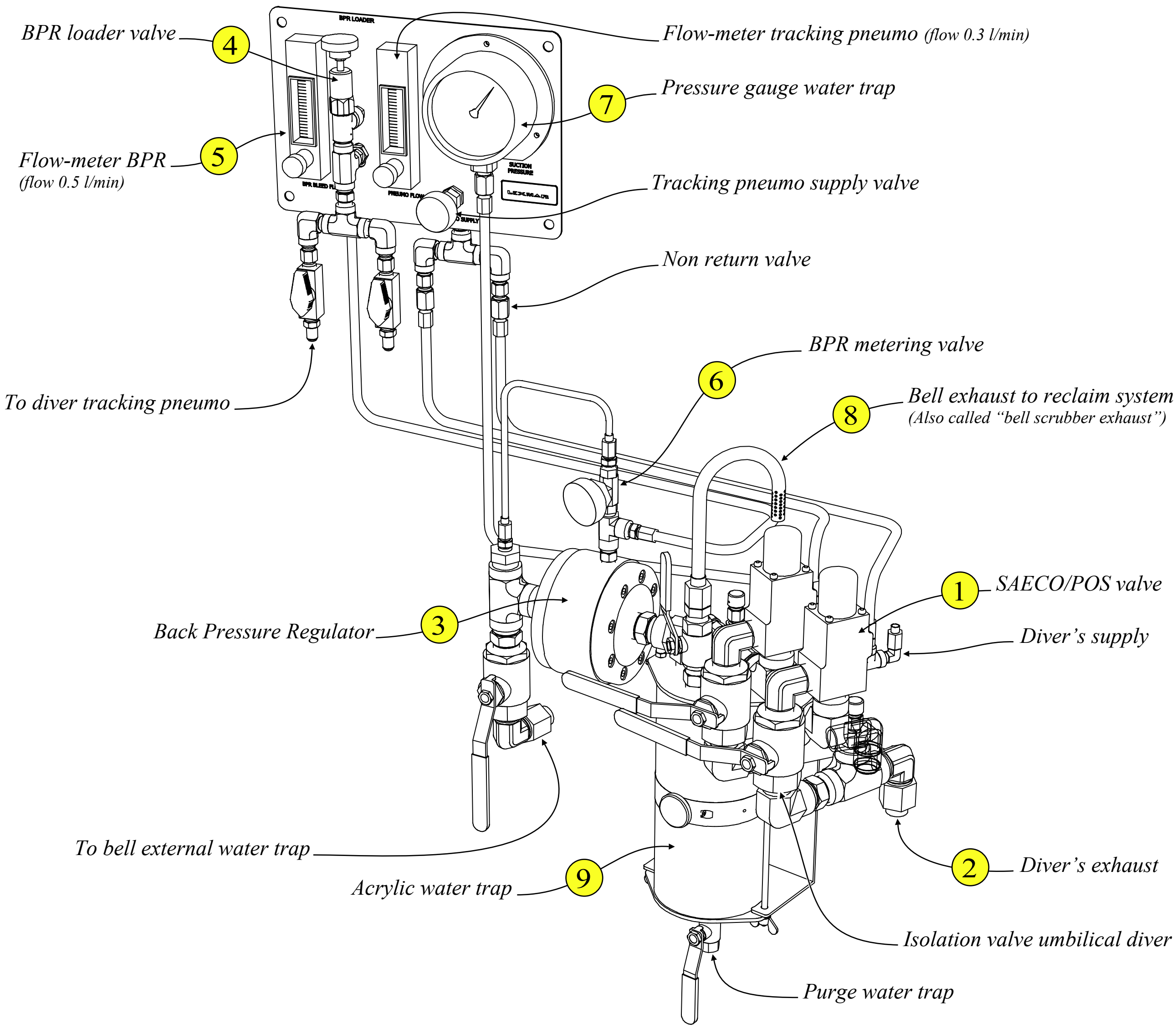
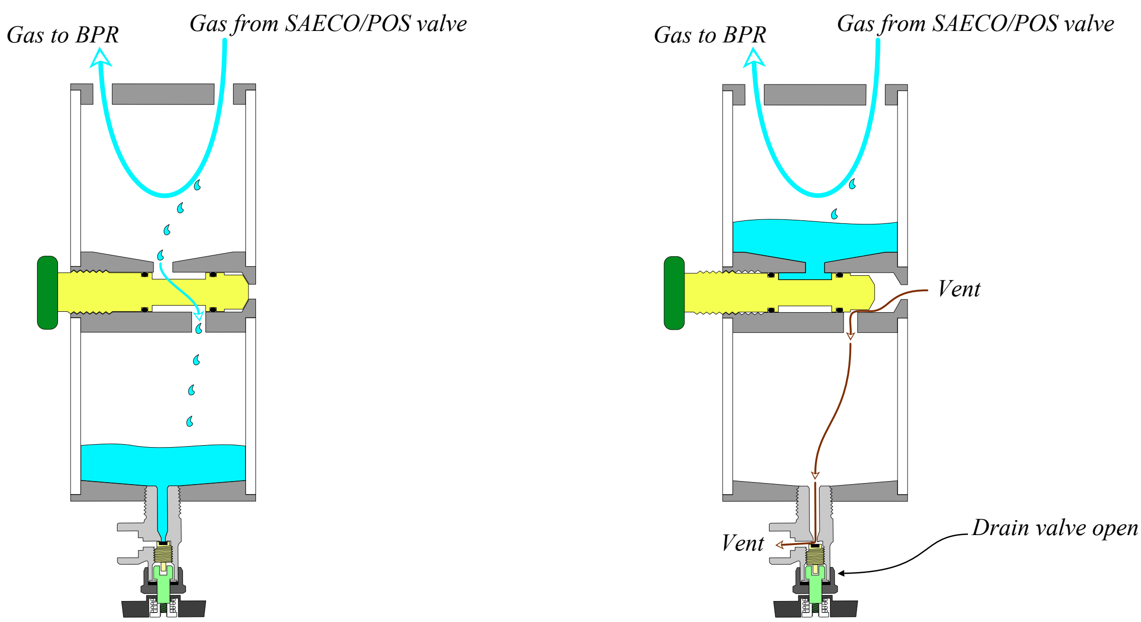


Figure C

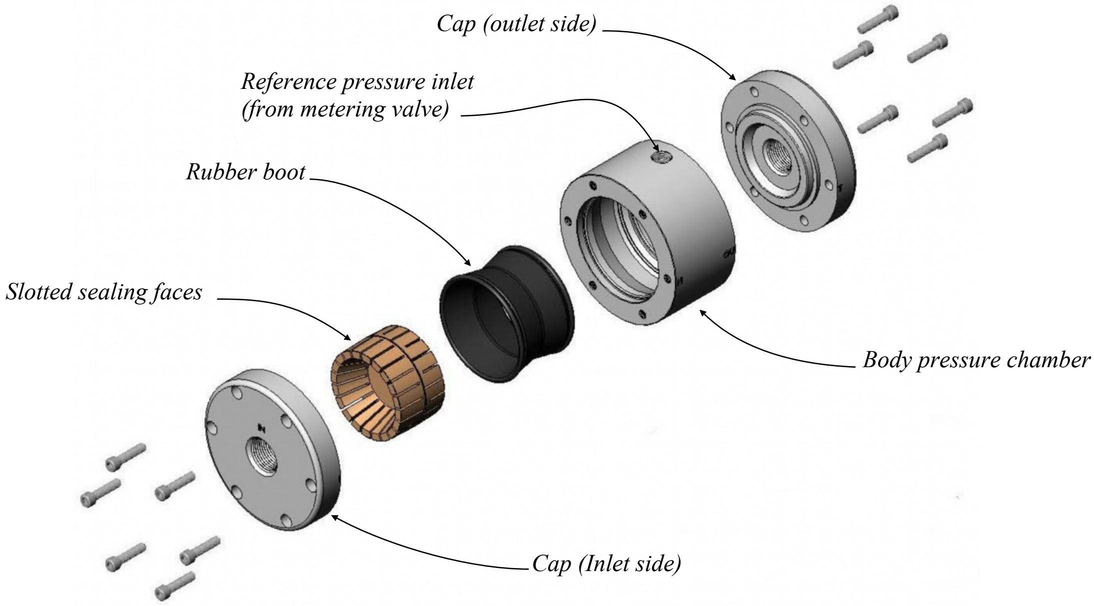


Water trap during normal operation:
With the plunger in the normal (in) position, the trapped water passes to the lower part of the cylinder.

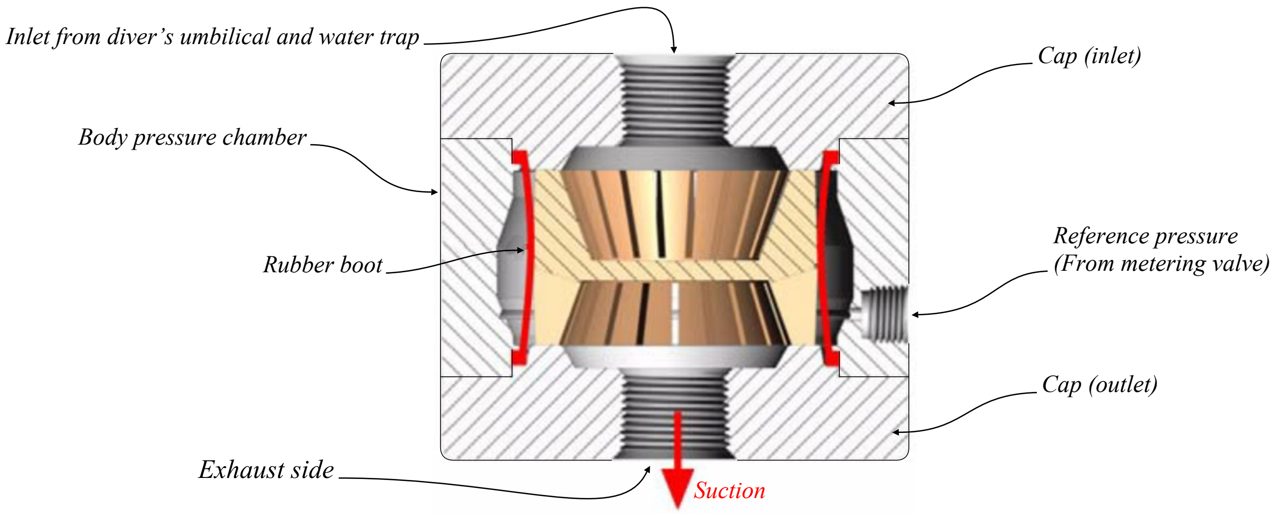
Water trap draining:
The isolation valve is pulled out, the upper and lower halves of the water trap are isolated and the lower half is vented to bell ambient pressure. The drain valve may now be opened to remove water while the upper half continues to collect water from the flowing gas.

- Back pressure regulator:

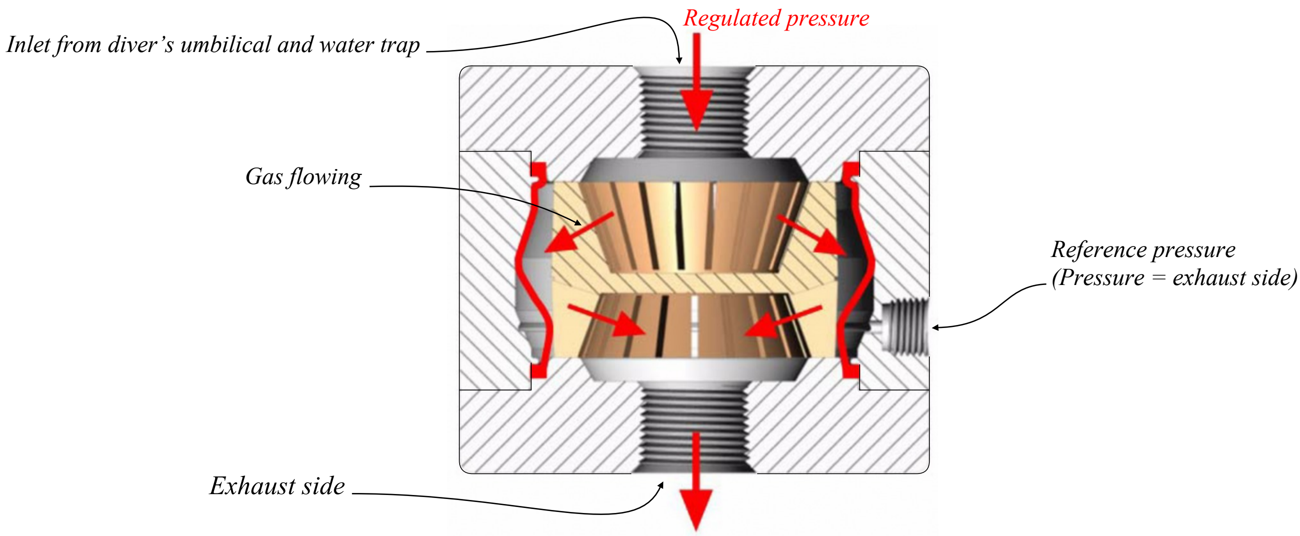
The back pressure regulator controls the pressure in the diver's umbilical to give a minimum breathing resistance. It is generally composed of two slotted sealing faces enclosed by a rubber boot. This assembly is housed inside a sealed pressure chamber into which a reference pressure may be applied. The model described below is designed by Divex. However, the system provided by Lexmar is very similar, so it uses the same principle.



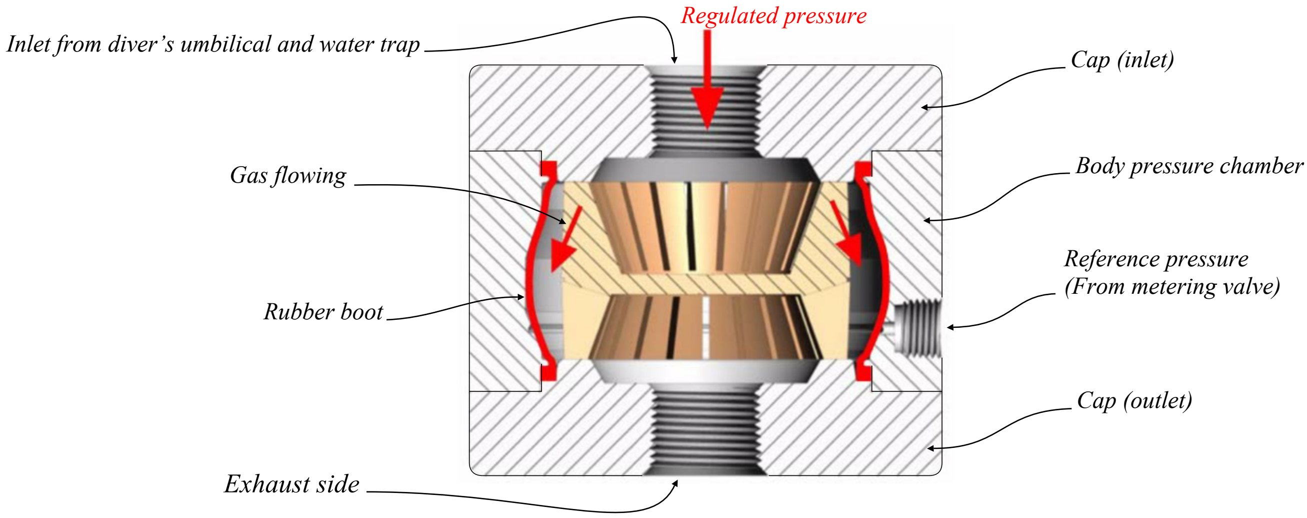
Initially, a suction is applied to the discharge side of the regulator and a reference pressure to the chamber.
If the pressure at the inlet side is below the reference pressure, the rubber boot is held in place by the pressure and no flow occurs.

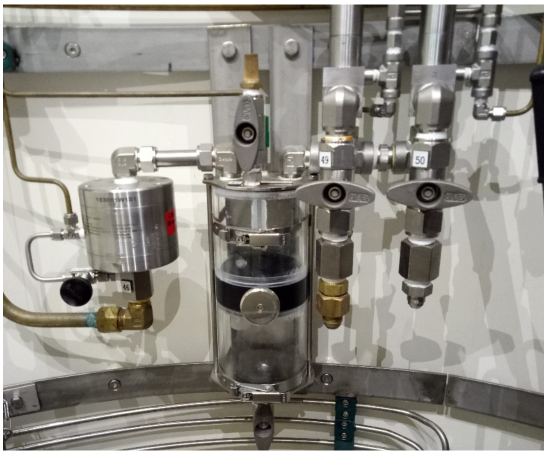


If the inlet pressure rises fractionally above the reference pressure, the diaphragm lifts, allowing the gas to flow. In this way the pressure in the exhaust umbilical is held at a level equal to the reference pressure.



A further increase in gas flow will result in increased opening of the regulator as shown



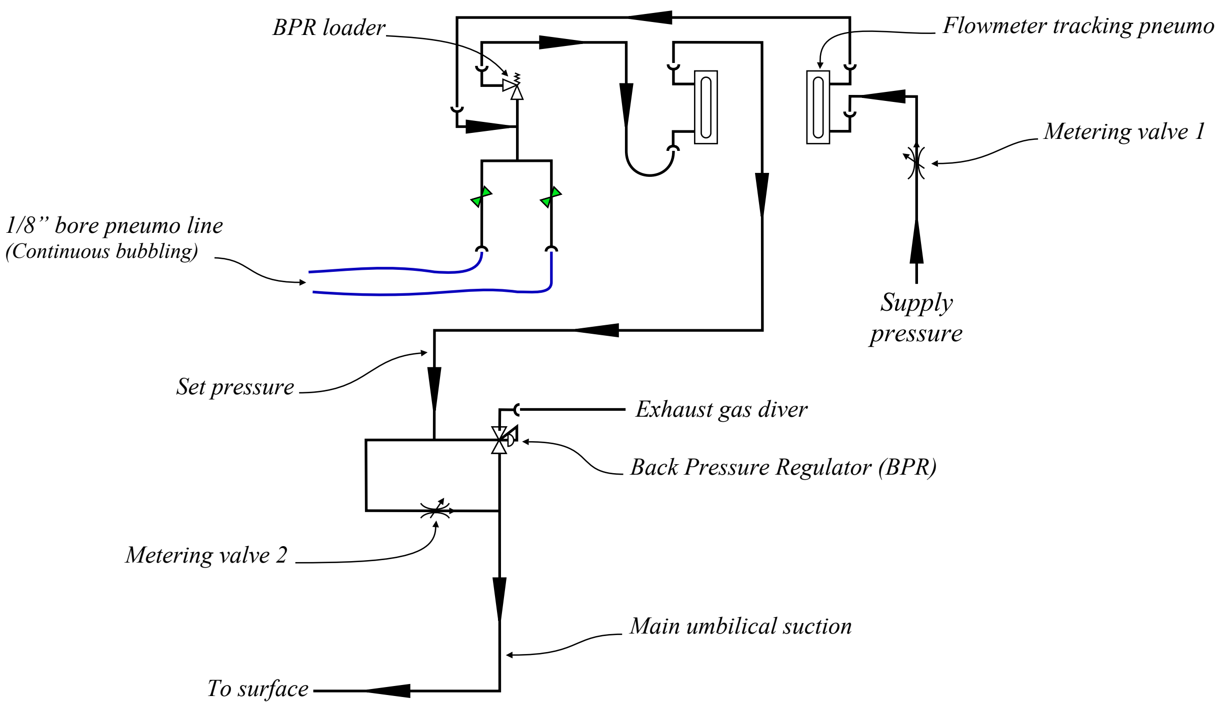

Back pressure regulator & water trap DIVEX

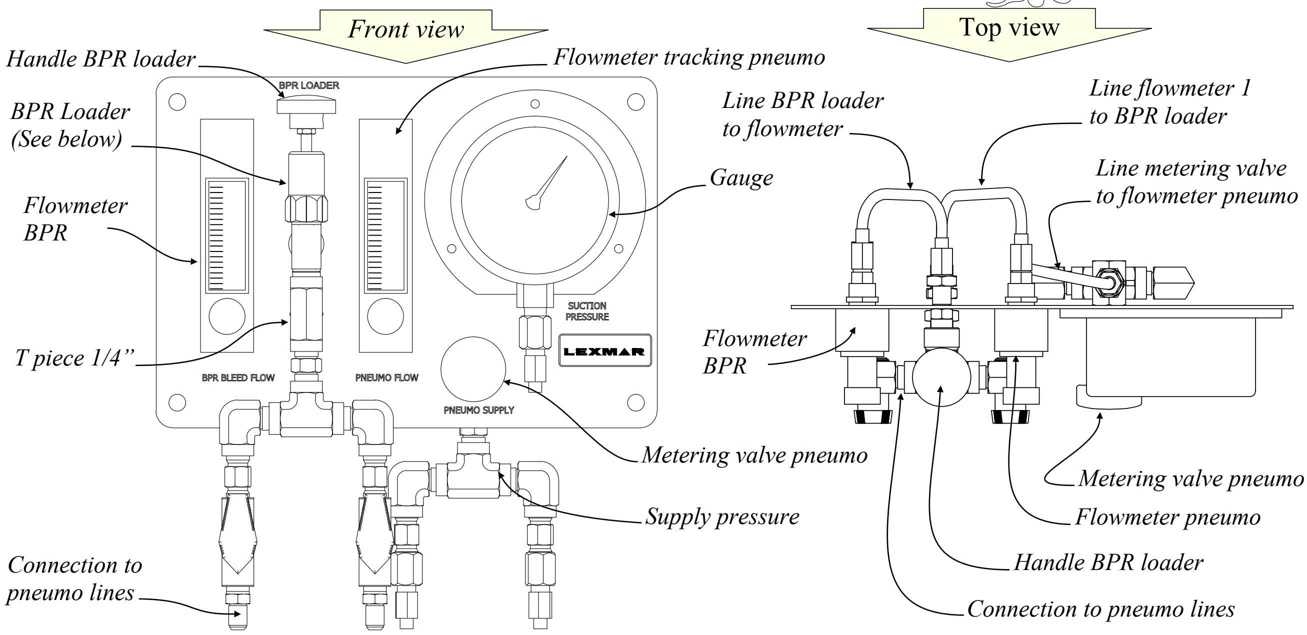

Back pressure regulator & water trap LEXMAR

- Diver tracking system:

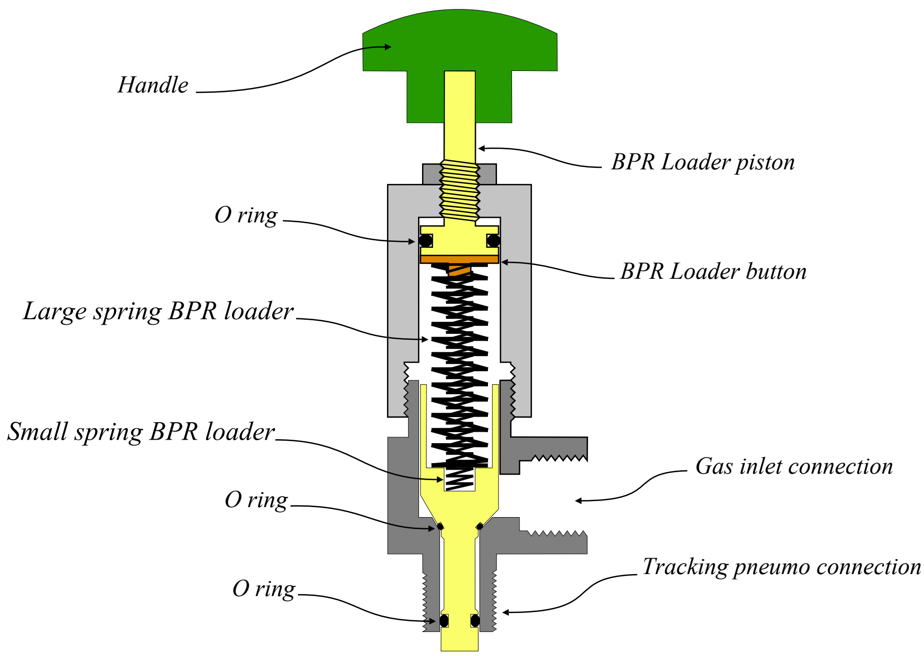
The diver tracking system adjusts the Back Pressure Regulator (BPR) loading accordingly to the depth of the diver to obtain a minimum breathing resistance from the reclaim valve. Note that the pressure in the return umbilical is adjusted approximately between 1 and 2 bar below the diver ambient pressure.

In addition to the equipment in place in the bell, a 1/8" internal diameter pneumo line is added to the diver umbilical. A slow gas bleed is drawn from the bell gas supply to this pneumo. As a result, gas bubbles emerge continually from this line at a slow rate. Note that an excessive flow will adversely affect gas recovery figures: Only a very small trickle of bubbles from the pneumo line should be evident to the diver.





The loader is a modified inward relieving relief valve which controls the set pressure for the BPR.
As suction is first applied to the system, gas will be drawn from the BPR loader line, reducing the pressure until it reaches the set pressure of the loader when it will lift, allowing gas to flow to prevent further depressurisation. In this way, a fixed reference pressure is available for the BPR.
The pressure in the diver pneumo line is applied to a piston (having the same area as the valve opening) on the bottom of the BPR loader. As the diver changes depth, the change in pressure in the pneumo line will produce a force on this piston which will in effect change the set pressure of the loader.



Functions of the diver tracking system components:

Diver pneumo	Monitors the diver’s depth.
Metering valve pneumo	Adjusts the supply gas to purge the diver pneumo. It is often adjusted at 0.3 litres/min; a maximum of 0.4 litre/min is recommended.
Flowmeter pneumo	Indicates the flow through metering valve pneumo.
Back Pressure Regulator loader	Maintains a constant pressure difference between diver ambient and BPR setting.
Back Pressure Regulator (BPR)	Controls the exhaust umbilical pressure to be equal to the BPR loader setting.
Metering valve BPR	Controls the gas bleed through the BPR loader to give stable operation. It should be set to 0.5 litre/min.
Flowmeter BPR	Records the flow through metering valve BPR

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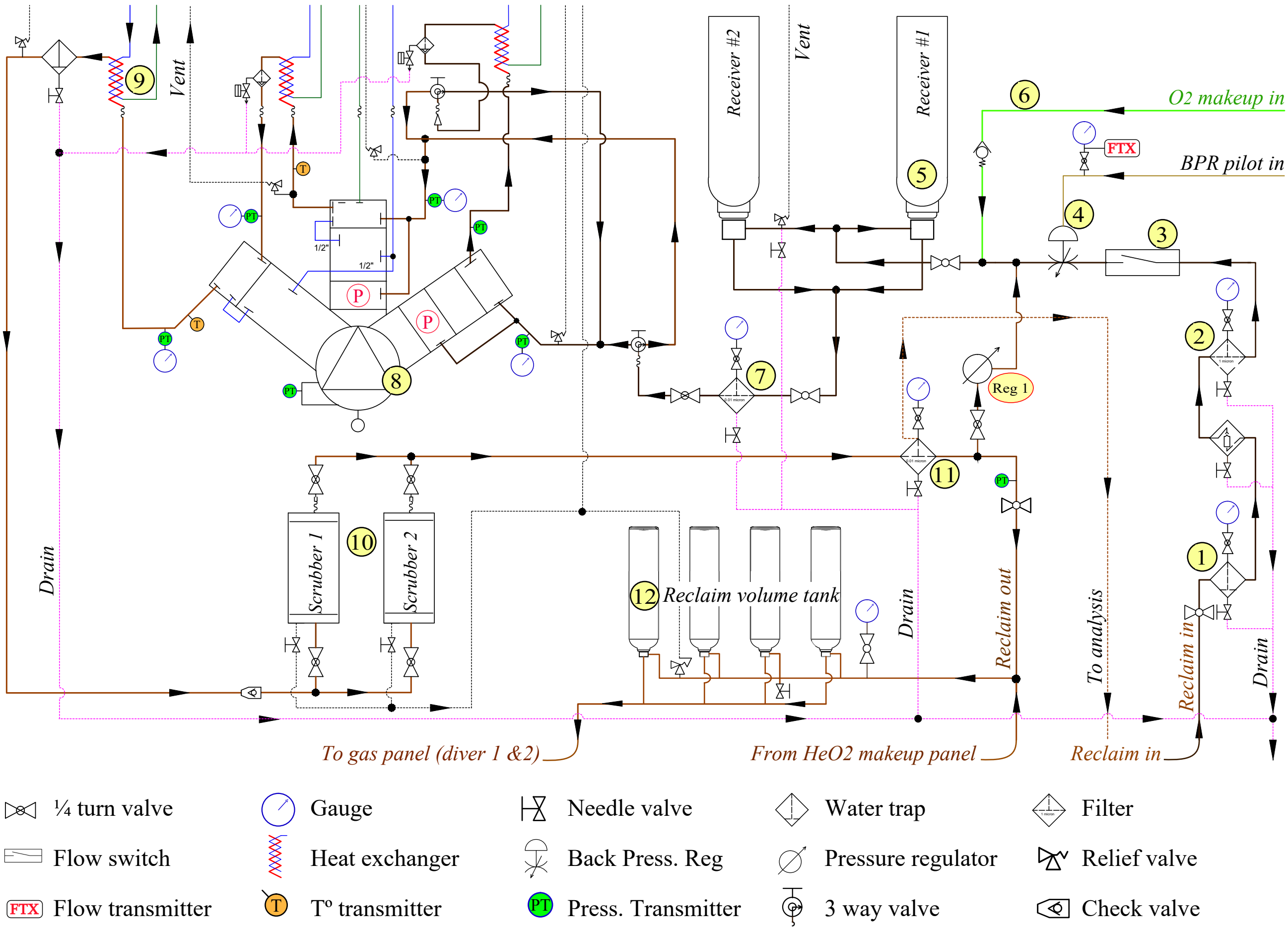
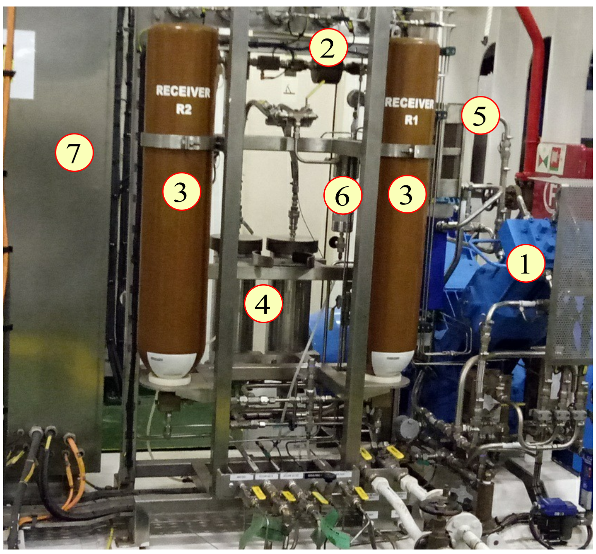
1.1.11.3 - Topside unit

The gas from the bell is drawn to the Topside Re-Processing Unit (TRU) through the bell umbilical.
The Topside Re-Processing Unit (TRU), recompresses the recovered gas, scrubs it to remove the CO2 and other contaminants, and adds oxygen to restore the correct PPO2 of the breathing gas supply.

- The inlet section consists of a water trap *(see #1 below)*, filter 1 micron with moisture separators *(see #2)*, flow switch *(see #3),* back pressure regulator *(see #4)*, and two receivers which smooth out fluctuations in the flow to the compressors *(see #5)*. Oxygen enrichment is also carried out in the inlet section (see #6).
- The gas is then sent to another 0.01 micron particle filters which is fitted with biological filters *(see #7)*
- The Compressor (gas booster) consists of one electric driven three piston compressor which brand is Hycomp for the system studied . It is described more on the next page *(see #8)*.
- The gas from the compressor is water-cooled through heat exchangers *(see # 9)*. It is discharged to the scrubbers where soda lime (9 litres each) and Purafil remove the carbon dioxide and other contaminants *(see #10)*. A further filtration 0.01 micron removes water particles or solid material *(see # 11)*. The gas is then stored in the “reclaim volume tank” *(see #12)* from which it is sent to the divers.
- Finally, the topside unit also houses electrical and computer systems necessary for the control and driving of the Hycomp compressor motors. Note that computers are monitored through a human machine interface (HMI).





#1: Compressor (booster)

#2: Back Pressure Regulator

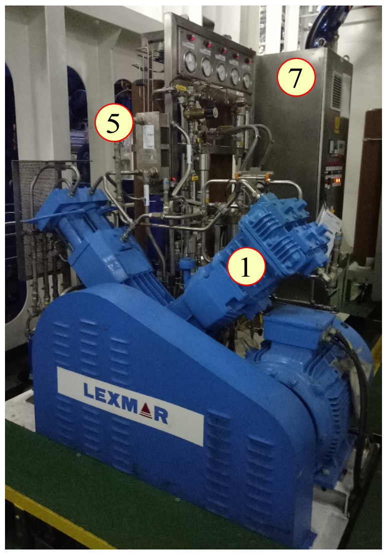
#3: Receivers (No 1 & No 2)

#4: Scrubbers

#5: Heat exchanger

#6: Micron filter

#7: Electrical enclosure



#1: Water trap	*#5: Receiver volume tank*	*#9: Water trap*
#2: floating valve	*#6: Filter 0.01 micron*	*#10: Scrubbers*
#3: Filter 1 micron	*#7: Compressor (gas booster)*	*#11: Filter 0.01 micron*
#4: Back Pressure Regulator	*#8: Heat exchanger*	*#12: Electrical control enclosure*

- Filters and moisture separators:

The filter elements coalesce the small liquid droplets into larger liquid droplets which drain to the bottom of the housing.

Two types of filtration are provided:

- Filter 1 – 1 micron
- Filter 2 – 0.01 micron
- Filter 3 – 0.01 micron

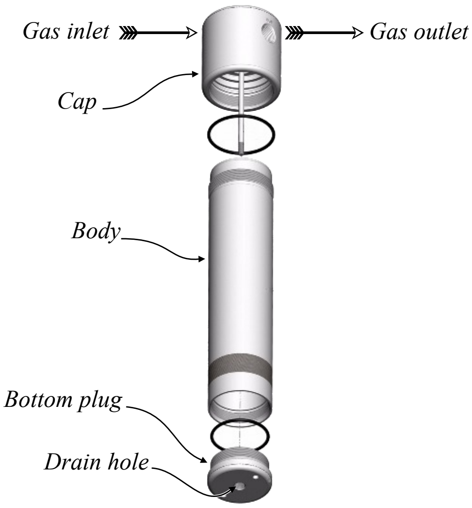
A filter housing is generally composed of three main parts, as shown in the drawing on the side.

All water traps and filter housings should be drained every hour or so.

It is recommended that filter elements be replaced at intervals of 500 operating hours.

Water traps prevent water from flooding the topside unit. Note that in addition to the moisture expelled by the divers, water incursion may happen in the case of a loose fitting.

A drain valve allows any accumulated water to be removed. Note that the water trap should be checked and drained at least every hour.



- Oxygen injection:

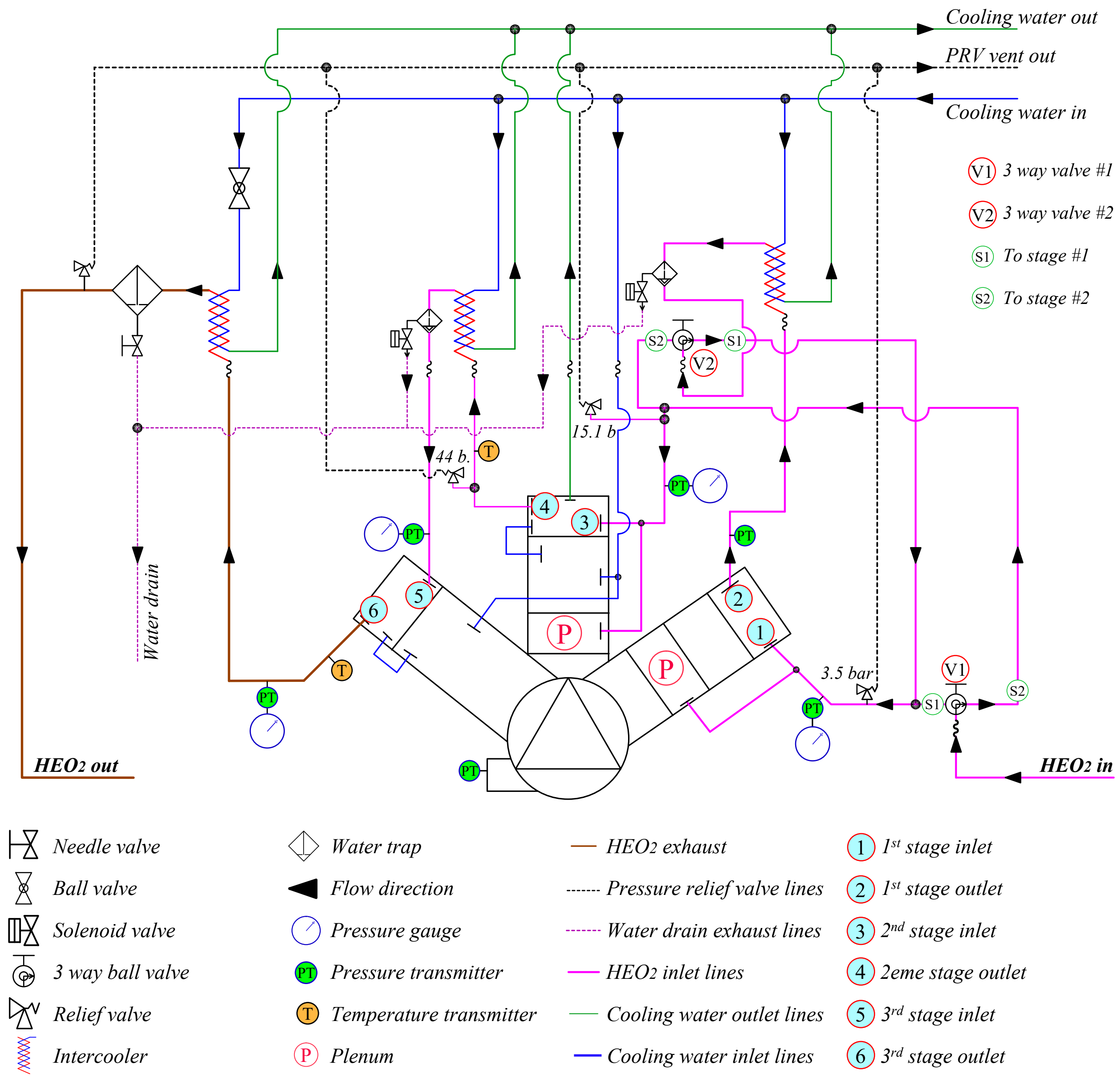
Oxygen from storage enters the panel by passing through isolation valve and O2 gauge and is injected into the gas after passing through the Back Pressure Regulator on the Topside Reprocessing Unit (TRU). The flow is controlled by setting a regulator for desired pressure of the oxygen supply to the system which is on the “oxygen make-up panel” in Dive control.

- Flow switch:

The flow switch senses the divers exhaled gas flow through the system. This switch controls two functions.

I. It activates the alarm in the control panel when the flow of gas through the topside unit stops.
II. It stops the addition of oxygen in the absence of flow.

- Back Pressure Regulator (BPR):
  The topside BPR controls the pressure in the main bell reclaim hose in the umbilical. It has a similar design as the one used in the bell. The bias pressure to the BPR is controlled from the "Reclaim panel" in the Dive Control.
- Compressor (booster):
  A compressor is a mechanical device that increases the pressure of a gas by reducing its volume. A gas booster is a compressor that is designed to increase the pressure of a gas that is already above ambient pressure.
  The compressors used in reclaim systems act as boosters as the gas received from the bell is already above the ambient pressure at the surface. However, most systems utilize machines that are capable of compressing gas at atmospheric pressure, or that is as low as 0.1 bar above atmospheric pressure. Note that the inlet gas pressure of each stage of the compressor must conform with the specifications it has been calculated for and that the machine will be damaged if the inlet gas pressure is higher than recommended.
  Compressors are more described in another chapter. However, the machines commonly used in reclaim systems are membrane and piston compressors. As a result of a more reduced cost, piston compressors are the most used with modern reclaim systems. As an example in the diving system taken as reference for this description, the gas from the bell is pumped by a 3 stage compressor driven by a variable speed-controlled electrical motor and is designed with inter, and after-coolers. It is capable of receiving input pressures from as low as 0.1 bar and supplying an output pressure of up to 55 bar. Also, it can sustain flows of up to 135 L/min at bottom pressure for a diving depth of up to 300 MSW. The speed range of this compressor is between 400 and 800 RPM.
  Note that its 1st stage can be deactivated or activated through manual 3-way valves. It must be bypassed for operations in the range of depths deeper than 160 MSW; the determining factor is the maximum allowed input pressure of 3.4 Bar at stage 1 inlet. Of course. a relief valve preventing the introduction of gas above 3.5 bar protects the 1st stage.



Additional technical information regarding the compressor taken as an example:

- Dimension of the compressor are L: 2650 mm, H: 2225 mm, W: 1750 mm and its weight is 2500 kg.
- This machine is protected by a computer that monitors its functions and shut it down in the case of incorrect parameters. A Human Machine Interface (HMI), which is on the electrical enclosure, allows controlling it.

- Power requirements are 440 Vac/ 60 Hz/ 40 KW.
- Suction gauges, which indicate the gas pressure into the compressor are provided at the inlet of each stage. A gauge is also provided to indicate the discharge pressure.
- Max inlet pressure: 31 bar / Max outlet pressure 55 bar. As already said, the inlet pressure must never be above the recommended value or the compressor can be damaged. High and low pressure switches are provided to shut down the compressor in the event of high discharge pressure or low inlet pressure.
- A Shut-off valve that isolates the compressor’s suction gas from the inlet section is also provided.
- Gas temperature switches are provided to shut down the compressor in the event that the discharge gas temperature rises above the normal operating temperature. This may occur if the cooling water supply to the compressor is disrupted.
- Intercoolers fitted with water traps are installed to cool the gas and protect the compressor from damage due to carry-over water entering the inlet stages. Cooling water supply: 20 litres/minute & 3 to 6 bar / Max cooling water supply temperature: 32 ºC. Note that an automatic draining system is provided. However, the manufacturer recommends to regularly check that it is functioning.
- An oil pressure switch shutdowns the electrical motor in the case of low oil pressure.

- Automatic inlet gas pressure management

In the installation taken as example, the computer mentioned above monitors the inlet pressure and automatically adjusts the compressor rotation speed to keep this inlet pressure to a constant value.

When there is insufficient mixed gas returning from the divers and the reclaim volume tank, a heliox make-up system automatically keeps the volume tank pressure to a preset value, and an alarm is triggered on the reclaim panel in the dive control.

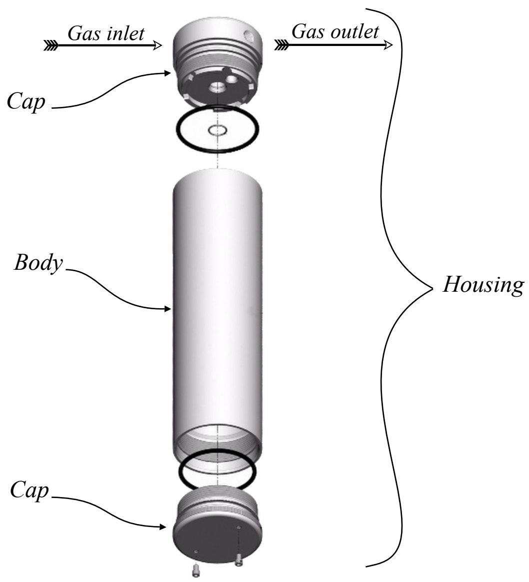
- Scrubber assembly

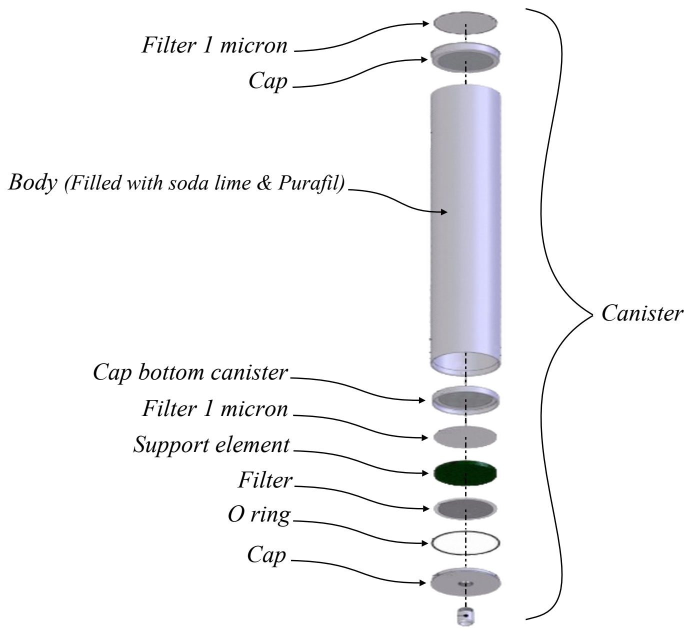
Two scrubber units that consist of housings into which a canister assembly filled with soda lime (also called soda sorb) and Purafil are provided.

Soda lime is a widely used absorbent for carbon dioxide. 1 kg of soda lime absorbs 120 litres of CO_2 (1 litre of soda lime absorbs 90 litres of CO_2). A canister assembly is to be changed every 8 hours for 1 diver at work. Thus, the duration of one canister is 4 hours for two divers at work.

Purafil is used to remove odours and a wide range of trace contaminants. They can be listed as follows:

- Mercaptans, amines and ketones *(responsible for many common odours)*;
- Ammonia;
- Hydrogen sulphide;
- Sulphur dioxide;
- Carbon monoxide *(trace quantities only)*.





- Bypass regulator

Excess gas volume which is being delivered is re-circulated back to the suction side of the compressors at the inlet to the gas receivers.

This re-circulation line is fitted with a pressure regulation system. The bypass regulator *(see “Reg 1” in the scheme that represents the entire topside unit at the beginning of this topic)* is loaded by the gas that flows in the line from the scrubbers to the "reclaim volume tank". This gas passes through an orifice. Downstream of this orifice is a pressure regulator which is set to open at a value below that set on the return line BPR. If the pressure downstream of the return line BPR falls below its set point, the bypass regulator will sense this drop in pressure and open, with this regulator open the BPR load pressure will also fall and allow the BPR to open, bypassing into the "receivers" the gas flowing from the scrubbers.

1.1.11.4 - Control console unit

The control console is situated in “dive control. It is generally composed of four parts:

- Analysis panel
- Oxygen make-up panel
- HeO2 make-up panel
- Back pressure regulator loader panel

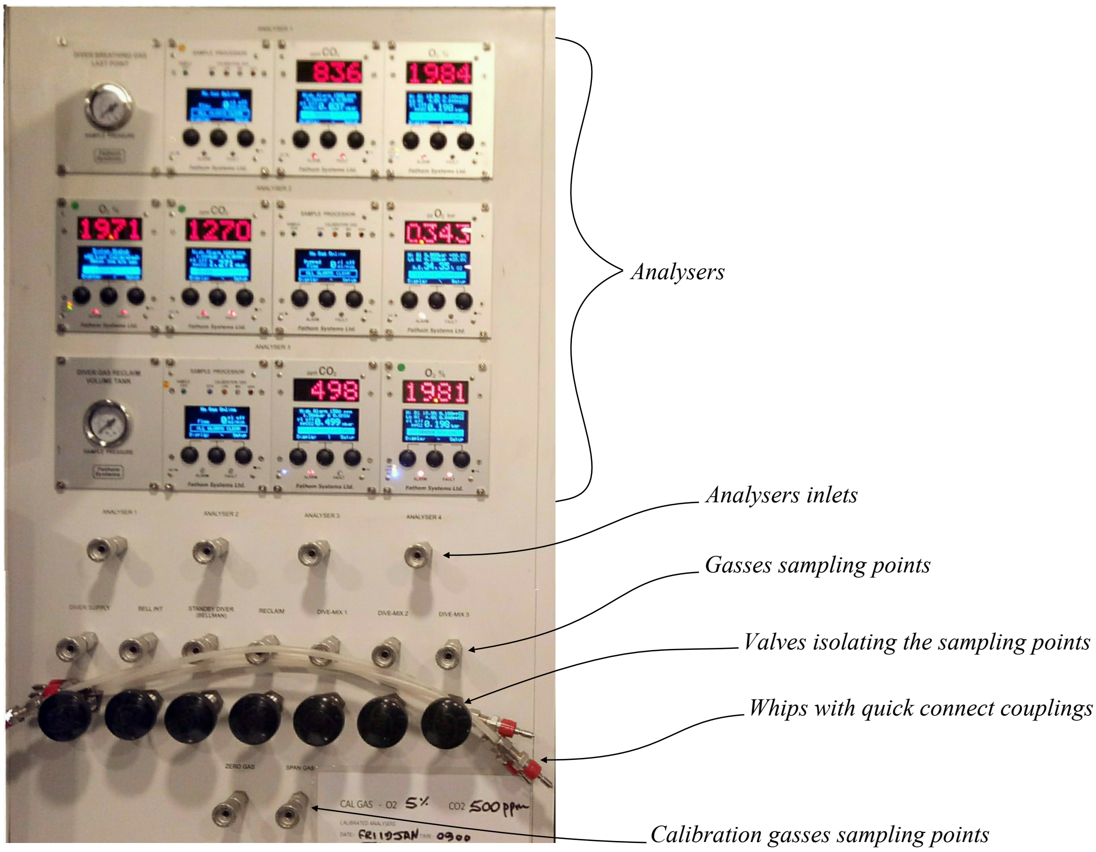
- Analysis panel:

The analysis panel is essential to ensure that the reclaim system works accordingly to what is expected and to monitor the gasses that are ready to be in line. IMCA says the following:

- *There must be an oxygen analyser with an audible and visible high and low alarm fitted in line on the downstream gas supply to the divers*
- *If diver gas reclaim is being used, there must be a carbon dioxide analyser with audible and visible high level alarm fitted to the down-stream side of the diver gas supply. The adjustment of gas sample flow rate must not affect any other analyser fitted*
- *There must be a means by which the diving supervisor can monitor the bell atmosphere for oxygen and carbon dioxide levels. This may be by a manual procedure carried out by the bellman or by a remote reading in dive control*

The analysers used on control panels are separate devices which are designed for a dedicated gas. They are typically grouped together and at the direct proximity of the diving supervisor. Flexible whips with quick connect couplings are used to connect these O2 and CO2 analysers to the various sampling sources that are regulated by flowmeters. These sampling points are usually organized as follows:

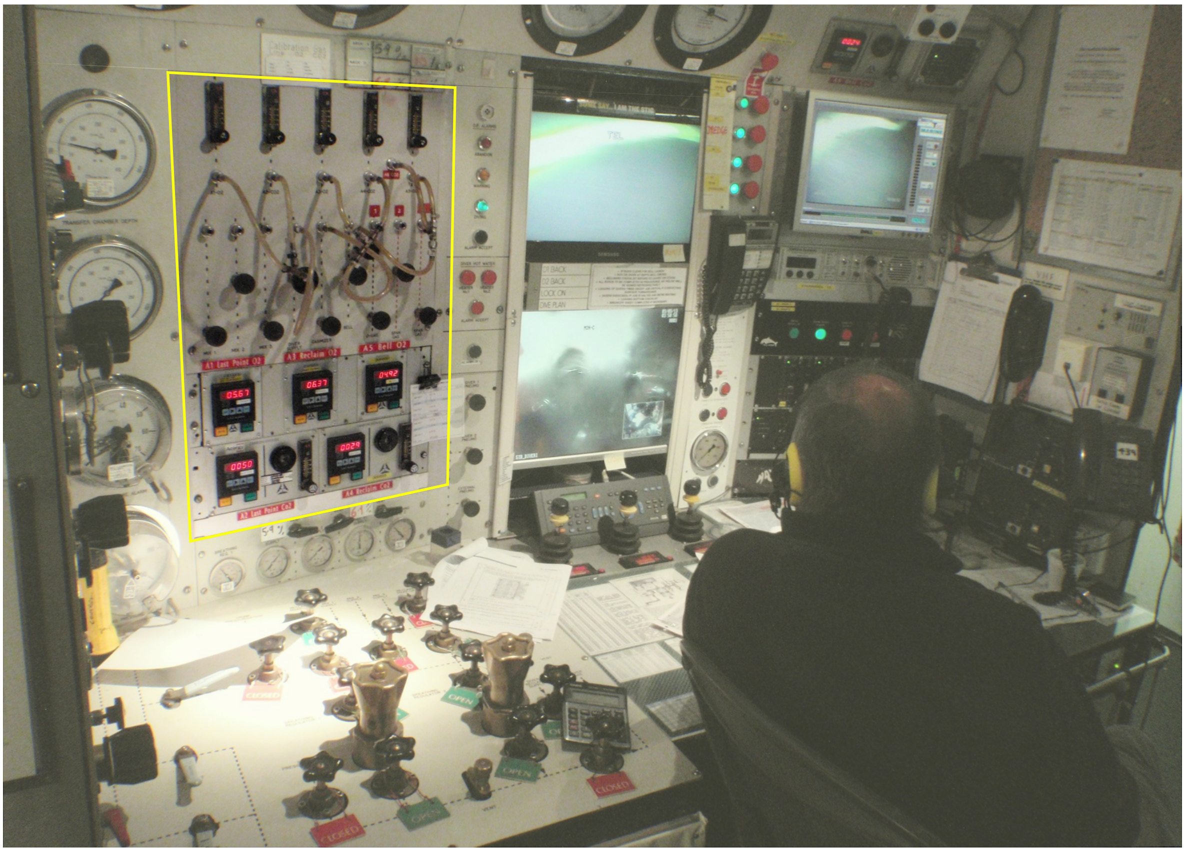
- Span & zero gas sampling points: Analysers must be frequently calibrated, and it is recommended to use a zero gas and a span gas to do it. For this reason, these gases must be available at all times. Note that:
  - A “zero gas” is a neutral gas, that does not contain any molecule of the gas the analyser to calibrate and is designed to detect, which is used to set the zero of this analyser. As an example, pure nitrogen or helium are often used to perform the zero calibration of an oxygen or carbon dioxide analyser.
  - A “span gas” is a gas in which there is a precisely known concentration of a detectable gas which is exposed towards an analyser designed to detect it in order to calibrate it.
- Divers supply sampling point allows to control the gas delivered to the divers in the bell.
- Bell Internal sampling point allows monitoring the atmosphere of the bell.
- Standby diver sampling point provides a control of the gas ready to be delivered to the stand by diver..
- Reclaim sampling allows monitoring the reclaimed gas before its delivery to the bell.
- Mix #1, #2, and #3 sampling points allow controlling the stored gasses that are ready to be introduced and which have been fabricated by the life support technician or specifically manufactured.
- Depending on the diving system, other sampling points may be available.



Analysers should provide the operator with a clear and accurate display of the gas concentrations within the bell and the gas supply lines being monitored. The values are displayed as follows.

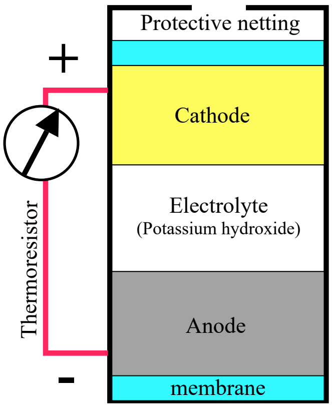
- Concentration of a gas: Percentage (%) and part per million(PPM) are commonly used.
- Pressures: Bar and millibar (mbar) are today the most employed units of measure (1 bar = 100000 Pa). However, PSI (pound per square inch) and Atmosphere (atm) are the preferred units in several areas. Note that NORSOK uses kilopascals (KPa) to quantify small pressures (1 KPa = 10 mbar) in some documents. However, this unit is unusual with the analysers commonly found in dive & saturation controls.
- Gas flow rate: Litres per minute (L/min) is the most used unit.
- Depth: Metres of seawater (MSW) becomes the preferred unit. However, feet of seawater (FSW), continue to be used in a lot of countries.
- Time: Hours, minutes and seconds.

The majority of analysers in use with saturation systems are robust machines that act individually. They usually have only one type of display and are fitted with an audio alarm which is generally reinforced by warning lights *(see in the photo below)*. Note that the analysis of the bell atmosphere is today remote on the wide majority of saturation systems. However, depending on the number of sampling points and analyser available, it is not always possible to analyse the CO2 and O2 at the same time.



Oxygen analysis may be carried out using a fuel cell analyser or a magneto-dynamic cell (also called paramagnetic).

- Fuel cell analysers are the more widely used because they are robust, lightweight and suitable for remote readings.



The device attached to the gauge allows either a measurement of the partial pressure or a measurement in expanded gas (percentage).

- The O_2 sensor acts as a battery.
- The difference of potentials between anode and cathode is going to be proportional to the quantity of oxygen which will go through a semi-permeable membrane (capillary barrier) and will ionise at the contact with the cathode and will oxidise the anode.
- The lead anode and copper/beryllium cathode are plunged in an electrolyte (a solution of potassium hydroxide).
- A semi-permeable membrane allows the gas to pass through and forbids the electrolyte to follow.
- Between the anode and cathode a thermo-regulator compensates the temperature variations.

The cell may be fitted inside or outside the analyser with the gas sample flowing over it, or placed in a chamber and connected to the analyser in the control room.

A fuel cell analyser should be calibrated with a zero gas and scale gas, but it must be noticed that a lot of new models can be calibrated with air (for example : "Analox" O_2EII). The calibration with air is based on the fact that fresh air has a proportion 20.9% oxygen. To increase accuracy, the manufacturers provide a humidity compensation chart with each instrument, to show whether to use 20.9% or some slightly lower value when calibrating. Calibration with air can be considered reliable for surface supplied diving, nevertheless the monitoring of saturation diving requires more accuracy, and the use of calibration gas instead of air is recommended.

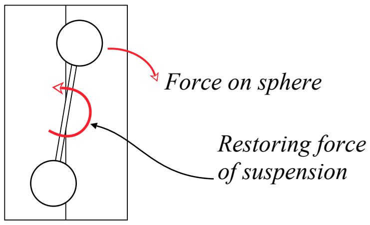
If the fuel cell is placed in a chamber, it can only be calibrated when the chamber is on the surface, or by reference to another analyser sampling the gas on the surface.

A fuel cell in the chamber can only be used as a guide to the PPO_2. Errors may be caused by condensation on the fuel cell, changes in chamber temperature, changes in the temperature of the wires carrying the signal to the analyser and radio transmissions and other electromagnetic fields.

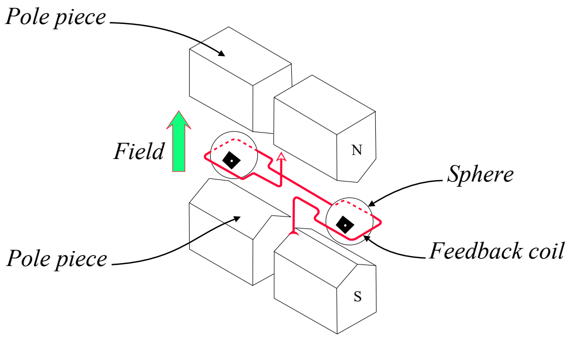
Since the fuel cell is a battery, it will run out, normally in about six months, but depending on the concentration of oxygen in the gas analysed, it will often be less. Erratic reading is an indicator that the cell needs to be changed.

- Magneto-dynamic (Paramagnetic):
  This system is based on the measures of the paramagnetic susceptibility of the sample gas by means of a proven magneto-dynamic type measuring cell.
  The paramagnetic susceptibility of oxygen is significantly greater than that of other common gases. This means that oxygen molecules are attracted much more strongly by a magnetic field than are molecules of other gases, most of which are slightly diamagnetic (repelled by a magnetic field).

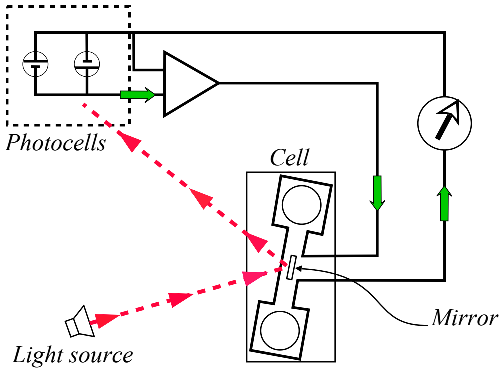
Magneto-dynamic oxygen analysers are based upon Faraday's method of determining the magnetic force developed by a strong non-uniform field on a diamagnetic test body suspended in the sample gas. The test body of all measuring cells oxygen analysers consists of two nitrogen filled quartz spheres arranged in the form of a dumb-bell.



A single turn of fine platinum wire (the feedback coil) is secured in place around the dumb-bell. A rugged taut band platinum ribbon suspension, attached to the midpoint of the dumb-bell, positions the dumb-bell in the strong non-uniform magnetic field between the pole pieces of the permanent magnetic structure.



The angular rotation of the dumb-bell is sensed by a light beam projected onto a mirror attached to the dumb-bell from which it is reflected onto a pair of photocells. The difference in the outputs from these photocells is fed to an amplifier whose output is zero when both photocells are illuminated equally.



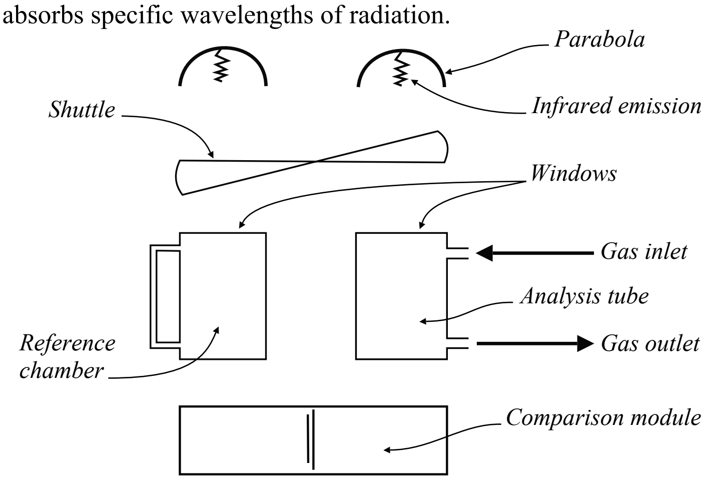
Carbon dioxide analysers rely on the fact that each gas absorbs specific wavelengths of radiation.

Equal infra-red beams of the appropriate wavelength are shone onto two cells. One cell contains a reference gas, and the other cell contains the sample gas.

The sample gas absorbs radiation in proportion to its carbon dioxide content and heats up.

By comparing the temperature rise with the temperature of the reference cell, the proportion of carbon dioxide can be measured.

Calibration normally requires a zero gas and scale gas.

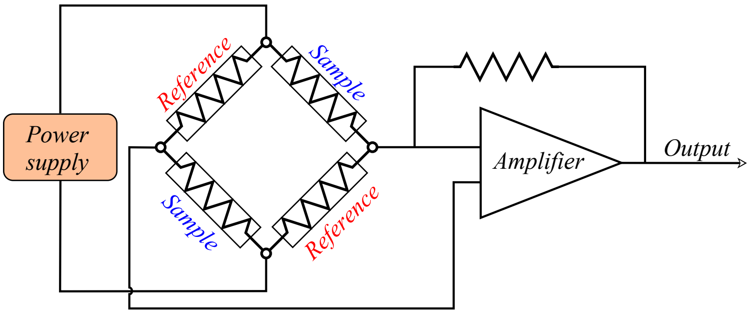


Some analysers require a set up procedure which should be repeated at regular intervals according to the manufacturer's instructions or if it becomes impossible to calibrate the instrument.

Because measurement depends on temperature, it is essential that the analyser warms up to a stable temperature before use. Readings are commonly given in parts per million.

Oxygen and Carbon dioxide can also be detected using thermal conductivity detectors (also called universal detectors):

The system consists of an electrically heated filament in a temperature-controlled cell. Under normal conditions there is a stable heat flow from the filament to the detector body. When a gas is introduced and the thermal conductivity of the column effluent is reduced, the filament heats up and changes resistance. This resistance change is sensed by an electronic circuit which produces a measurable voltage change.
As for the infrared analysers, thermal analysers comprise two chambers, each with an identical thermal conductivity sensor. The reference chamber is filled with a reference gas, and the other receives the gas to analyse. The difference in thermal conductivity of the reference and gas to be analysed is measured and converted into a concentration value by the electronic circuitry in the instrument.



The system can have an accuracy and display precision of around 0.1% when precise temperature compensation is made, and is reputed stable and robust.
Thermal conductivity is used to detect various gases such as:

- Oxygen
- Carbon dioxide
- Carbon monoxide
- Nitrogen
- Hydrogen
- Methane and various hydrocarbons
- Water vapour

The last generation analysers are designed in the same manner than the previous generation. However, electronic continues to progress and offer more functions. Also, manufacturers, such as Fathom systems, a company based in the United Kingdom, group the analysers in modules that are designed to analyse the O_2 and CO_2 at the same time and can display some measurement in different units. As an example, oxygen can be shown in percentage and partial pressure at the same time.
Also, these analysers are connected to a computer system through Ethernet link. Note that the "master" is the oxygen analyser displaying results in percentages and that the other analysers of the group act as "slaves" *(In computer networking, master/slave is a model for a communication protocol in which one device or process, known as the master, controls one or more other devices or processes, which are known as slaves)*. In addition the systems of alarms have been reinforced so the diving supervisor is informed more precisely of the problem occurring. As an example, with the analysers taken as reference, the alarms generated by the system can have one of three different states:

I - No Alarm: All parameters are within the acceptable limits / set-points. In this case, the display is green, the Alarm LED is off and there are no spoken warning messages.

II - Active Alarm: It is caused by a parameter moving outside its alarm threshold set-point (or the set-point being changed to put the parameter into an alarm state). As a result, the display flashes between Red and Green, the Alarm LED on the front panel flashes and warning messages are produced every 30 seconds.

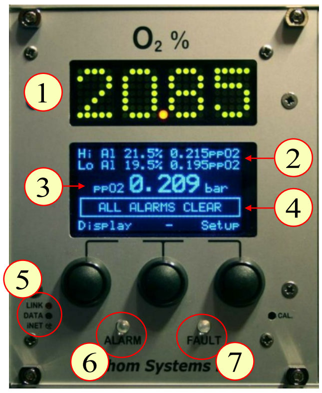
III - Accepted Alarm: An alarm that has occurred has been acknowledged or accepted by the operator (by pressing the appropriate front-panel button). In this case, and provided there are no other active alarms, the display changes to solid red, the alarm LED remains on red (not flashing) and the audible alarm is silenced. This state continues until the parameter returns to a healthy condition or the set-point is modified to be outside an alarm condition.

Note that a second red warning LED that indicates the presence of a fault is on the front panel. This LED flashes and a warning message is generated when there is a system fault present such as follows:

- Incorrect supply voltages
- Failure of sensor sub-systems or components
- Sensors not correctly calibrated
- Missing data communications with external devices / systems
- Internal temperature too high

Also, three additional small LED indicators are on the front panel of the O2 analyser to provide the following information about the telemetry status:

- Link LED indicates when the Ethernet cable is connected to the network.
- Data LED flashes when data is being transmitted or received
- Inet LED flashes when the %O2 master analyser is transmitting data to other modules in the same rack.



#1 Main display (no alarm)

#2 Calibration setup

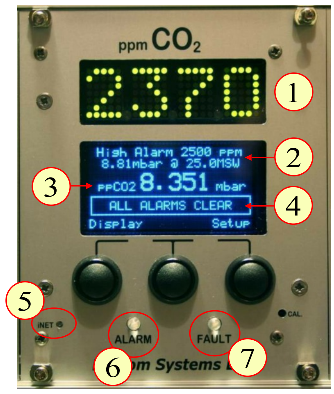
#3 2nd display in Partial Pressure

#4 Alarm display (all clear)

#5 Telemetry status

#6 Alarm LED light

#7 Fault LED light

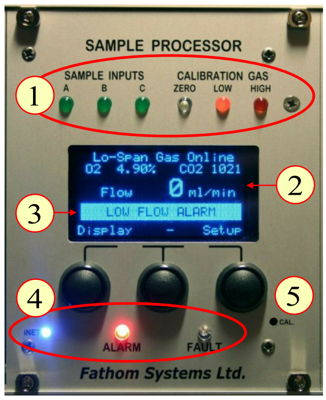


With the new systems described for example, the sample and calibration gases being sent to the CO2 slave and O2 master analysers are managed by the "sample processor", which is a slave module.
With this module, the classical flowmeter that is usually operated manually is replaced by a sensor that measures the mass-flow of gas through the system. The Sample processor automatically calculates the gas density (based on either the known calibration gas oxygen concentration or from the O2 concentration measured by the O2 analyser), and this figure is used to convert the mass-flow measured into a volumetric flow that is displayed on the sample processor displays. The flow rate is normally set between 80 ml/min to 100 ml/min for all gases including calibration gases. Two input versions are proposed by the manufacturer:

A - The single sample version is normally used where the sample to the analyser is not normally changed or 'patched' between different samples. Usually, four quick-connect couplings are available on the rear of the device: One for the zero gas, one for the low span calibration gas, one for the high span calibration gas, and one for the sample to be analysed. However some models have an additional calibration gas (medium).

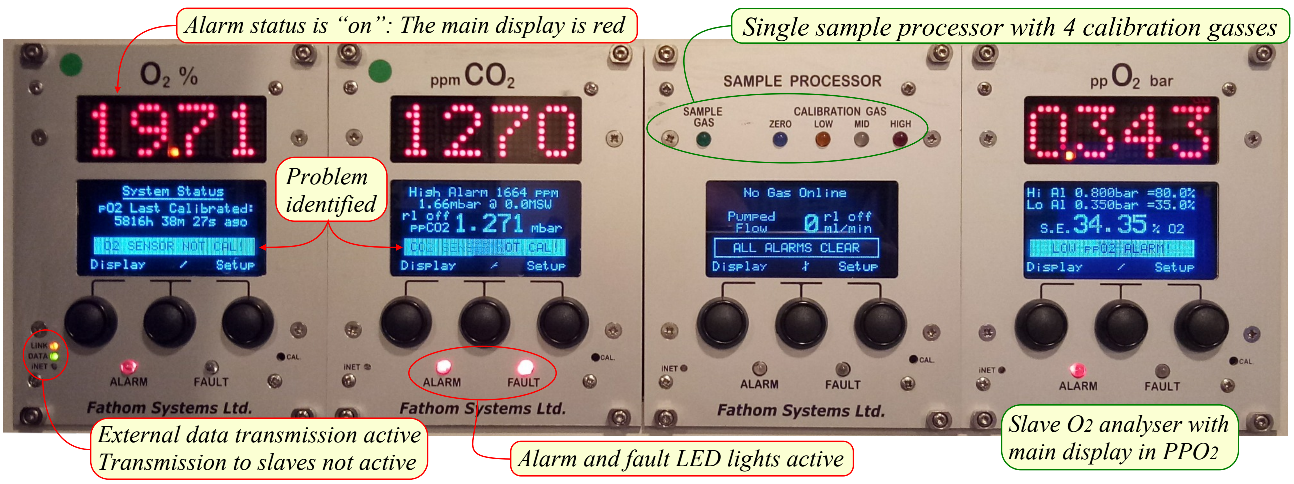
B - The 3-inputs version allows one of three different samples to be selected by the user, and 'switched' internally by the Sample Processor unit. As a result, six quick-connect couplings are available on the rear of the device: One for the zero gas, one for the low span calibration gas, one for the high span calibration gas, and three for the samples to be analysed.

Lights corresponding to the rear inputs are displayed on the front of the device and indicate which gas is monitored by the machine *(see #1 in the photo on the side)*. .
A message is also displayed on the small screen to indicate which operation is ongoing and the flow rate *(see #2)*.
Also, a sample pump is available when there is insufficient pressure from the chambers to allow a suitable sample flow rate at the end of a decompression. However, this pump is normally unnecessary for bell monitoring.
In addition to managing the online gas selection and controlling / measuring gas flow accurately, the sample processor is also able to raise alarms in the event of high or low gas flow conditions, and coordinate an automated calibration process.
Alarms are displayed and processed in the same way as the O2 master analyser *(see #3 & #4 in the photo on the side)*.
The sample processor, and all the analysers can be calibrated using a small screw driver through the hole labelled "CAL" *(see #5)*.

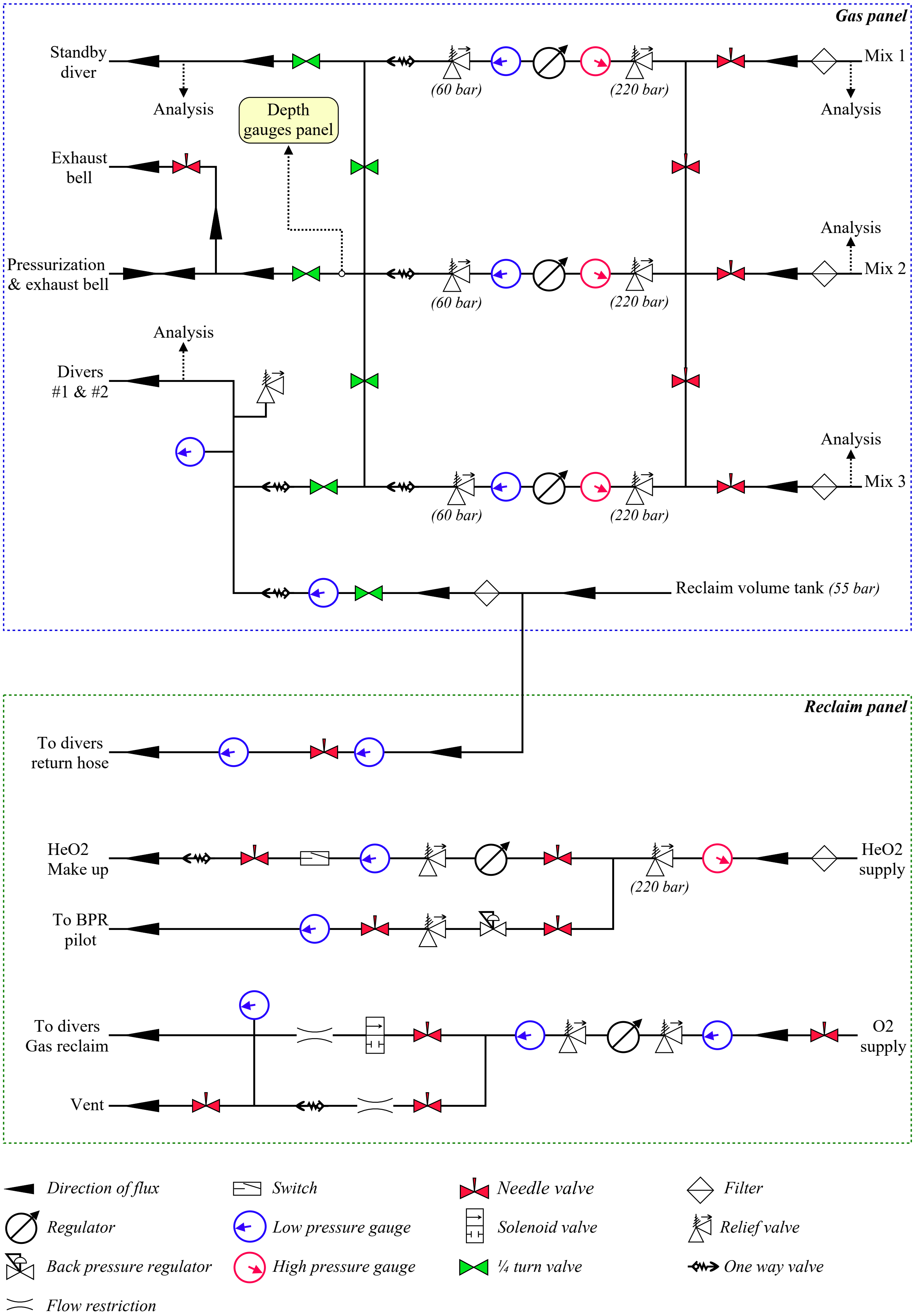


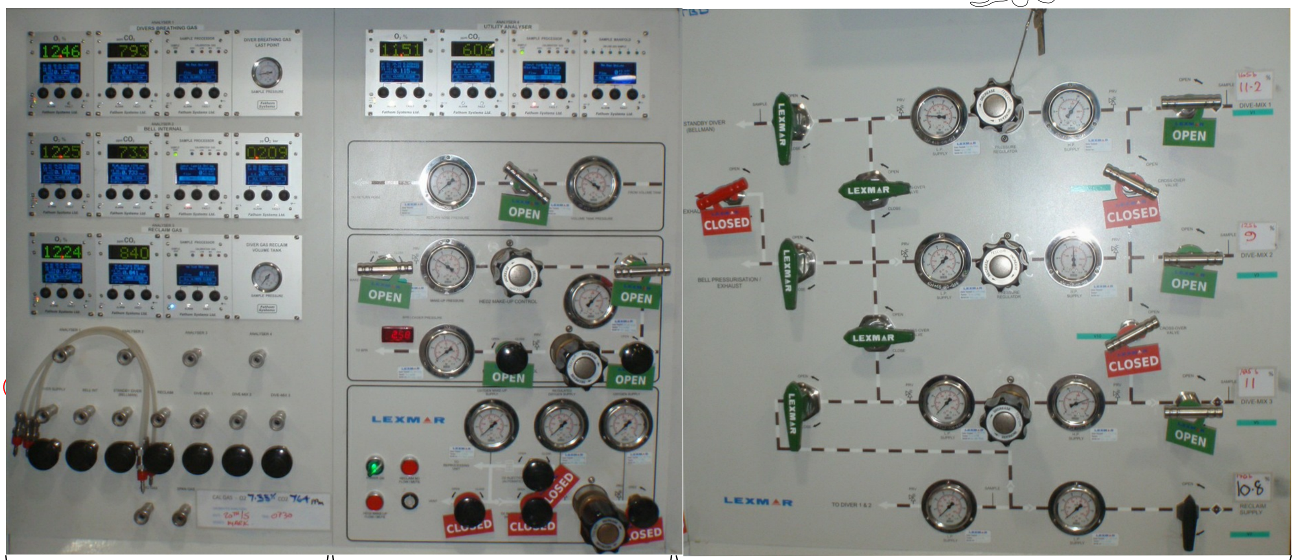
3-inputs sample processor

The photo below shows one of the modules from an analysing panel of a dive system that was not yet fully operational. As a result, the analysers were not calibrated and were raising alarms: We can note the following:



- Oxygen make-up, heliox make-up, and back pressure regulator loader are part of the “reclaim panel", which is supplied by the “gas panel”. As indicated previously, they are situated near the analysis panel in the dive control.
  The scheme below shows the connections between the two panels and the elements of the system they supply. Note that the divers and the bell can be supplied with stored mixes *(Mix 1, Mix 2, Mix 3, HeO2 supply)* or with the gas from the reclaim volume tank. As a result, the divers are not deprived of gas in the case of a problem with the reclaim system.





Analysis panel | Reclaim panel | Gas panel

Panel monitoring the divers' return hose pressure (inlet TRU) and the "volume tank" pressure (outlet TRU), with a cross-over valve allowing to run the system in a closed-loop.

Heliox make-up control & back pressure regulator loading control panel

Oxygen make-up panel

- The "oxygen panel" controls the flow of make-up oxygen into the system.

  As already said, the system is based on high pressure stored oxygen which is injected into the circuit through an adjustable regulator and across a fixed multi orifices injector that restricts its flow to a calculated rate. As a result, a controlled bleed of oxygen is supplied into the system. The flux of oxygen depends on the inlet pressure to the multi orifices injector and the heliox pressure in the circuit where the oxygen is bleed. Thus, too high or low inlet oxygen pressure may result in too much or not enough oxygen in the system. It is the reason that "reclaim tables", where the pressure of the inlet oxygen is indicated according to the depth planned for the operation, are provided. Note that these tables are called "diving tables" by the manufacturer. Gauges are provided to manage the inlet and outlet pressures.

  Lexmar says that if the setting of the regulator is correct, the oxygen flow does not require further adjustments during the dive. Also, the quantity of gas stored in the system is sufficiently large that a change of oxygen uptake rate of the diver will result in a negligible effect during the dive. However, in the case of a change in the proportion of oxygen is noticed, the regulator may have to be slightly increased or decreased to return to the planned value.

  As this system is based on a constant bleed, there must be a device to stop oxygen delivery when the gas flow through the system has stopped unexpectedly. It is achieved by the flow switch, already described in point 2.3.12.3, that closes the oxygen flux automatically in the case that the gas flow in machinery is stopped.

The oxygen make-up panel is designed as follows:

A - The isolation valve allows opening or closing the oxygen supply *(see "Bb5")*.

B - The oxygen supply gauge indicates the pressure available to the system *(see "Gb1")*.

C - The regulator controls the oxygen pressure to the orifice *(see "Reg 3b")*.

D - The solenoid stops oxygen addition when gas flow through the system has stopped *(see "b1")*.

E - The regulator outlet gauge, also called "regulated oxygen supply", indicates the oxygen pressure available to the solenoid valve *(see "Gb2)*.

F - The oxygen orifice regulates the flow of Oxygen to the topside unit *(see "b2")*.

G - The oxygen make-up supply pressure gauge shows the pressure out of the solenoid valve *(see "Gb3")*.

H - The supply receiver pressure gauge indicates the pressure in the supply volume tank in the machinery van *(see "Gb7")*.

I - The exhaust hose (or return hose) pressure indicates the bell divers exhaust hose pressure at the inlet of the Topside Reprocessing Unit (TRU) *(see "Gb8")*.

J - Automatic injection valve: It is kept open during normal diving operations *(see "Vb6")*

K - Manual O2 injection valve *(see "Vb8"): It* can be used to increase the amount of O2 in the system rapidly, but never be used when divers are in the water. The vent valve must be closed while this valve is open.

L - The manual O2 injection orifice is mounted after the O2 injection needle valve to control the amount of oxygen being manually injected into the system *(see "b3")*.

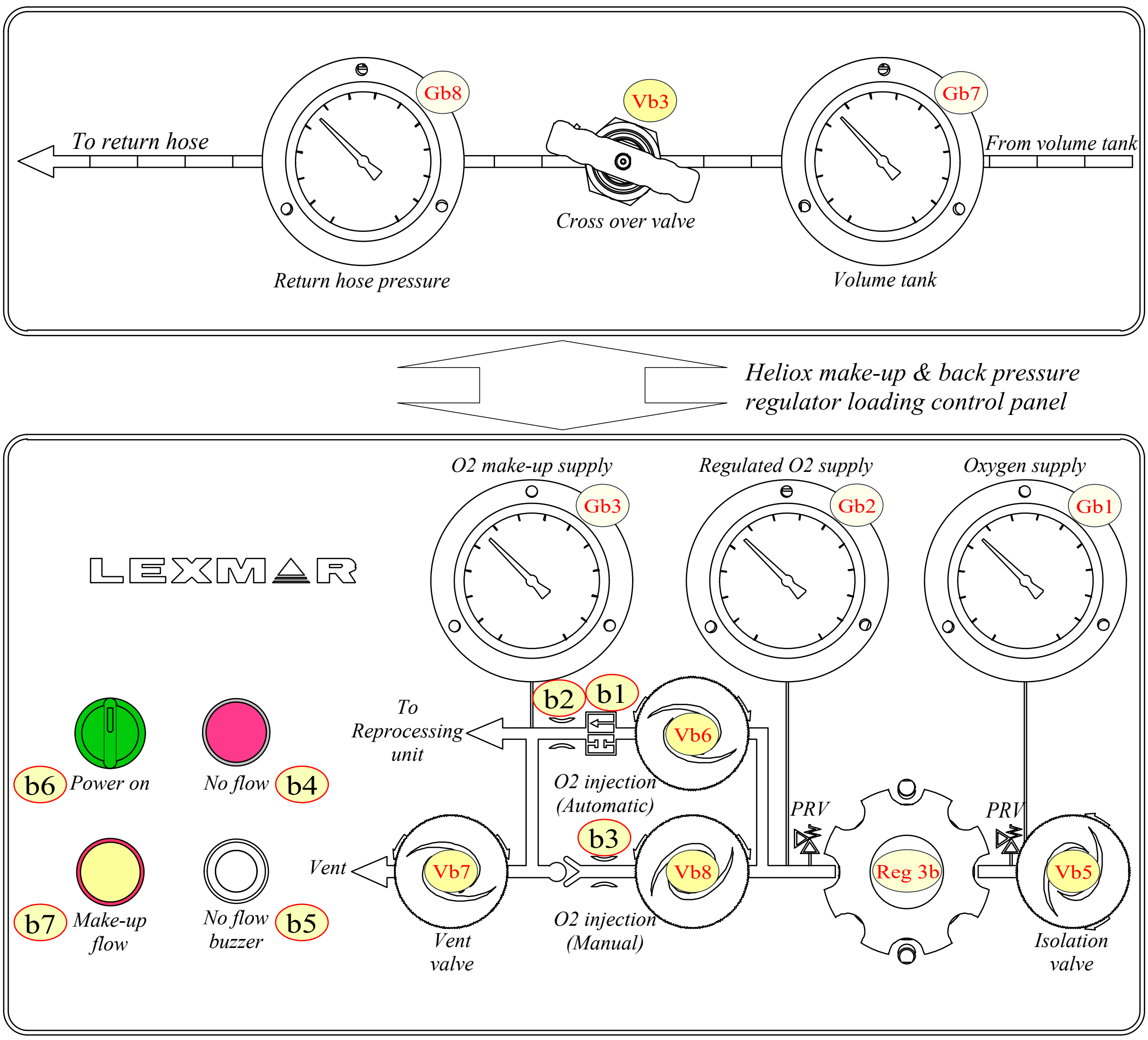
M - Manual vent valve: This valve must remain open to vent any leakage of oxygen that may pass through the manual O2 injection valve while it is closed. Also, it must be closed for manual injections and then reopened when the injection is completed *(see "Vb7")*.

N - The "No flow" LED light indicates that there is no gas flow as a result of the flow switch of the Topside Reprocessing Unit in the "normally closed position" *(see "b4")*.

O - No flow audible buzzer *(see "b5")* will sound to indicate that there is no gas flow as a result of the flow switch of the Topside Reprocessing Unit in the 'normally closed position'. This buzzer can be muted.

P - Power ON / OFF switch allows turning on or turning off the power of the Reclaim Management Panel *(see "b6")*. A green light is illuminated whenever power is on to the Reclaim Management Panel.

Q - Make up flow light is illuminated when make-up gas is flowing into the volume tank.*(see "b7")*.

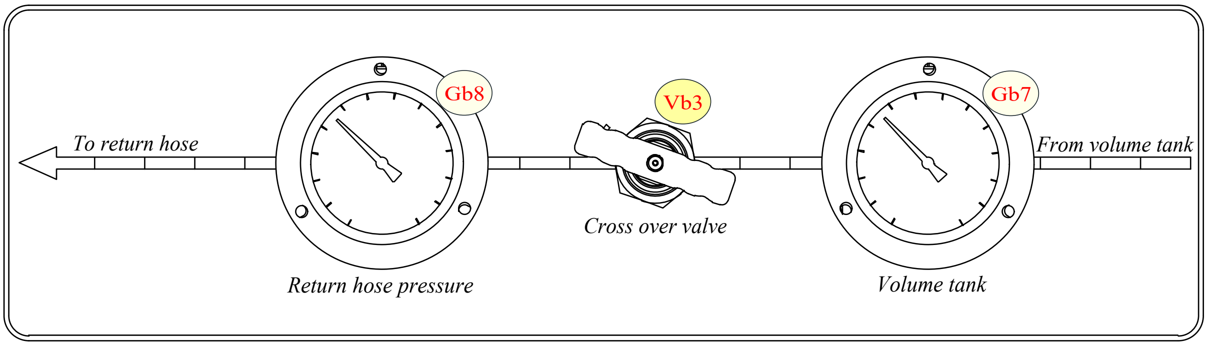


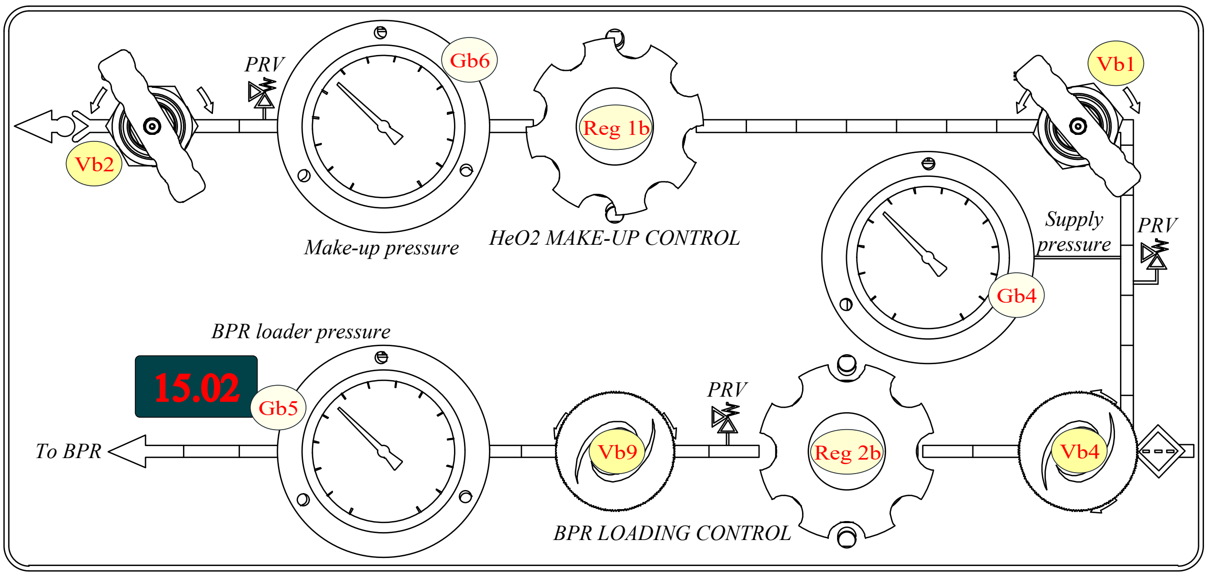
Remember that LEXMAR says the following:

- In operation, the Oxygen shut-off valve *(see "Vb5" in the drawing on the previous page)* is opened and the oxygen regulator *(See "Reg 3b")* set to the value recommended in the divers reclaim table.
- Manual Oxygen make-up should never be carried out while diving is in progress.
- When reclaiming oxygen manually, the supply exhaust cross-over valve *(see "Vb3" in the drawings on the previous page and below)* should be open, and the compressor should be running to provide circulation and mixing through the system.

- The HeO_2 make-up gas panel provides both gas to increase the working depth of the system and make-up for any losses either at the surface or at the diver.
  1 - The HeO_2 regulator is a high flow, self-venting regulator which controls the make-up gas pressure available to the volume tank *(see "Reg 1b" in the drawing below)*.
  2 - The "HeO_2 supply gauge" indicates the HeO_2 pressure available to the make-up system *(see "Gb4")*.
  3 - The "HeO_2 supply valve provides manual shut-off control of HeO_2 to the regulator *(see "Vb1")*.
  4 - The "HeO_2 make-up pressure gauge" indicates the pressure available to the volume tank. The reading on this gauge is the minimum volume tank pressure desired *(see "Gb6")*.
  5 - The "HeO_2 outlet valve" "Vb2" provides manual isolation of the HeO_2 supply system to the volume tank.

- The "Back Pressure Regulator (BPR) loader panel" enables the BPR in the topside reprocessing unit to be remotely loaded. This panel houses the following components:
  1 - The BPR loader supply valve enables manual opening and closing of HeO_2 to the BPR regulator *(see "Vb4" in the drawing below)*.
  2 - The BPR loader regulator allows controlling the BPR load pressure *(see "Reg 2b")*.
  3 - The BPR loader isolation valve provides manual isolation of the BPR loader shut-off valve *(see "Vb9")*.
  4 - BPR loader pressure gauges (analog and digital) indicates what pressure is being felt on the BPR loader. That will vary according to the regulator setting *(see "Gb5")*.
  5 - The cross over valve *(see "Vb3"*), which is already mentioned for manual oxygen reclaiming, allows the flowing of gas directly from the supply to the exhaust side of the system and being stirred up and mixed. <u>It is opened or 'cracked' during initial pressurization of the system or when the compressors are required to be run without the helmets or bell being affected.</u> This valve is also identified in the previous drawing.





1.1.11.5 - System start-up and operational procedures

Reclaim systems are sophisticated equipment. For this reason, the study of the starting procedures published by the manufacturer is the best method to understand how they work.

- Precautions prior to starting the set up procedures:

1. The operator must ensure that the appropriate gases are online. This operation is performed through the gas panel: Three mixes from the gas storage should be online. They are suitable diving mixes for the depth planned and should be analysed using the analysis panel. One mix is selected to supply the gas reclaim system, and the two other mixes can be used as backup, for bell pressurization, and to supply the standby diver umbilical.
2. The selected make-up gas is supplied to the "reclaim panel". Note that in the event that the topside unit operation is interrupted, it will automatically become diver gas supply.
3. Pure Oxygen is required for oxygen make-up.
4. Pure helium should not be connected to the system under any circumstances.
5. The operator ensures that all the valves of the control panels are closed and that the hand-knobs of the regulators have been returned to zero (fully turn the hand-knob anticlockwise and then turn it back ¼ turn)
6. The operator prepares the compressor:
    - He ensures that suitable electrical power is available for the compressor drive motors. It should be 440 Vac/ 60 Hz/ 40 KW for the model taken as an example.
    - He also checks the level of oil and that the cooling system of the compressor is ready for use.
    - The depth of the dive should be indicated to the technician so he can prepare the compressor and switch off the 1st stage of the compressor if the dive is planned at 160 m or below.
    - When the electrical power is supplied, the compressor can be started when the "Start" push button on the electrical panel is pressed.
    - As already said the compressor taken as an example is provided with a computer management system that optimises its performances and protects it from incorrect procedures. This computer is operated through a Human Machine Interface (HMI) that is on the electrical enclosure *(see below).*
      The HMI serves as a graphic interface between the operator and the controlling system
      The various measured values can be read on the screen, and parameters can be entered from there.
      Also displayed are the error messages as and when they occur, as well as warning messages.

7. The scrubbers must be prepared: The Sodalime canisters must be changed and the time required to replace them should be indicated on the control console panel. Note that each scrubber contains 9 litres of soda lime.
   One or two scrubbers are online depending on the duration of the bell run and the number of divers in the water. If only one scrubber is used, the isolation valves of the second one are closed, so it can be online when necessary. The procedure for the change of Sodaline (or Sodasorb) is as follows:
    - Slowly open the new canister inlet, on the bottom of the tower body.
    - Ensure that the flexible hose is connected through the quick connect then slowly open the new canister outlet, on the top of the tower cap.
    - Slowly close the inlet to the used canister; it is on the bottom of the tower body.
    - Slowly close the outlet from the used canister; it is on the top of the tower cap.
    - Slowly open the drain valve at the base of the used canister.
    - Disconnect the quick connect from the top of the used tower when the remaining pressure has been vented.
    - Unscrew the top cap by hand.
    - Remove the internal Sodasorb canister using the handle.
    - Remove the top gauze and empty the contents.

- Fill the canister to two thirds full with Sodasorb (or soda lime).
- Add 100 ml of Purafil (half a cupful).
- Fill to top with Sodasorb (Sodalime).
- Replace top filter gauze.
- Lower the inner canister slowly into the tower body. Ensure that it is seated on the lower seal.
- Inspect the top cap O-ring, clean or replace as required, replace top cap. It is O-ring sealed and seals when hard hand tight.
- Close drain valve at base and reconnect the quick connect hose to the top of the top cap.
- Slowly open inlet valve on the bottom, to pressurize the Scrubber Tower then close the Inlet valve.
- Check for leaks. If no leaks, the refilled canister is ready for use.

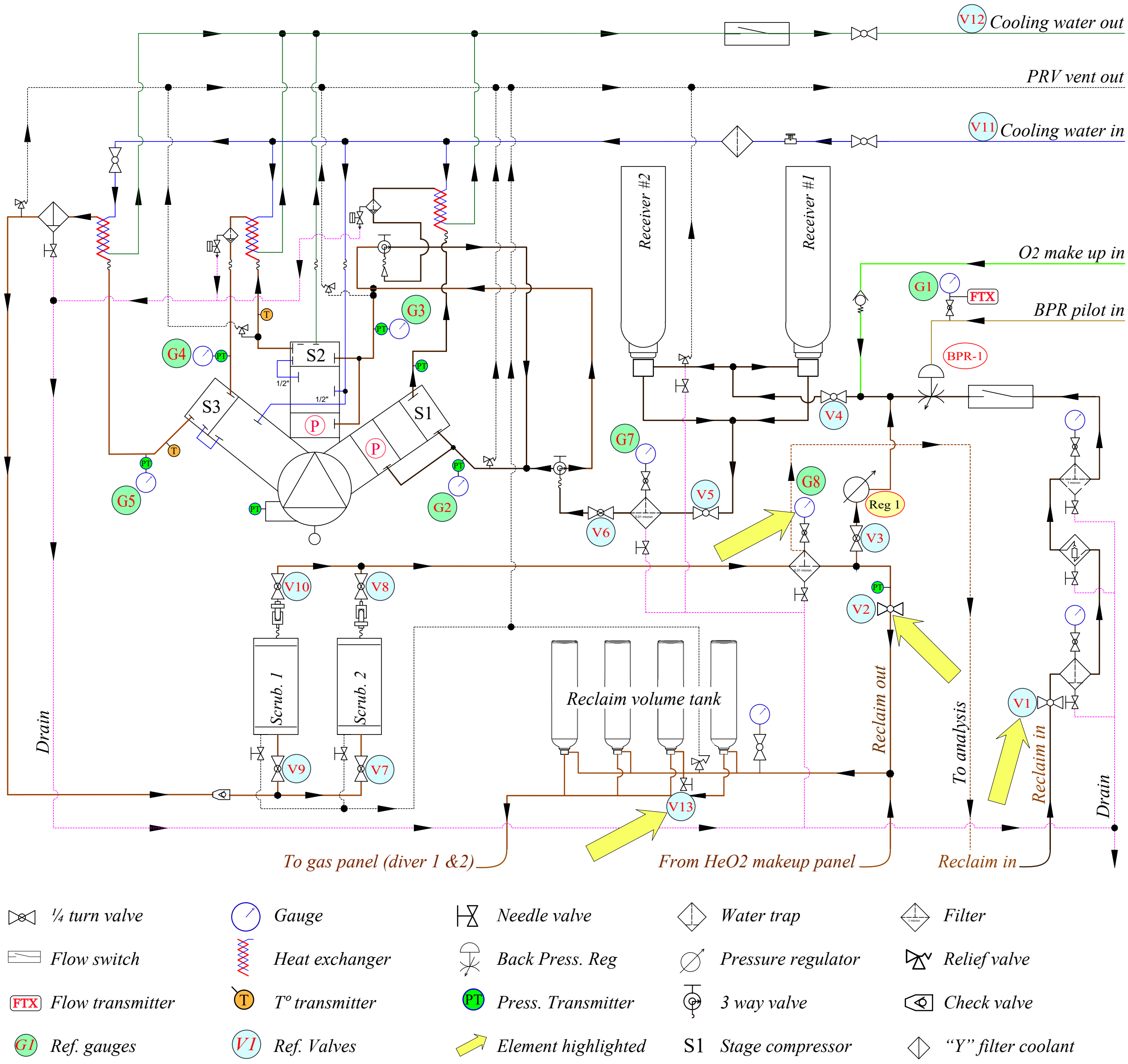
- Top side system setup

1 - Start the compressor:

If the pressure of the reclaim volume tank is below 45 bar, the outlet valve V2 *(See in the drawing below)* on the TRU must be closed prior to starting the compressor. When the compressor is started, the operator waits for the machine to reache its normal speed, then the outlet valve V2 on the TRU is opened again.

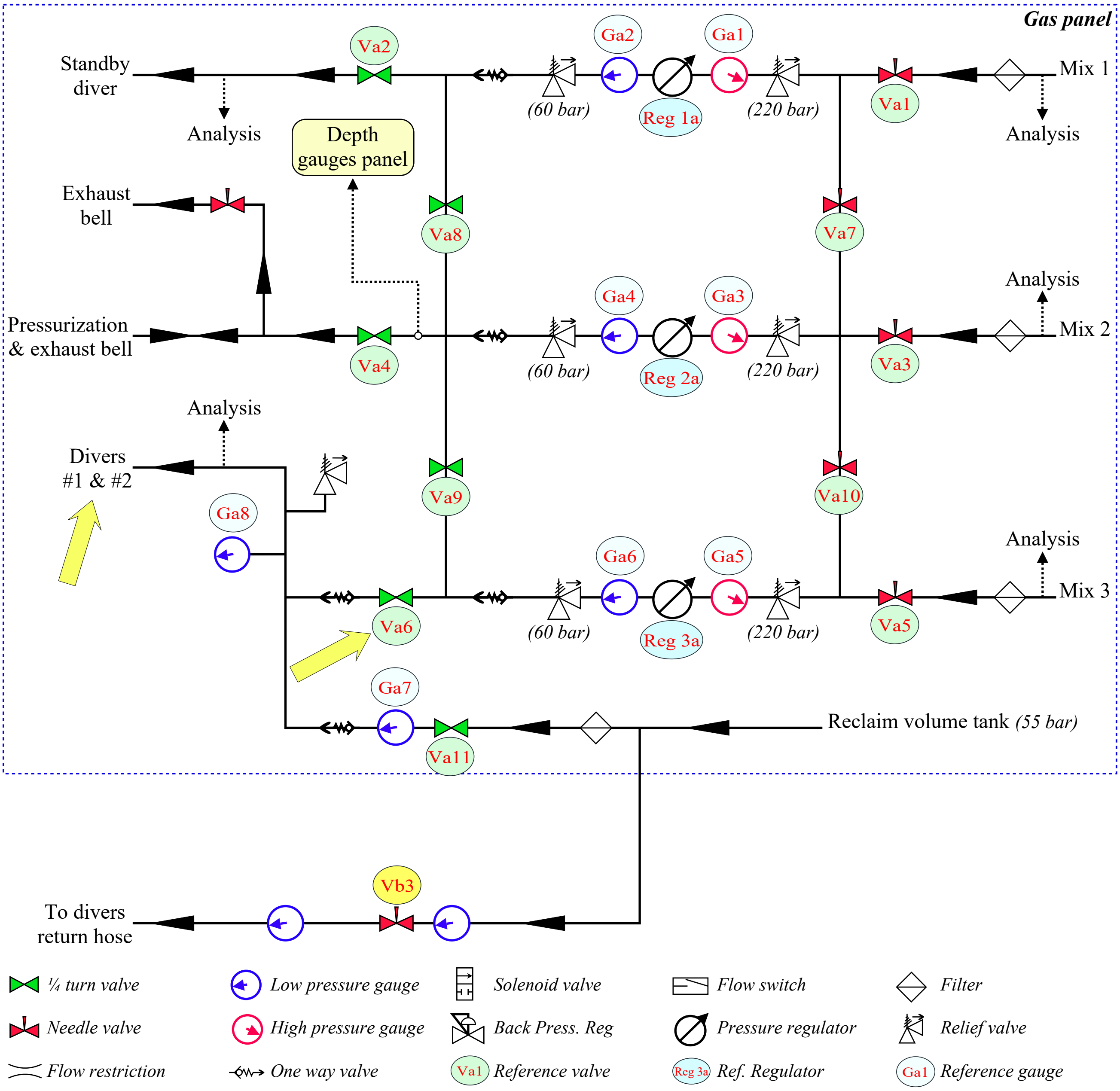
<u>If the volume tank is at a pressure above 45 Bar, the compressor cannot be started</u> due to the high resistance of this pressure. If this is the case a message will come up on the HMI saying “Press. too hi for start” and the amber “warning” pilot light will be on.

- To start the compressor the outlet valve V2 *(See in the drawing below)* on the TRU must be closed, then the the volume tank must be vented using the dedicated valve *(V13)* until the pressure on gauge G8, which is the gauge of the 3rd filter, *(See in the drawing below)* reads below 45 Bar.
- Once the pressure is below 45 bar, the operator can start the compressor and waits for the machine to reach its normal speed, then the outlet valve V2 on the TRU can be opened again.
- When the compressor is started, the volume tank can be pressurized to the required value

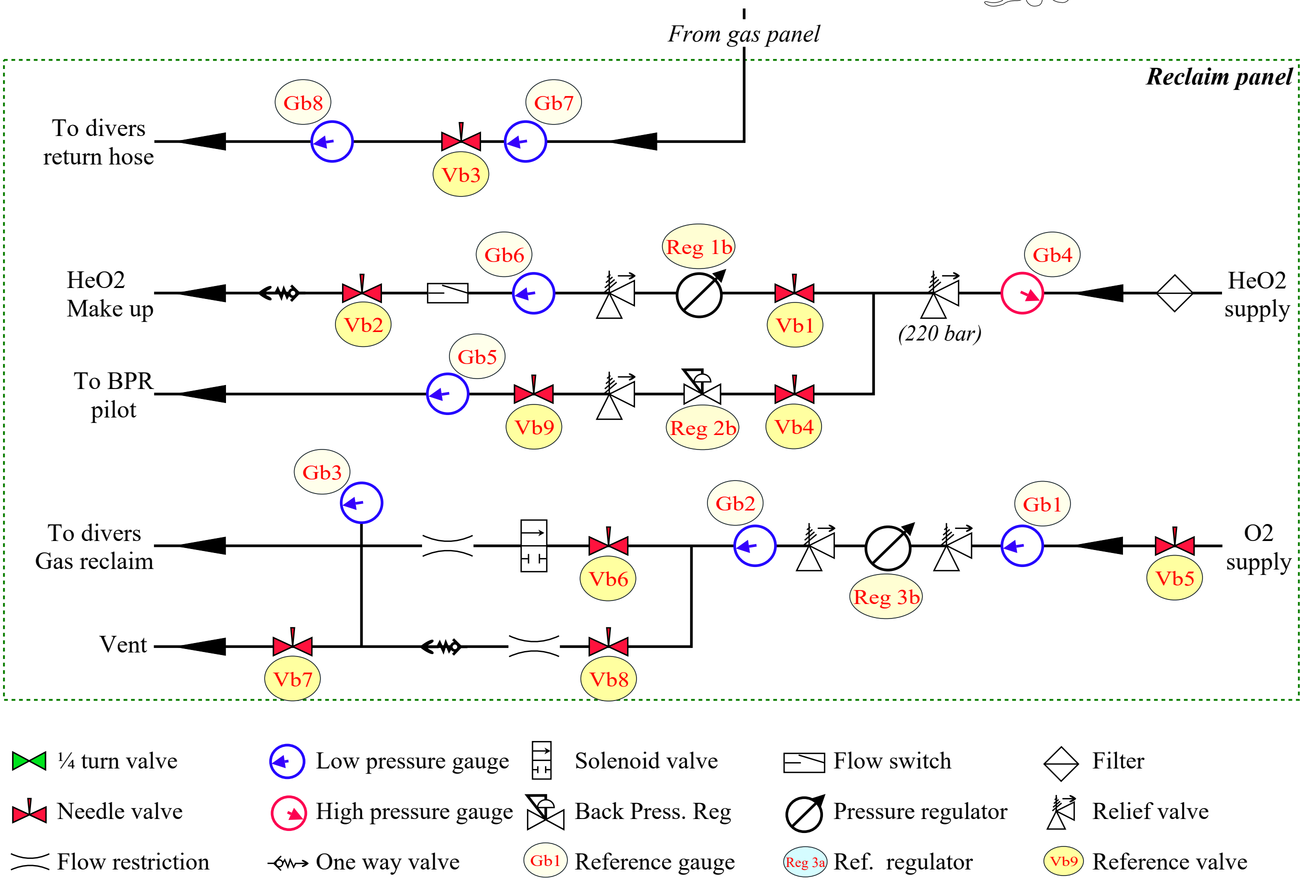


2 - Charge the “reclaim volume tank”:

- On the “gas panel” in the dive control:
  - The operator selects the mix to be used as the source in the reclaim system among mixes 1 *(valve Va1)*, mix 2 *(valve Va2)*, or mix 3 *(valve Va5)*.
  - Then he opens the corresponding valves of mix 1 *(valve Va1)*, mix 2 *(valve Va2)*, or mix 3 *(valve Va5)*, and sets the regulators “Reg 1a”, “Reg 2a”, “Reg 3a” to the correct pressures *(see in the drawing below)*.
  - When the regulators are adjusted to the desired pressures, he uses the cross-over valves Va7-Va10 or Va8-Va9 to supply the "makeup supply valve" Va6 with the mix selected and also have the “standby diver” and “bell pressurization” lines ready for use.
  - When the regulators are set up and the selected mix is supplied to the makeup supply valve “Va6”, and he opens this valve. As a result the selected gas flows to “divers 1 & 2” line.



- On the “reclaim panel” in the dive control:
  - The operator sets the make-up regulator *(see “Reg 1b” in the drawing on the next page)* to the desired “reclaim volume tank” pressure.
  - Then he opens valves “Vb1” and “Vb2”. These valves should be kept open throughout the diving mission. Note that the pressure can be read on the pressure gauge G8 on the TRU *(see in the corresponding drawing)*.
- On the Topside Reprocessing Unit (TRU)
  - The technician ensures that the “Reclaim gas out valve” V2 and “HEO2 makeup inlet valve” V1 are open.
  - He enters the “reclaim volume tank” pressure as an alarm setpoint through the human Machine Interface (HMI). As a result, a warning light is visible if the actual pressure is 3 bar above the set point.



3 - Charge the return line and set up the BPR pilot pressure:

- On the "reclaim panel" in the dive control:
  - The operator opens the supply valve Vb4 and exhaust valve Vb9 *(see in the drawing above)*.
  - Then, he slowly opens the cross-over valve Vb3 until the entire umbilical reaches the bottom depth pressure. Note that the pressure can be read on the pressure gauge G6 on the TRU. When the pressure is reached the valve Vb3 is closed.
  - When the valve Vb3 is closed, the operator sets the BPR *(see "Reg 2b")* to the requested pressure indicated in the "reclaim table".

4 - Set the bypass BPR pressure:

- On the Topside Reprocessing Unit (TRU) and using valve Vb3 on gas the reclaim panel:
  - To prevent the compressor from speeding up during the set-up stage, the operator sets the bypass pressure to 15.5 Bar on the Human Machine Interface (HMI) on the TRU.
  - Then, he starts the compressor and keeps the compressor suction pressure to at least a pressure equal to the bypass pressure set point according to the "reclaim table" with the cross-over valve Vb3 on the gas reclaim panel.
  - When the pressure on the G8 gauge on the TRU is at the required volume tank pressure, the operator stops the compressor
  - The inlet valve V1 on the TRU is closed
  - The operator sets the bypass pressure as a set point on the HMI on the TRU according to the "reclaim table".
  - The operator opens the Back Pressure Regulator "Reg 1" one turn
  - The compressor is started and with "Reg 1" the operator regulates the compressor suction until this pressure has stabilised at the bypass pressure set point according to the "reclaim table".
  - The operator sets the required bypass pressure according to the dive table as a set point on the HMI.

5 - Set the O2 to the required level:

- On the Topside Reprocessing Unit (TRU):
  - The reclaim gas inlet valve V1 is opened.
- On the "reclaim panel" in the dive control:
  - The operator slowly opens the cross-over valve "Vb3" and leaves this valve in this position.
- On the Topside Reprocessing Unit (TRU):
  - When the compressor suction pressure has reached a value higher than the bypass pressure set point, the operator starts the compressor. As a result, the gas is circulating through the volume tank
- On the "reclaim panel" in the dive control:
  - The Oxygen regulator *(see "Reg 3b)* is adjusted to the desired pressure for the planned dive.
  - The valve Vb3 is then closed

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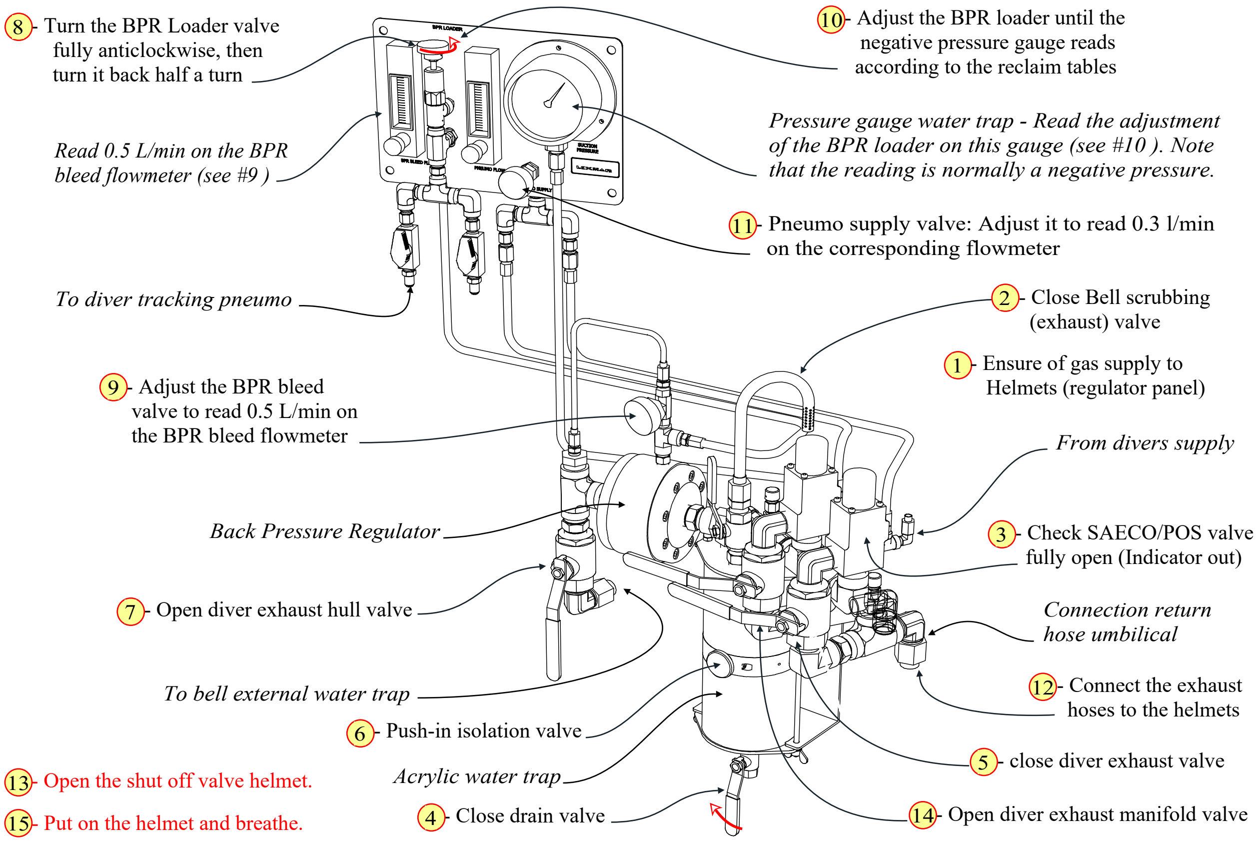
6 - Setting up in the bell

Note: The numbers below are those of the drawing

1. Ensure that Diver has gas supply to helmet (regulator adjusted to the value indicated in the “reclaim table”).
2. Close the bell scrubber valve.
3. Check that the SAECO/POS valve is fully open (The indicator is out).
4. Close water trap drain valve.
5. Close the diver exhaust manifold valve.
6. Push in the water trap isolation valve.
7. Open the diver exhaust hull valve slowly.
8. Turn the BPR Loader needle valve anticlockwise until it stops rotating, then turn back half a turn.
9. Adjust the BPR bleed (metering) valve to read 0.5 L/min on the BPR flowmeter (once set do not re-adjust).
10. Adjust the BPR loader until the negative pressure gauge reads according to the “reclaim tables” *(If using a different brand of helmet than Divex, the manufacturer’s recommendations)*. The Diving Supervisor must advise the divers of the desired negative pressure.
11. Adjust the pneumo supply valve to read 0.3 l/min on the corresponding flowmeter (0.4 l/min maximum)
12. Connect the exhaust hose to the helmet.
13. Open the “shut off valve” of the helmet.
14. Open the diver exhaust manifold valve.
15. Put on helmet and breathe on recovery.



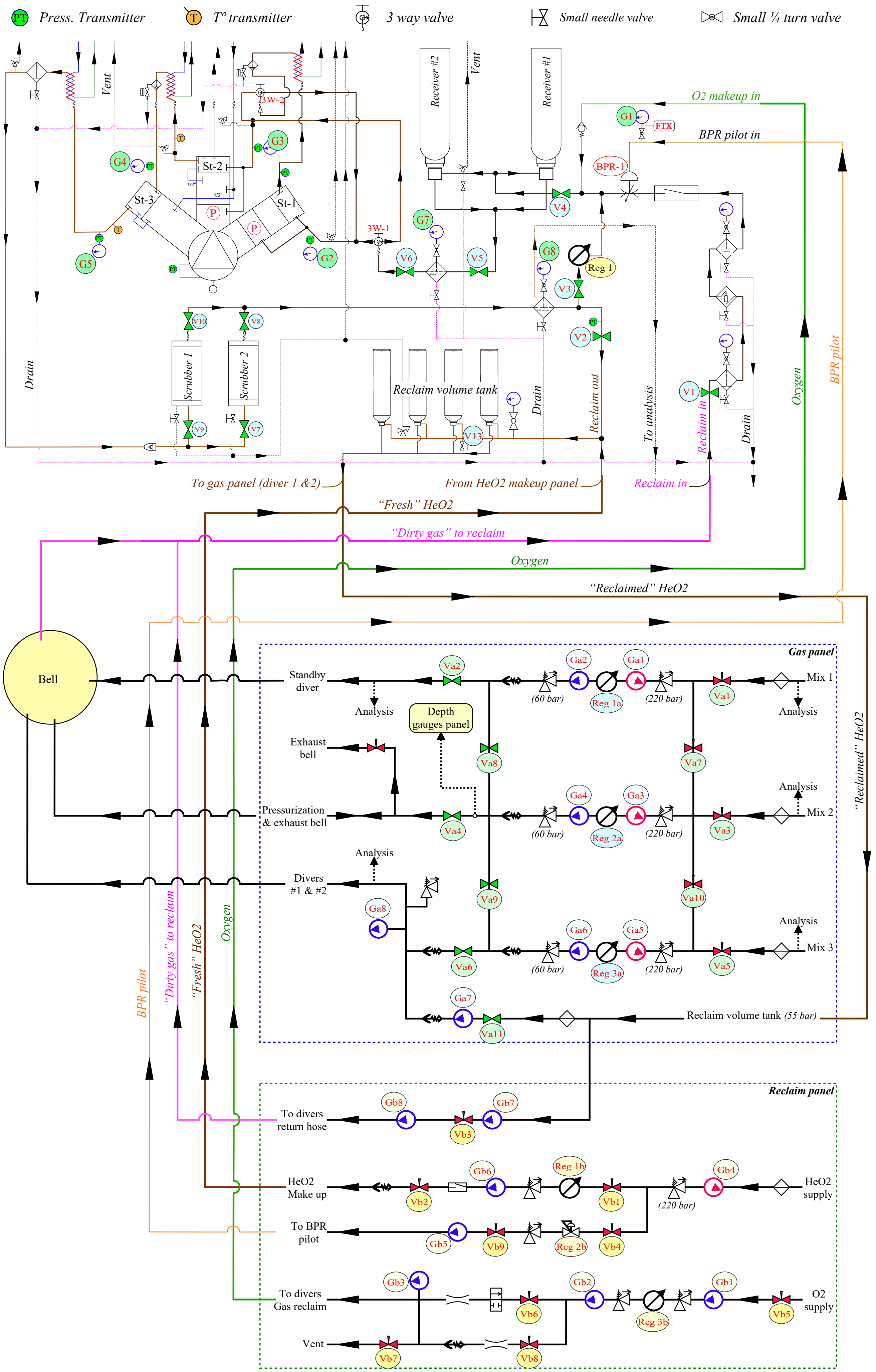
- Important note from the manufacturer of the equipment taken as example regarding shallow diving procedures:
  Diving at depths less than 40 MSW (130 SFW), makes further demands on the system. At shallow depths, the compressors are exposed to the highest-pressure ratio and, as such, shallow diving makes the greatest demands on the compressors.
  For this reason, the regulator settings advised should be rigidly adhered to. Low range gauges are also required for the BPR loader and umbilical suction. It might even be advisable to go for a shorter main umbilical, bypassing the umbilical winch, in order to reduce pressure losses.

1.1.11.6 - General view of the reclaim system

The drawing on the next page gives a general view of the reclaim system and highlights the connections between the panels in the dive control and the Topside Reprocessing Unit (TRU). The legends are those previously used.

¼ turn valve	*Low pressure gauge*	*Water trap*	*Flow switch*	*Filter*
Needle valve	*High pressure gauge*	*Back Press. Reg*	*Regulator*	*Relief valve*
Flow restriction	*One way valve*	*Back Press. Reg*	*Heat exchanger*	FTX Flow transmitter

Hyperlink Tables of contents



1.1.11.7 - Reclaim tables

Lexmar has designed "Reclaim tables" for the correct setting of the equipment *(Note that the manufacturer calls them "diving tables")*. These tables that cover dives from 30 m to 300 m are displayed on the next page.
The elements which are taken into consideration in these "reclaim tables" are those listed in the table below.
They are also described in the method recommended by the manufacturer to set up the system that is explained in the previous pages, and it is crucial not to confuse them with others. For this reason, a description of their function and their situation in the system are provided with the reference numbers used in the drawings displayed on the previous pages.

Elements indicated in the tables	*Description*
Depth	It is the depth of the bell at the lowest level (bottom door). It is the reference from which the other values should be selected when using the tables.
HeO2 make-up regulator "volume Tank" (Bar)	It is the regulator "Reg 1b" which is on the "reclaim panel". The pressure to read is displayed on the gauge "Gb6", which is directly downstream. This regulator feeds the "Reclaim volume tank" of the TRU with "fresh" heliox. Thus when the valve "Vb2" is open, the pressure read on the gauge "Gb6" should be the pressure of the "reclaim out" of the TRU and of the "volume tank", except if their pressure is above the pressure delivered by the regulator *(the regulator "Reg 1b" is isolated by a non-return valve).*
TRU BPR Setting (bar)	The setting of the Back Pressure Regulator "BPR-1" which is on the TRU is made through the regulator "Reg 2b" which is on the "reclaim panel". The setting pressure can be read on the gauge "Gb5" which is directly downstream the regulator "Reg 2b". It can also be read on the gauge "G1" which is upstream "BPR-1" on the TRU.
Compressor Suction Pressure (Bar)	It can be monitored through the "Human Machine Interface" (HMI) and gauge "G2" if 1st stage "St-1" of the compressor is activated, or gauge "G3" if the 1st stage is deactivated.
Stage 1 active	This column indicates whether the 1st stage must be activated or not. Activation /deactivation of the first stage "St-1" is performed through the three-way valves "3W-1" & "3W-2". It can be monitored through the HMI and the inlet gauges G2 (1st stage inlet pressure) or G3 (2nd stage inlet pressure).
Bypass BPR Pressure (bar)	The bypass BPR is the regulator "Reg 1" which is situated on the TRU and allows to bypass into the receivers the excess of gas flowing from the scrubbers to the volume tank, which is the final storage before delivery. It is said in the setup procedure that the pressure of setup can be monitored on gauge "G8" on the TRU. Also, as valve "Vb3" , which is on the "reclaim panel" has to be opened to establish a close circuit during the setup, the pressure of setting can be monitored on gauges "Gb7" & "Gb8" during this time.
Bell Divers Supply Regulator bias (bar)	It is the divers (1& 2) regulator that is situated on the "gas management panel" in the bell. It is also described in point 2.3.2.7 (items 8 & 27) of this document.
Bell BPR Setting bias (msw)	The bell Back Pressure Regulator (BPR) is adjusted through the BPR loader (see #8 in the bell setup procedure) which is situated in the bell. The pressure is read on the pressure gauge which is connected to the water trap and is mounted on the same panel as the BPR loader (see #8 in the setup procedure). Note that this gauge provides positive (overpressure) and negative (depression) values and that the reclaim tables provide negative values as the line should be in a slight depression.
Oxygen regulator setting	It is the regulator "Reg 3b" of the oxygen supply line which is on the "reclaim panel". The reading should be performed on the gauge "Gb2", which is immediately adjacent downstream.

To read the tables, select the planned bell storage depth and read across the corresponding values.

Lexmar also indicates the following elements:

- Weight seawater: 1.025 kg/litre
- Bypass BPR pressure: 0.30 bar below compressor suction pressure
- Required flowrate: 135 lpm at bottom pressure

Depth (MSW)	*Make-up Regulator "volume Tank" (Bar)*	*TRU BPR Setting (Bar)*	*Compressor Suction Pressure (bar)*	*Stage 1 Active*	*Bypass BPR Pressure (bar)*	*Bell Divers Supply Regulator bias (bar)*	*Bell BPR Setting bias (msw)*	*Oxygen Reg'r Setting 1 Diver*	*Oxygen Reg'r Setting 2 Divers*
30	18.6	1	0.9	Yes	12	12	-15	19	40
35	19.3	1.4	1	Yes	0.7	12	-15	19	40
40	19.9	1.9	1.1	Yes	0.8	12	-15	19	40
45	20.6	2.3	1.2	Yes	0.9	12	-15	19	40
50	21.2	2.7	1.25	Yes	0.95	12	-15	19	40
55	21.9	3.2	1.3	Yes	1	12	-15	19	40
60	22.5	3.6	1.4	Yes	1.1	12	-15	19	40
65	23.2	4	1.5	Yes	1.2	12	-15	19	40
70	23.8	4.5	1.6	Yes	1.3	12	-15	19	40
75	24.5	4.9	1.75	Yes	1.45	12	-15	19	40
80	25.2	5.4	1.9	Yes	1.6	12	-15	19	40
85	25.8	5.8	1.95	Yes	1.65	12	-20	19	40
90	26.5	6.2	2	Yes	1.7	12	-20	19	40
95	27.1	6.7	2.1	Yes	1.8	12	-20	19	40
100	27.8	7.1	2.2	Yes	1.9	12	-20	19	40
105	28.4	7.5	2.25	Yes	1.95	12	-20	19	40
110	29.1	8	2.3	Yes	2	12	-20	19	40
115	29.7	8.4	2.4	Yes	2.1	12	-20	19	40
120	3.4	8.8	2.5	Yes	2.2	12	-20	19	40
125	31.1	9.3	2.6	Yes	2.3	12	-20	19	40
130	31.7	9.7	2.7	Yes	2.4	12	-20	19	40
135	32.4	10.1	2.8	Yes	2.5	12	-20	19	40
140	33	10.6	2.9	Yes	2.6	12	-20	19	40
145	33.7	11	3.05	Yes	2.75	12	-20	19	40
150	34.3	11.4	3.2	Yes	2.9	12	-20	19	40
155	35	11.9	3.3	Yes	3	12	-20	19	40
160	35.6	12.3	8.6	NO	8.3	12	-20	19	40
165	36.3	12.8	8.85	NO	8.55	12	-20	19	40
170	37	13.2	9.1	NO	8.8	12	-20	19	40

Depth (MSW)	*Make-up Regulator "volume Tank" (Bar)*	*TRU BPR Setting (Bar)*	*Compressor Suction Pressure (bar)*	*Stage 1 Active*	*Bypass BPR Pressure (bar)*	*Bell Divers Supply Regulator bias (bar)*	*Bell BPR Setting bias (msw)*	*Oxygen Reg'r Setting 1 Diver*	*Oxygen Reg'r Setting 2 Divers*
175	37.6	13.6	9.25	NO	8.95	12	-20	19	40
180	38.3	14.1	9.4	NO	9.1	12	-20	19	40
185	38.9	14.5	9.6	NO	9.3	12	-20	19	40
190	39.6	14.9	9.8	NO	9.5	12	-20	19	40
195	40.2	15.4	10	NO	9.7	12	-20	19.3	40
200	40.9	15.8	10.2	NO	9.9	12	-20	19.7	40
205	41.5	16.2	10.4	NO	10.1	12	-20	20	40
210	42.2	16.7	10.6	NO	10.3	12	-20	20.3	40
215	42.9	17.1	10.8	NO	10.5	12	-20	20.7	40
220	43.5	17.5	11	NO	10.7	12	-20	21	40
225	44.2	18	11.15	NO	10.85	12	-20	21.3	40
230	44.8	18.4	11.3	NO	11	12	-20	21.7	40
235	45.5	18.8	11.55	NO	11.25	12	-20	22	40
240	46.1	19.3	11.8	NO	11.5	12	-20	22.3	40
245	46.8	19.7	11.85	NO	11.55	12	-20	22.7	40
250	47.4	20.1	11.9	NO	11.6	12	-20	23	40
255	48.1	20.6	12.45	NO	12.15	12	-20	23.3	40
260	48.8	21	13	NO	12.7	12	-20	23.7	40
265	49.4	21.5	13.6	NO	13.3	12	-20	24	40
270	50.1	21.9	14.2	NO	13.9	12	-20	24.3	40
275	50.7	22.3	14.8	NO	14.5	12	-20	24.7	40
280	51.4	22.8	14.2	NO	13.9	12	-20	25	40
285	52	23.2	14.55	NO	14.25	12	-20	25.3	40
290	52.7	23.6	14.9	NO	14.6	12	-20	25.7	40
295	53.3	24.1	15	NO	14.7	12	-20	26	40
300	54	24.5	15.1	NO	14.8	12	-20	26.3	40

1.1.11.8 - Routine maintenance and inspection

Periodic maintenance and test should be carried out on a regular basis according to IMCA D 018 and D 024. They are displayed and the end of this document. However, the following rules apply:

Items	*Visual external + function test , calibration*	*Visual internal + external + gas leak test at max. Working pressure*	*Internal + external+ leak test 1,5 max. working pressure*	*Other*
High pressure vessels	6 months	30 months	5 years	
Welded pressure vessels	6 months	30 months		
Relief valves	6 months	30 months		Manufacturers recommendations
Pipework	6 months	24 months	5 years (1st install.)	
Power failure closure oxygen makeup	6 months			
Sensors, alarm & electrical systems.	6 months			Manufacturers recommendations
Analysers	6 months			
Output purity of compressors	6 months			
Delivery and rate of pressure compressors	6 months			
Various mechanical equipment	6 months			Manufacturers recommendations

Maintenance should also be scheduled according to the requirements of equipment manufacturers:
- Topside Reprocessing Unit:

- Filters:
  - They must be drained at least every 4 hours. It is said that, depending on the environmental conditions, Filter 1 (1 micron) should contain about a cup of condensate maximum and that the two others (0.01 micron) should not contain more than a spoon of condensate.
  - It is recommended to change the filters at intervals of 500 operating hours.
- Scrubbers:
  - Cartridges of scrubbers must be renewed after each bell run: A canister assembly is to be changed every 8 hours for 1 diver at work. Thus, the duration of one canister is 4 hours for two divers at work.
  - Filter pads on the top and bottom of the canisters should be renewed every 500 hours.
- Drain valves and float valves:
  - They should be checked every 40 hours.
- Compressors:
  - Oil level should be checked before starting the machine and oil pressure regularly during the operations.
  - Oil + filter should be replaced according to the recommendation of the manufacturer:
    - It is essential to use the quality of oil indicated. Note that the type of oil to be used often depends on the environmental conditions. In addition, some compressors are lubricated with “synthetic oil” and other models accept only “mineral oil”. It must be remembered that manufacturers recommend not mixing a synthetic oil with a mineral one.
    - Environmental conditions and the quality of oil may also influence the frequency of the oil change: It is said that under Normal conditions (no extreme temperatures) some synthetic oils allow being renewed every 8,000 hours of run time or 12 months in the case of moderate use. This frequency drops to approximately 5000 hours with mineral oils. However, this frequency can be as low as every 1000 hours if the machine is exposed to extreme environmental conditions.
  - Coolant should be checked before starting the machine, and the temperature monitored during the operations. It may have to be changed at seasonal periods.
  - The machine should be checked for leaks every day.
  - A lot of manufacturers recommend checking the tension and the alignment of the belt every 2000 hours.
  - Suction, delivery, and pressure relief valves should be controlled according to the recommendations of the manufacturer. It is usually recommended every 1000 hours.
  - Some compressors have parts that are identified as more sensitive to wear than others. As a result, they have to be changed at indicated periods as a precaution.

- Bell:
  Bell equipment requires only a limited amount of maintenance, which may be carried out at a convenient time when the bell is the on surface and depressurized while carrying out the following checklists:
  - Bell internal system:
    - Acrylic water trap drained as required, during the dive (without interrupting gas recovery).
    - Water trap dismantled, cleaned and inspected every 500 hours
    - Check the condition and operation of SAECO/ POS valves and relief valves every 3 months.
    - Over a period of time the acrylic housing of the Bell internal water trap and the flow meters will become discoloured. This may be removed by washing in warm BIOX or other detergent and flushing with clean water. Note that the Flow meter must be internally dried when reinstalled on the system.
  - Bell external system
    - The Bell external water trap should be drained upon completion of each dive, or prior to the Bell being redeployed
    - Check operation of externally mounted check valve very 6 months.

4.3.12.9 - Trouble shooting

- System fault

Fault	***Fault diagnosis***	***Action***
High current, high discharge temperature, compressor drive motor amperage high and gas outlet temperature high, despite adequate cooling water flow.	Diving at deeper depths than 160 msw with both stages of the compressor on line.	Bypass the 1st stage of the compressor.
Low suction pressure	BPR loader pressure set too high.	Reset BPR loader pressure.
	Filters #1 & #2 chocked	Change the filters
High Pressure reading on the return hose	Return line set too high	- Load the regulator to 3 bar less than working depth. - Check LP receiver pressure. - Check compressor supply valve is open. - Check oil pressure and high temperature. - Switch the compressor off.

- Bell equipment fault

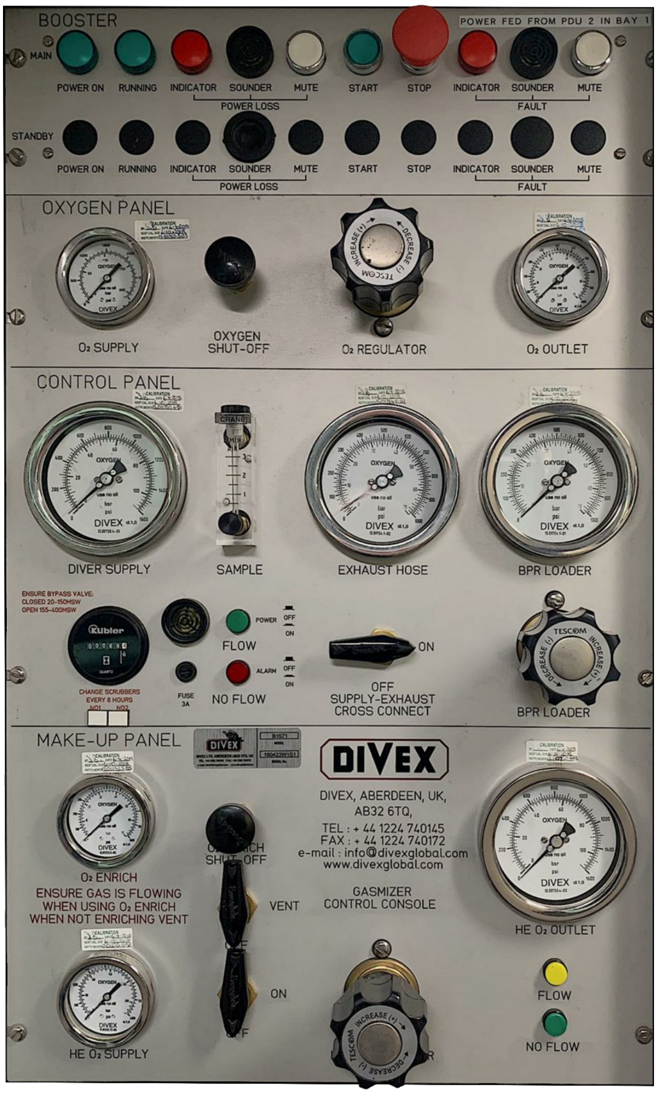
Fault	***Fault diagnosis***	***Action***
Volume tank relief valve popping off	Diver supply valve closed	Reduce volume tank pressure and slowly open diver supply valve.
Suction pressure loss at helmet: The diver loses suction at the valve and finds difficulty exhaling. As a result, the diver goes on “Open Circuit”.	Suction dropping off due to insufficient topside unit pumping capacity.	Ensure that the compressor is operating correctly
	SAECO/POS valve shut, closing off exhaust circuit. The bellman should check the pin on the SEACO/POS valve: The pin should be out.	Ensure that the diver has adequate supply pressure of 12 bar recommended in the reclaim table from the bell panel and the surface. Check whether the bellman has turned the diver’s supply gas off.
	Bellman may have shut diver exhaust manifold bell water trap	Open valve
	Hull exhaust valve may have been closed by mistake.	Open hull exhaust valve.
	Diver working above Bell & tracking pneumo not following the diver.	Reclaim should resume when diver goes below the Bell. Or Adjust diver tracking pneumo to give a bleed of approximately 0.3 to 0.4 litres per minute.
	BPR loader in the Bell not set up properly.	The bellman closes the diver manifold exhaust valve and sets up again the pre-dive checks. *(See points 5 & 14 in the bell setup procedure)*.
	Main umbilical hose collapsed, or/and main umbilical return shut off valve closed.	Replace hoses or cut back flattened area. Open main umbilical shut off valve slowly.

Fault	***Fault diagnosis***	***Action***
Suction pressure loss at helmet: The diver loses suction at the valve and finds difficulty exhaling. As a result, the diver goes on "Open Circuit". *(Continuation of the previous page)*	Bell umbilical and external water trap filled with water.	- The dive may be continued by backing off BPR loader slightly in the dive control. - Set up to 1 bar below the recommended value. - Drain the umbilical and water traps at the end of the bell run and check for a loose fitting on the outside of the bell and on the helmet. - Ensure that divers' helmet and mask are in good condition and not leaking water and the oral-nasal properly fitted to lower exhaust connectors. - Most importantly, the bellman must always drain the internal water trap when it is filled with water.
Volume tank pressure increase: Pressure increase in the system volume tank when make-up regulator is not flowing.	Diver using standby onboard gas instead of umbilical supply in the Bell.	Diver to be put on umbilical supply.
	Standby gas supply being used as umbilical supply and coming back up the exhaust hose to the volume tank.	Regulate standby gas below make-up regulator pressure.
Volume tank pressure increase: Pressure increase in the system volume tank when make-up regulator is not flowing. Gas escaping from the Bell into the exhaust circuit and the Bellman has to blow down regularly to prevent water coming up the Bell trunk.	Bell scrubbing valve open.	Close the valve *(see point 2 in the bell setup procedure).*
	Bell water trap drain valve open with isolation valve pushed in	Close the water trap drain valve *(see point 4 in the bell setup procedure).*
	Leaks at inward relieving valves on umbilical fitting below diver umbilical exhaust manifold	Check for gas being sucked into the valves. Also, check that the relief valves on top of the water trap are not relieving inwards. Removing the caps may be necessary for these checks.
	Metering valve BPR *(also called "bleed valve BPR")* opened too far	Set "BPR bleed valve" as per bell setup procedure *(see point 9 in the bell setup procedure).*
	Hose to helmet disconnected and manifold valve knocked open	Close the valve of the diver's umbilical exhaust *(see point 5 in the bell setup procedure).*
	O-rings on isolation valve damaged or water trap large O-rings leaking	Replace the damaged O-ring
Gas losses: A great deal of gas used for the dive but the diver assures the supervisor that he is on closed circuit and losing very few bubbles at his helmet	Loose fittings on the outside of the bell or the inside of the bell losing gas.	Check for leaks in the diver's supply. Tighten loose fittings
	Diver tracking pneumo flow set far too high.	Set to correct flow in the bell of 0.4 litres/min. maximum. When the diver leaves the bell there should be one bubble every 10-20 seconds at the tracking pneumo end on his umbilical
No gas coming back from diver	Umbilical return line pressure too low.	Ensure that the umbilical return line is pressurised when lowering the Bell into the water.
		Ensure the proper setting on return line loader. Visually check end of hose at Bell for flattening.

1.1.11.10 - Divex bell reclaim system

The 1st Divex bell reclaim system has been proposed to manufacturers and owners of existing saturation systems during the eighties, and from this 1st launch, its general architecture has remained the same over the years. As a result, it is currently the most employed bell reclaim system in the world.
The general design of the Divex and Lexmar systems is very similar. As a conclusion, it is reasonable to say that the diving personnel using one of these systems should be able to adapt to the other one quickly. Note that Lexmar and Divex are two companies of the JFD group.
Apart from some minor details, the commands in the bell are the same and situated at the same places. However, there are some differences between the topside reprocessing units. Also, the control panels that are installed in the dive control provide similar functions, but their commands are arranged differently. For this reason, a comparison of these elements is necessary for a smooth transfer from one system to the other.

- The main difference of the topside reprocessing unit is the gas booster which is a two piston compressor that delivers 150 l/min with a maximum discharge pressure of 100 bar and is rated to 500 metres depth, while the compressor of the reclaim unit Lexmar model LME-RC-03-S-HY provides 135 l/min at a pressure of 55 bar. Note that the compressor provided by Lexmar is widely sufficient for the diving system it is installed on, because this system is rated for 300 m maximum. Also, the saturation procedures Normam 15 promoted in this manual are limited to 350 m, the US navy procedures to 300 m, and there are currently no published tables allowing deeper depths. As a conclusion dives to 500 m depth are to be considered experimental dives only.
  Note that the commands of the system Divex are electro-mechanical while the system Lexmar is managed through a computer. As a result, there is not a Human Machine Interface (HMI) where menus and alerts are displayed with the system Divex. Nevertheless, audio and visual alarms are provided on the machine and in the dive control.
  Note that similarly to the compressor used with the system Lexmar, the 1st stage of the compressor Divex is to be disconnected for dives below 150 metres depth.
- The reclaim control panel of the system Divex includes a module for the control of the compressor, which is not installed on the Lexmar one where a computer controls the system through the Human Machine Interface (HMI) which in on a separate console. The Last generation of Divex reclaim panel is organised as follows:



Booster panel:
It provides essential information and alarms regarding the booster.
Note that the line "stand by" is in the prevision of an optional second booster.

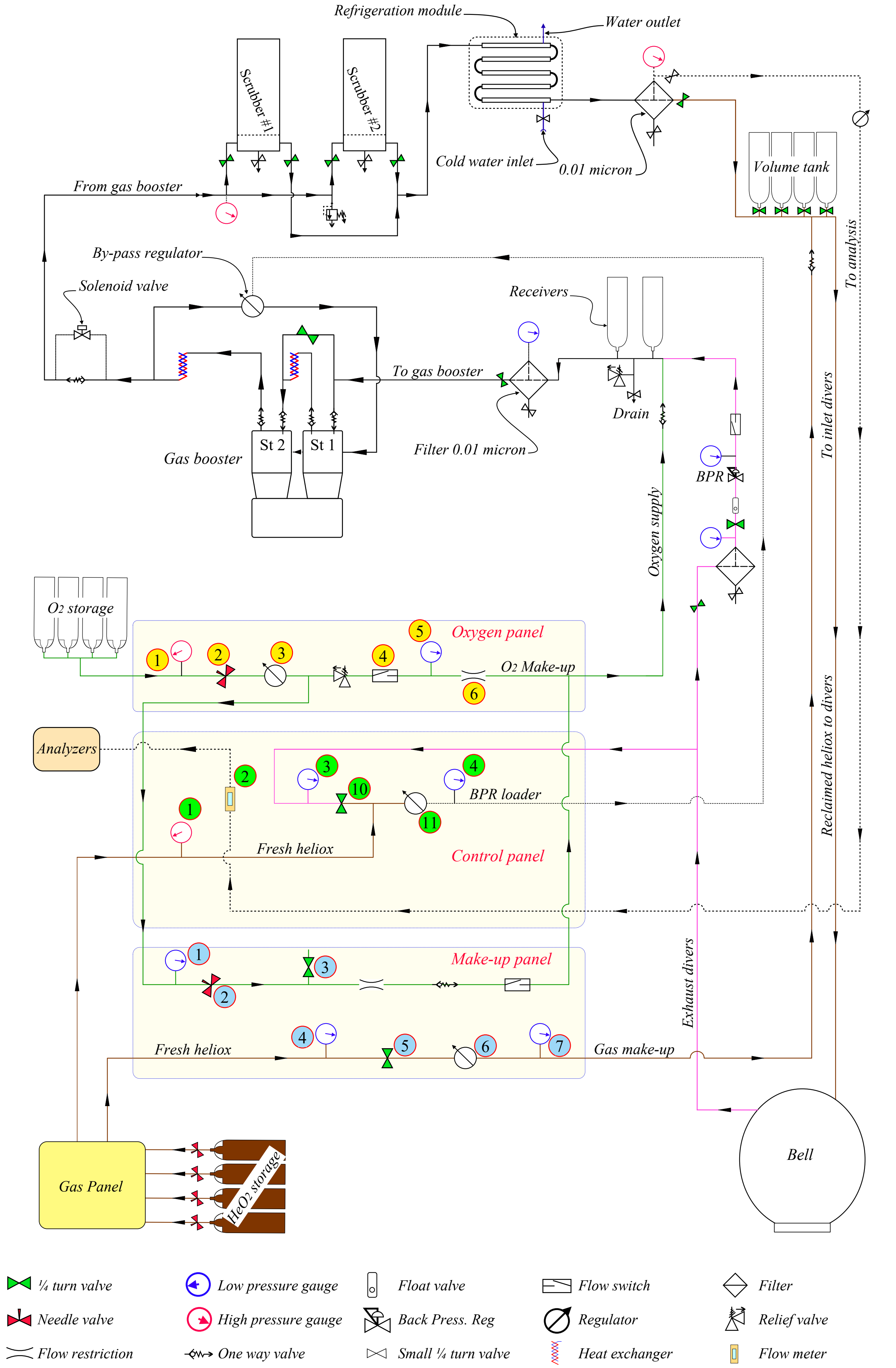
Oxygen panel:
Opposite to the panel from Lexmar, it is installed at the top of the reclaim panel and the manual enrichment of oxygen is not operated from this panel, but from the "Make-up panel".

Control panel:
Its 1st function is to control the back-pressure regulator of the topside reprocessing unit. On the system Lexmar, it is performed through the regulator reference "Reg 2b" (see in the drawings) which controls the BPR "BPR-1"
The 2nd function is to control the pressures in the exhaust hose from the bell and the outlet of the reclaim system and create a closed-loop when the cross over valve is opened. On the system Lexmar, it is done through the gauges "Gb8" & "Gb7", and the valve "Vb3".

Make-up Panel:
It groups the commands for the "heliox make-up control", thus on the panel Lexmar, the function of the gauges "Gb4" & "Gb6", the valves "Vb1" & "Vb2" and the regulator "Reg 1b" (see on the corresponding drawings).
Also, it allows performing manual oxygen injection and venting. On the Lexmar panel, these operations are performed through the valves "Vb8" & "Vb7".

For a better comprehension of this system, it is essential to read the explanations from the manufacturer and check the function of the items using a general drawing of the system which are available on the next pages.

- The general scheme below allows checking the functions of the elements described in the next pages. For this reason, the references numbers of the commands of the reclaim panel are those used in this description.

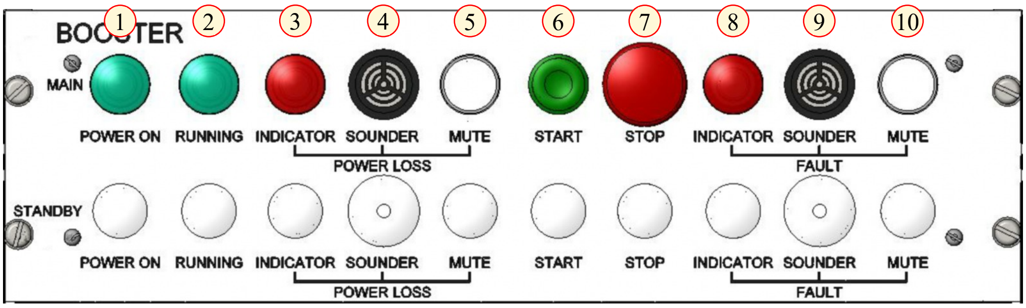


- Booster panel -

The booster panel provides the following commands:

1 - Power on indicator light
2 - Running indicator light
3 - Power loss indicator light
4 - Power loss sounder
5 - Power loss sounder mute
6 - Start push button switch
7 - Stop push button switch
8 - Fault indicator light
9 - Fault sounder
10 - Fault sounder mute

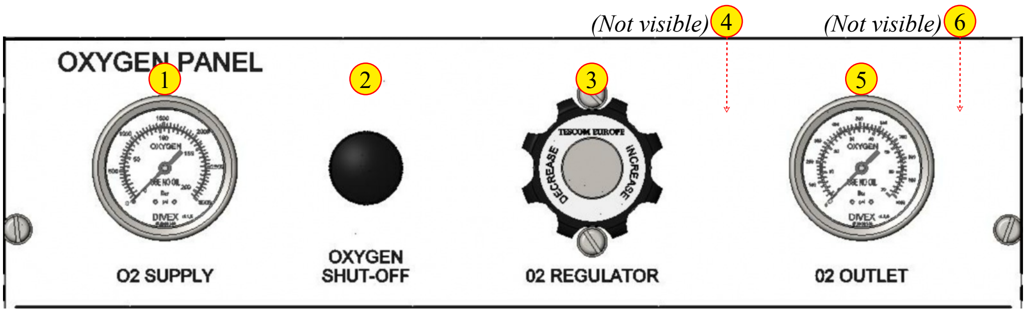
As indicated, a second set of controls can be added for an optional stand-by booster.



- Oxygen panel -

Oxygen panel provides the automatic functions and elements described with the Lexmar system. The commands are the following:

1 - O2 supply gauge – indicates the oxygen pressure available to the system. It corresponds to the valve “Gb1” of the Lexmar system
2 - Oxygen shut-off valve – provides manual isolation of the oxygen supply. It corresponds to the valve “Bb5” of the Lexmar system.
3 - O2 regulator – controls the oxygen pressure to the O 2 orifice. It corresponds to the regulator “reg 3b” of the Lexmar system.
4 - The O2 solenoid – stops oxygen addition when gas flow through the system has stopped *(Not visible)*.
5 - O2 outlet gauge – monitors the oxygen pressure available to the O 2 orifice. It corresponds to the gauge “Gb3” of the Lexmar system.
6 - O2 orifice – multi-orifice restrictor which regulates flow of oxygen to the Reprocessing Unit *(not visible)*.



- Control panel -

The control panel allows monitoring the system operations during a dive. The front panel layout is shown below. In addition to the functions indicated previously, a flowmeter is installed on it to monitor the flow to the analysers. This function does not exist on the Lexmar system where the gas to analyse is directly sent to the analysing panel.

This panel is composed of the following elements:

1 - Diver supply pressure gauge – indicates supply pressure available to the main umbilical. It corresponds to the gauge “Gb7” of the Lexmar system.
2 - Sample flow meter – monitors the sample gas flow to an external gas analyser.
3 - Bell exhaust hose pressure gauge - indicates pressure in the main umbilical exhaust hose. It corresponds to the gauge “Gb8” of the Lexmar system.
4 - BPR loader pressure gauge – indicates the pressure set on the (surface) BPR loader. It corresponds to the gauge “Gb5” of the Lexmar system.

6 - No flow sounder – sounds when gas flow stops.

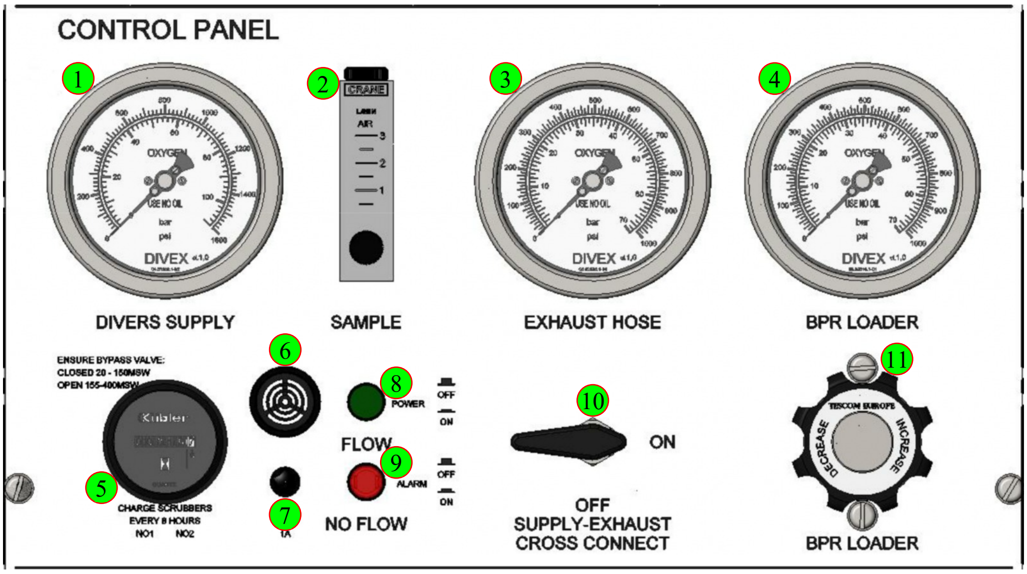
7 - Fuse holder – contains 3 amp fuses for protection of the 12 volt DC power system.

8 - Power switch/flow light – when depressed, the 12 volt DC system is energised. When the green light is on, gas is flowing through the system.

9 - Mute switch/no flow light – when the alarm switch is in the OUT position the alarm will sound if the gas flow stops. When the red light is ON, gas is not flowing through the system.

10 - Supply exhaust cross connect valve – allows gas to flow directly from the supply to the exhaust side of the system during initial pressurisation or when changing gas mixes. It corresponds to the valve “Vb3” of the Lexmar system.

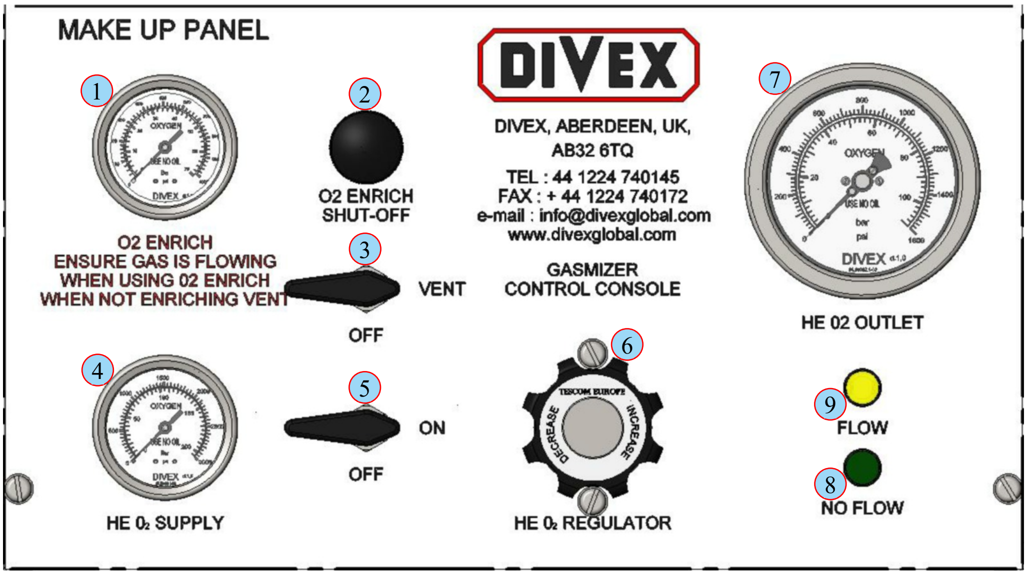
11 - The BPR loader regulator – regulates the pressure set on the Reprocessing Unit back pressure regulator. It corresponds to the regulator “Reg 2b” of the Lexmar system.



- Make-up panel -

As indicated previously this panel provides the make-up gas section which is used to increase the working depth of the system and replace the gas lost, and the manual oxygen enriching section which is used to rapidly add oxygen to the system. As with the Lexmar system, this function must not be used during a dive.

Please remember that this gas comes from the O2 regulator on the oxygen panel *(see in the general scheme)*.



1 - O2 supply gauge – indicates oxygen pressure available to the panel.

2 - O2 supply valve – provides manual shut-off of oxygen to the O2 enriching orifice. It corresponds to the valve “Vb8” of the Lexmar system.

3 - Vent valve – is normally open to prevent accidental addition of oxygen into the system. It corresponds to the valve “Vb7” of the Lexmar system.

4 - The HeO2 supply gauge – indicates the HeO2 pressure available to the make-up system. It corresponds to the gauge “Gb4” of the Lexmar system.

5 - The HeO2 supply valve – provides manual shut-off control of HeO2 to the regulator. It corresponds to the valve “Vb1” of the Lexmar system.

6 - The HeO_2 regulator – is a high flow, self venting regulator which controls the make-up gas pressure available to the volume tank. It corresponds to the regulator “Reg 1b” of the Lexmar system.

7 - The HeO_2 outlet gauge – indicates the pressure available to the volume tank. The reading on this gauge is the minimum volume tank pressure desired. It corresponds to the gauge “Gb6” of the Lexmar system.

8 - The make-up gas flow light – indicates yellow when make-up gas is flowing into the volume tank.

9 - The make-up gas no flow light – indicates green when there is no flow through the make-up gas section.

- Oxygen content management tables:
The make-up panel is provided to allow the oxygen content of the breathing gas to be altered rapidly to a new diving depth. As a result of this depth change, it may happen that the partial pressure of oxygen has to be changed. For this reason, Divex provides tables that should be used to measure the time required to decrease or increase the oxygen content to the desired level.
Note that helium dilution may be achieved by venting the system, partially or completely and re-pressurizing with the appropriate gas mixture.

Table #1: For use with an Air or Electric Driven Gasmizer System. Using 3/4” supply & exhaust umbilicals length of 350 metres.

	Partial pressure oxygen						*Breathing time*		*Oxygen enriching time*				
	Time to drop 0.7 PPO2 to 02 PPO2 with NO oxygen injection (1 diver)						*Time to breathe the same molecule of gas @ 40 lpm*		*Time required to enrich oxygen content with a 40 bar oxygen supply pressure through both the O2 injection systems*				
Depth	***0.7 PPO2***		***0.2 PPO2***		***Time***		***System total***	***Time***	***0.25%***	***0.50%***	***0.75%***	***1.0%***	***1.25%***
msw	%O2	Litres	%O2	Litres	Min.	Hr:Min.	Litres	Min.	Min.	Min.	Min.	Min.	Min.
30	17.5	1700	5.0	485	1013	16:53	9700	60	3	7	10	13	16
40	14.0	1510	4.0	432	898	14:58	1,0800	54	4	7	11	15	18
50	11.7	1400	3.3	400	833	13:53	12,000	50	4	8	12	16	20
60	10.0	1320	2.9	377	786	13:06	13,200	47	4	9	13	18	22
70	8.8	1260	2.5	360	750	12:30	14,400	44	5	10	15	19	24
80	7.8	1210	2.2	344	722	12:02	15,500	43	5	10	16	21	26
90	7.0	1170	2.0	334	697	11:37	16,700	41	6	11	17	22	28
100	6.4	1140	1.8	325	679	11:19	17,900	40	6	12	18	24	30
110	5.8	1117	1.7	318	660	11:00	19,100	39	6	13	19	26	32
120	5.4	1090	1.5	311	649	10:49	20,200	38	7	14	20	27	34
130	5.0	1070	1.4	306	637	10:37	21,400	38	7	14	22	29	36
140	4.7	1050	1.3	300	625	10:25	22,500	37	8	15	23	30	38
150	4.4	1040	1.3	296	620	10:20	23,700	37	8	16	24	32	40
160	4.1	1030	1.2	293	614	10:14	24,900	36	8	17	25	33	42
170	3.9	1020	1.1	290	608	10:08	26,100	36	9	18	26	35	44
180	3.7	1000	1.1	286	595	9:55	27,200	35	9	18	27	37	46
190	3.5	990	1.0	284	588	9:48	28,400	35	10	19	29	38	48
200	3.3	986	0.95	282	586	9:46	29,600	35	10	20	30	40	50
210	3.2	979	0.91	280	583	9:43	30,800	34	10	21	31	41	52
220	3.0	970	0.87	277	578	9:38	31,900	34	11	21	32	43	54
230	2.9	967	0.83	276	576	9:36	33,100	34	11	22	33	44	56
240	2.8	958	0.80	274	570	9:30	34,200	34	11	23	34	46	58
250	2.7	955	0.77	273	568	9:28	35,500	34	12	24	36	48	60
260	2.6	948	0.74	271	564	9:24	36,600	33	12	25	37	49	61
270	2.5	945	0.71	270	563	9:23	37,800	33	13	25	38	51	63
280	2.4	938	0.69	268	558	9:18	38,900	33	13	26	39	52	65
290	2.3	934	0.67	267	556	9:16	40,100	33	14	27	41	55	69
300	2.2	933	0.65	266	556	9:16	41,300	33	14	29	43	58	72
310	2.2	931	0.63	265	555	9:15	42,500	33	15	30	45	60	75
320	2.1	924	0.61	264	550	9:10	43,600	33	16	31	47	63	79
330	2.1	923	0.59	263	549	9:09	44,800	32	16	33	49	66	82
340	2.0	918	0.57	262	547	9:07	45,900	32	17	35	52	69	86
350	1.9	916	0.56	262	545	9:05	47,200	32	18	36	55	73	91

Table #2: Note for use with an electric Gasmizer system (Based on results obtained at NUTEC, March 85) Using 3/4" supply & exhaust umbilicals length - 500 metres.

	Partial pressure oxygen						*Breathing time*		*Oxygen enriching time*				
	Time to drop 0.7 PPO2 to 02 PPO2 with NO oxygen injection (1 diver						*Time to breathe the same molecule of gas @ 40 lpm*		*Time required to enrich oxygen content with a 40 bar oxygen supply pressure through both the O2 injection systems*				
Depth	***0.7 PPO2***		***0.2 PPO2***		***Time***		***System total***	***Time***	***0.25%***	***0.50%***	***0.75%***	***1.0%***	***1.25%***
msw	%O2	Litres	%O2	Litres	Min.	Hr:Min.	Litres	Min.	Min.	Min.	Min.	Min.	Min.
20	23.3	2875.3	6.7	821.5	1711.5	28.5	12322.6	102.7	3.6	7.3	10.9	14.5	18.2
25	20.0	2555.7	5.7	730.2	1521.3	25.4	12778.7	91.3	3.9	7.9	11.8	15.7	19.7
30	17.5	2316.1	5.0	661.7	1378.6	23.0	13234.8	82.7	4.2	8.4	12.6	16.8	21.0
35	15.6	2129.7	4.4	608.5	1267.7	21.1	13691.0	76.1	4.4	8.9	13.3	17.8	22.2
40	14.0	1980.6	4.0	565.9	1178.9	19.6	14147.1	70.7	4.7	9.4	14.0	18.7	23.4
45	12.7	1858.6	3.6	531.0	1106.3	18.4	14603.3	66.4	4.9	9.8	14.7	19.6	24.5
50	11.7	1756.9	3.3	502.0	1045.8	17.4	15059.4	62.7	5.1	10.2	15.3	20.5	25.6
55	10.8	1670.9	3.1	477.4	994.6	16.6	15515.5	59.7	5.3	10.6	16.0	21.3	26.6
60	10.0	1597.2	2.9	456.3	950.7	15.8	15971.7	57.0	5.5	11.1	16.6	22.1	27.6
65	9.3	1534.2	2.7	438.3	913.2	15.2	16437.7	54.8	5.7	11.5	17.2	22.9	28.7
70	8.7	1484.0	2.5	424.0	883.4	14.7	16960.3	53.0	6.0	11.9	17.9	23.8	29.8
75	8.2	1439.8	2.4	411.4	857.0	14.3	17483.0	51.4	6.2	12.3	18.5	24.7	30.9
80	7.8	1400.4	2.2	400.1	833.6	13.9	18005.7	50.0	6.4	12.8	19.2	25.5	31.9
85	7.4	1365.2	2.1	390.1	812.6	13.5	18528.3	48.8	6.6	13.2	19.8	26.4	33.0
90	7.0	1333.6	2.0	381.0	793.8	13.2	19051.0	47.6	6.8	13.6	20.4	27.3	34.1
95	6.7	1304.9	1.9	372.8	776.7	12.9	19573.6	46.6	7.0	14.1	21.1	28.1	35.1
100	6.4	1278.9	1.8	365.4	761.2	12.7	20096.3	45.7	7.2	14.5	21.7	28.9	36.2
105	6.1	1255.1	1.7	358.6	747.1	12.5	20619.0	44.8	7.4	14.9	22.3	29.8	37.2
110	5.8	1233.3	1.7	352.4	734.1	12.2	21141.6	44.0	7.7	15.3	23.0	30.6	38.3
115	5.6	1213.2	1.6	346.6	722.1	12.0	21664.3	43.3	7.9	15.7	23.6	31.5	39.3
120	5.4	1194.7	1.5	341.3	711.1	11.9	22187.0	42.7	8.1	16.1	24.2	32.3	40.4
125	5.2	1177.5	1.5	336.4	700.9	11.7	22709.8	42.1	8.3	16.6	24.8	33.1	41.4
130	5.0	1161.6	1.4	331.9	691.4	11.5	23232.3	41.5	8.5	17.0	25.5	34.0	42.4
135	4.8	1146.8	1.4	327.7	682.6	11.4	23755.0	41.0	8.7	17.4	26.1	34.8	43.5
140	4.7	1133.0	1.3	323.7	674.4	11.2	24277.6	40.5	8.9	17.8	26.7	35.6	44.5
145	4.5	1120.0	1.3	320.0	666.7	11.1	24800.3	40.0	9.1	18.2	27.3	36.4	45.5
150	4.4	1107.9	1.2	316.5	659.5	11.0	25323.0	39.6	9.3	18.6	27.9	37.3	46.6
155	4.2	1096.5	1.2	313.3	652.7	10.9	25845.6	39.2	9.5	19.0	28.6	38.1	47.6
160	4.1	1085.8	1.2	310.2	646.3	10.8	26368.3	38.8	9.7	19.4	29.2	38.9	48.6
165	4.0	1075.6	1.1	307.3	640.3	10.7	26891.0	38.4	9.9	19.9	29.8	39.7	49.6
170	3.9	1066.1	1.1	304.6	634.6	10.6	27413.6	38.1	10.1	20.3	30.4	40.5	50.7
175	3.8	1057.0	1.1	302.0	629.2	10.5	27936.3	37.8	10.3	20.7	31.0	41.4	51.7
180	3.7	1048.5	1.1	299.6	624.1	10.4	28459.0	37.4	10.5	21.1	31.6	42.2	52.7
185	3.6	1040.4	1.0	297.2	619.3	10.3	28981.6	37.2	10.7	21.5	32.2	43.0	53.7
190	3.5	1032.7	1.0	295.0	614.7	10.2	29504.3	36.9	11.0	21.9	32.9	43.8	54.8
195	3.4	1025.3	1.0	292.9	610.3	10.2	30027.0	36.6	11.2	22.3	33.5	44.6	55.8
200	3.3	1018.3	1.0	290.9	606.1	10.1	30549.6	36.4	11.4	22.7	34.1	45.4	56.8
205	3.3	1002.5	0.9	286.4	596.7	9.9	30792.2	35.8	11.5	22.9	34.4	45.8	57.3
210	3.2	998.0	0.9	285.1	594.0	9.9	31364.7	35.6	11.7	23.4	35.0	46.7	58.4
215	3.1	993.6	0.9	283.9	591.4	9.9	31937.2	35.5	11.9	23.8	35.7	47.6	59.5
220	3.0	989.4	0.9	282.7	588.9	9.8	32509.6	35.3	12.1	24.2	36.4	48.5	60.6
225	3.0	985.4	0.9	281.5	586.6	9.8	33082.1	35.2	12.3	24.7	37.0	49.4	61.7
230	2.9	981.6	0.8	280.5	584.3	9.7	33654.6	35.1	12.6	25.1	37.7	50.3	62.8
235	2.9	997.9	0.8	279.4	582.1	9.7	34227.0	34.9	12.8	25.6	38.4	51.2	63.9
240	2.8	974.4	0.8	278.4	580.0	9.7	34799.5	34.8	13.0	26.0	39.0	52.0	65.0

	Partial pressure oxygen						Breathing time		Oxygen enriching time				
	Time to drop 0.7 PPO2 to 02 PPO2 with NO oxygen injection (1 diver						Time to breathe the same molecule of gas @ 40 lpm		Time required to enrich oxygen content with a 40 bar oxygen supply pressure through both the O2 injection systems				
Depth	**0.7 PPO2**		**0.2 PPO2**		**Time**		**System total**	**Time**	**0.25%**	**0.50%**	**0.75%**	**1.0%**	**1.25%**
245	2.7	971.0	0.8	277.4	578.0	9.6	35372.0	34.7	13.2	26.5	39.7	52.9	66.2
250	2.7	967.7	0.8	276.5	576.0	9.6	35944.5	34.6	13.5	26.9	40.4	53.8	67.3
255	2.6	964.6	0.8	275.6	574.2	9.6	36516.9	34.4	13.7	27.3	41.0	54.7	68.4
260	2.6	961.6	0.7	274.7	572.4	9.5	37089.4	34.3	13.9	27.8	41.7	55.6	69.5
265	2.5	958.7	0.7	273.9	570.6	9.5	37661.9	34.2	14.1	28.2	42.3	56.5	70.6
270	2.5	955.9	0.7	273.1	569.0	9.5	38234.4	34.1	14.3	28.7	43.0	57.4	71.7
275	2.5	953.2	0.7	272.3	567.4	9.5	38806.8	34.0	14.6	29.1	43.7	58.2	72.8
280	2.4	950.5	0.7	271.6	565.8	9.4	39379.3	33.9	14.8	29.6	44.3	59.1	73.9
285	2.4	948.0	0.7	270.9	564.3	9.4	39951.8	33.9	15.0	30.0	45.0	60.0	75.0
290	2.3	945.6	0.7	270.2	562.8	9.4	40524.3	33.8	15.2	30.4	45.7	60.9	76.1
295	2.3	943.2	0.7	269.5	561.4	9.4	41096.7	33.7	15.4	30.9	46.3	61.8	77.2
300	2.3	940.9	0.6	268.8	560.1	9.3	41669.2	33.6	15.7	31.3	47.0	62.7	78.3
305	2.2	938.7	0.6	268.2	558.8	9.3	42241.7	33.5	15.9	31.8	47.7	63.5	79.4
310	2.2	936.6	0.6	267.6	557.5	9.3	42814.2	33.4	16.1	32.3	48.3	64.4	80.5
315	2.2	934.5	0.6	267.0	556.2	9.3	43386.8	33.4	16.3	32.7	49.0	65.3	81.6
320	2.1	932.5	0.6	266.4	555.0	9.3	43959.1	33.3	16.5	33.1	49.6	66.2	82.7
325	2.1	930.5	0.6	265.9	553.9	9.2	44531.6	33.2	16.8	33.5	50.3	67.1	83.8
330	2.1	928.6	0.6	265.3	552.7	9.2	45104.1	33.2	17.0	34.0	51.0	68.0	85.0
335	2.0	926.8	0.6	264.8	551.6	9.2	45678.5	33.1	17.2	34.4	51.6	68.8	86.1
340	2.0	925.0	0.6	264.3	550.6	9.2	46249.0	33.0	17.4	34.9	52.3	69.7	87.2
345	2.0	923.2	0.6	263.8	549.5	9.2	46821.5	33.0	17.7	35.3	53.0	70.6	88.3
350	1.9	921.5	0.6	263.3	548.5	9.1	47394.0	32.9	17.9	35.7	53.6	71.5	89.4
355	1.9	919.9	0.5	262.8	547.6	9.1	47966.4	32.9	18.1	36.2	54.3	72.4	90.5
360	1.9	918.3	0.5	262.4	546.6	9.1	48538.9	32.8	18.3	36.6	54.9	73.3	91.6

Note: Table intentionally limited to 360 metres (Normam-15 saturation procedures limited to 350 m)

- Regulator setting guidelines:
These tables have a similar function as those published by Lexmar and explained in point 2.3.12.7.
Divex provides a set for 1 diver and another one for two divers.
The elements indicated in these tables are the following:

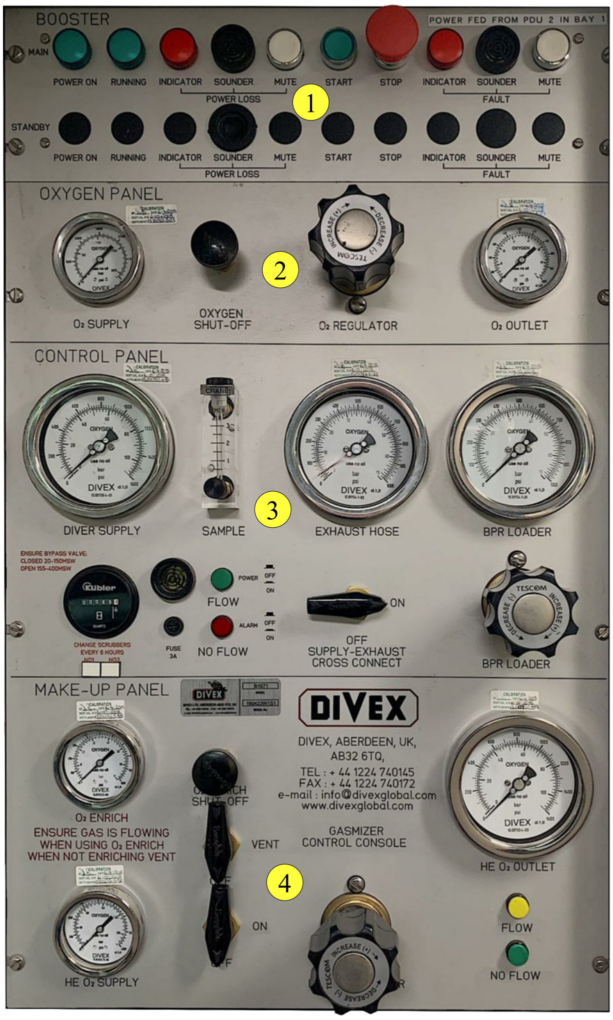
No	***Elements indicated in the tables***	***Description***
1	***Bell depth***	It is the depth of the bell at the bottom of the trunk
2	***BPR loader***	It is the Back Pressure Regulator loader on the “Gasmizer control console”. It sets the main exhaust umbilical pressure.
3	***Make-up reg.***	It is the Make-up regulator on the “Make-up panel” of the “Gasmizer control Console”. It sets the minimum “Volume tank” pressure
4	***O2 reg.***	It is the oxygen regulator on the “Oxygen panel” of the “Gasmizer control console”. This setting will provide 1.2 litres per minute oxygen flow. Occasional adjustments maybe required depending on the diver work rate.
5	***Diver(s) supply (bell)***	It is the divers supply pressure setting on the Bell diver supply regulator.
6	***Bell BPR loader***	It is the bell BPR loader setting required for the Ultrajewel 601 Helmet.

Table 2: Regulator setting guidelines for 2 divers

1	*2*	*3*	*4*	*5*	*6*	*1*	*2*	*3*	*4*	*5*	*6*
Bell Depth	***BPR loader***	***Make-up Reg.***	***O2 reg.***	***Diver supply (bell)***	***Bell BPR loader***	***Bell Depth***	***BPR loader***	***Make-up Reg.***	***O2 reg.***	***Diver supply (bell)***	***Bell BPR loader***
msw	***Bar***	***Bar***	***Bar***	***Bar***	***Msw***	***msw***	***Bar***	***Bar***	***Bar***	***Bar***	***Msw***
30	1	18.6	39	14	-15	***200***	15.5	42	39	16	-21.5
35	1.4	19.3	39	14	-15	***205***	15.9	42.3	39	16	-21.8
40	1.8	20	39	14	-15	***210***	16.3	43	39	16	-22.1
45	2.2	20.7	39	14	-15	***215***	16.8	43.8	39	16	-22.4
50	2.6	21.4	39	14	-15	***220***	17.2	44.6	39	16	-22.7
55	3	22.1	39	14	-15	***225***	17.7	45.3	39	16	-23
60	3.3	22.7	39	14	-15	***230***	18.1	46.1	39	16	-23.3
65	3.7	23.4	39	14	-15	***235***	18.6	46.8	39	17	-23.6
70	4.1	24.1	39	14	-15	***240***	19	47.6	39	17	-23.8
75	4.5	24.8	39	14	-15	***245***	19.5	48.4	39	17	24.1
80	4.9	25.5	39	14	-15	***250***	20	49.1	39	17	-24.4
85	5.3	26.2	39	14	-15	***255***	20.4	49.9	39	17	-24.7
90	5.7	26.9	39	14	-15.2	***260***	20.7	50.7	39	17	-25
95	6.1	27.6	39	14	15.5	***265***	21.3	51.4	39	18	-25.3
100	6.5	28.2	39	14	15.8	***270***	21.7	52.2	39	18	-25.6
105	6.9	28.9	39	14	-16.1	***275***	22.2	52.9	39	18	-25.9
110	7.3	29.6	39	14	-16.3	***280***	22.6	53.7	39	18	-26.2
115	7.8	30.3	39	14	-16.6	***285***	23.1	54.5	39	18	-26.4
120	8.2	31	39	14	-16.9	***290***	23.5	55.2	39	18	-26.7
125	8.7	31.7	39	14	-17.2	***295***	24	56	39	18	-27
130	9.1	32.4	39	14	-17.5	***300***	24.5	56.8	39	19	-27.3
135	9.6	33.1	39	14	17.8	***305***	24.9	57.5	39.1	19	-27.6
140	10	33.7	39	14	-18.1	***310***	25.3	58.3	39.3	19	-27.9
145	10.5	34.4	39	14	-18.4	***315***	25.7	59	39.5	19	-28.2
150	11	35.1	39	14	-18.7	***320***	26.2	59.8	39.7	19	-28.5
155	11.4	35.8	39	14	18.9	***325***	26.7	60.6	40	19	-28.8
160	11.9	36.5	39	14	19.2	***330***	27.1	61.3	40.2	19	-29
165	12.3	37.2	39	15	-19.5	***335***	27.6	62.1	40.4	20	-29.3
170	12.7	37.9	39	15	-19.8	***340***	28	62.9	40.6	20	-29.6
175	13.2	38.6	39	15	-20.1	***345***	28.5	63.6	40.8	20	-29.9
180	13.6	39.2	39	15	-20.4	***350***	29	64.4	41	20	-30
185	14.1	39.9	39	15	-20.7	***355***	29.4	65.1	41.2	20	-30.1
190	14.6	40.6	39	15	-21	***360***	29.8	65.9	41.4	20	-30.2
195	15	41.3	39	15	-21.3	***365***	30.3	66.7	41.6	20	-30.3

Note: Table intentionally limited to 365 metres (Normam-15 saturation procedures limited to 350 m)

Note:
As a proof that this system has remained the same over the years, the comparison of the latest model proposed *(on the left side below)* with the one produced in 1985 under the commercial brand “Gas Services” *(on the right side below)* shows that the only noticeable difference is the booster panel that have been modified and was initially at the bottom of the unit.



1 - Booster panel:
It is the only element that has been changed.

2 - Oxygen panel:
There is no modification of this panel

3 - Control panel:
This panel has not been modified.

4 - Make-up Panel:
As with the other gas panels its commands and gauges remain identical to the model sold in 1985.

1.1.12 - Bell hot water machine

This point describes the machine that supplies hot water to the bell and the divers and is situated on the surface support. It is the continuation of the bell heating system described in point 2.3.2.7 and of the hot water suits discussed in point 2.3.4.

As already said in these previous points, the temperature of the surface of the sea varies according to the location and the season. However, the temperature at deep depths may fall below four degrees and does not vary according to the seasons. This permanent temperature slightly changes with the latitudes and may be close to zero degrees Celsius near the poles. Because the loss of heat is 24 times faster in water than in air, and that umbilicals have a limited isolation, the loss of energy is considerable and increases with the deployed lengths. As a result, powerful machines are necessary to heat the divers during the bell run that can be up to 8 hrs. These machines can be electrically or fuel-powered. Nevertheless, it seems that the majority of modern in-built saturation systems are based on electrical devices.

1.1.12.1 - Recommendation IMCA:

IMCA D 022 point 10.4 “heating systems” highlights the following facts:

- There is a considerable temperature drop in the umbilical. This temperature drop depends on the temperature at the machine, umbilical length, flow rate and sea temperature.
    - A lower temperature and a higher flow rate can transport as much heat as a higher temperature and a lower flow rate.
    - A higher temperature transfers heat more effectively to the diver, but increases the risk of scalding and hyperthermia which may happen if the water reaching the diver is at temperatures in excess of about 45°C. Also, if the temperature or flow rate is too low there is a risk of hypothermia.
- After some time in the water, the diver may not be able to assess his heating requirements adequately. Also, hyperthermia and hypothermia are gradual processes and may not be noticed by the diver focusing on his task.
- Respiratory heat loss is particularly hard to detect because the body only has temperature sensors in the skin, not in the lungs. Also, as already discussed in the presentation of the bell and helmet, the diver’s respiratory heat loss increases with depth, as the density of the breathing gas increases, and the gas must be heated for dives deeper than 150 msw (495 fsw).
- Note that according to DMAC 08 “Thermal stress in relation to diving”, the comfortable skin temperature in hot-water suits was shown to be about 34°C (Presentation Dr Kuehn).
- The supply to the bellman must also be considered as too much heat to the divers may deprive the bell.

IMCA D 024 gives in section 8 the following guidelines regarding the way hot water machines should be organised:

- The equipment used to generate and supply the hot water to the diver must be suitable for the purpose
- There must be an alternative and independent source for supplying heat to the diver
- If electricity is required to generate heating or pump it to the diver then there must be a back-up system in the event of primary failure (such as the vessel losing main power). This must be able to function for as long as it takes to recover the diver(s) to safety.
- The diving supervisor must have a display showing the temperature of the water being supplied to the diver
- A high and low temperature alarm (audible and visible) must be fitted to alert the diving supervisor if pre-set upper and lower limits are exceeded:
- All hot water machines need to have suitable provision of firefighting equipment in their vicinity. This may be by means of permanent ship or platform provided equipment or by means of portable extinguishers etc. It must be capable of dealing with any type or size of foreseeable fire hazard.
- If any hot water machines are situated in enclosed and unmanned areas then consideration should be given to fitting a fire detection system. This should be particularly considered for oil-fired units.

IMCA also says that manufacturers usually publish charts or tables for the adjustment of the hot water machines they sold. However, note that these documents may not be necessary with some last generation models.

1.1.12.2 - Description of a hot water machine

The machine used for this description is the electric water heater installed on UDS Lichtenstein and Picasso that was fabricated by Comanex (http://www.comanex.fr/), a well known company based in Marseille (France).
Note that because these vessels have two bells, three hot water units are provided. Each machine is designed to deliver heated seawater from 30ºC to 80ºC with a continuous flow up to 60 l/min (3.6 m³/hr) at a maximum pressure of 65 bar, which is sufficient to supply one bell during extreme conditions. Thus, one unit is provided for each bell, and the third one is to be online in the case of a breakdown.
The Machine is designed as follows:

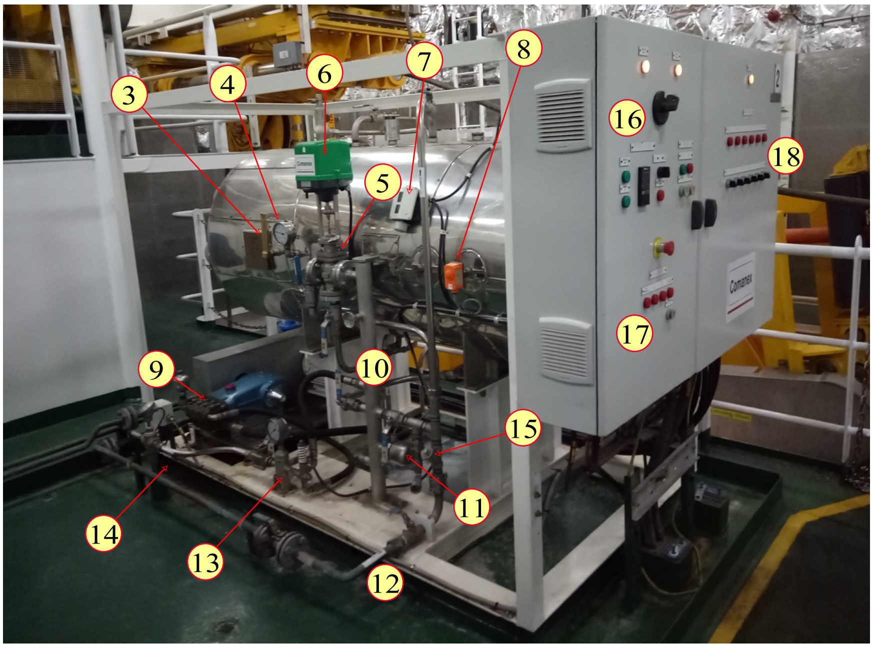
- The unit is composed of an isolated water tank of 830 litres capacity where the water is heated using six heat elements of 35 kW/h each (total = 210 kW/h). This tank allows regulation of the water temperature. Also, it stores sufficient hot water to supply the diver for 20 min in the case of a failure of the heating elements, which allows returning safely to the bell or starting the backup unit. A temperature controller automatically switches the heating elements on or off, and a safety thermostat stops them in the case of overheating.
  A 3-way valve mixes the hot water with cold sea water to adjust the selected temperature to the flow rate. The water is then pressurized to the desired pressure through a booster pump specially designed to handle hot sea

water. As a result, this device automatically delivers the water at the selected temperature at all times, and the charts used with the machines of the previous generation for the manual adjustment of flow rates according to the number of heating banks activated are unnecessary with this last generation machine.

- Depending on the option selected by the owner, the machine can be controlled by a computer through a Human Machine Interface (HMI) which is provided on its electrical enclosure and in the dive control, or manually through electrical panels in the dive control and on the machine.

The photo on the side shows the three hot water machines of UDS Picasso. They are installed at the direct proximity of the bell reclaim system, above the dive control.

Note the six heaters (see #1) at the extremity of each machine, and the motor of the pump with the protection of its transmission belt to the pump (see #2).

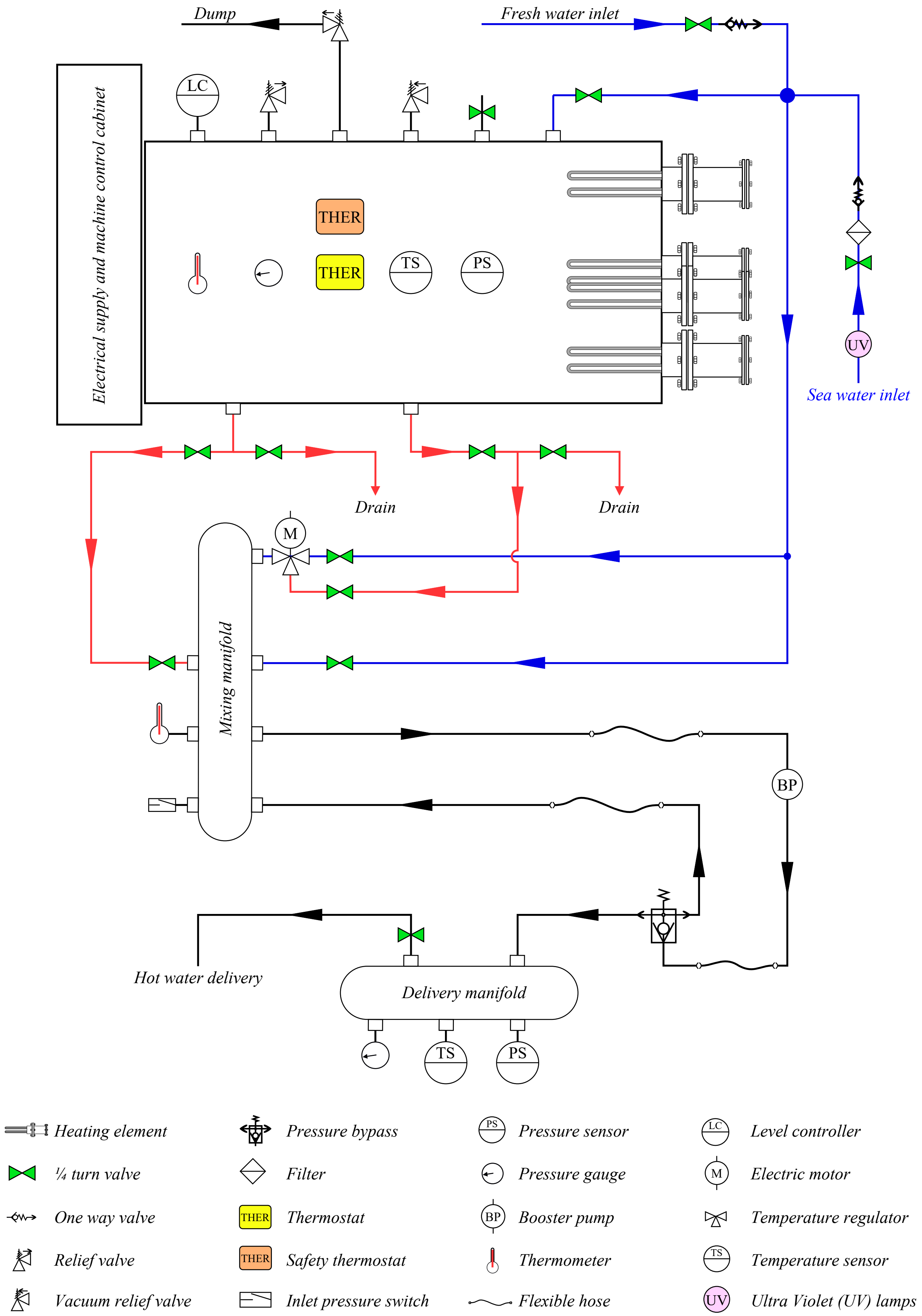


View of a hot water machine above from the other side:
- *Thermometer (#3)*
- *Pressure gauge (#4*
- *Regulation valve (#5)*
- *Regulation valve motor (#6)*
- *Thermostat (#7)*
- *Safety thermostat (#8)*
- *Pump (#9)*
- *Mixing manifold (#10)*
- *Flow controller (#11)*
- *Water inlet (#12)*
- *Delivery manifold with the temperature sensor, and the bypass regulator (#13)*
- *Hot water outlet (#14)*
- *Sea water filter (#15)*
- *Controls (#16)*
- *Alarms + emergency stop (#17)*
- *Heaters switches and their corresponding lights (#18)*

Control panels of the machines in the dive control:
- *On the left the system installed on the Picasso, on the right the system installed on Lichtenstein.*
- *The difference is that Picasso has a classical system that is electrical (see #19), and that Liechtenstein has a last generation system that is managed through computers which are controlled through a HMI.*

Note the two HMI which each one corresponds to a machine (#19 and #20). Also, note the emergency stop on the side of each HMI.

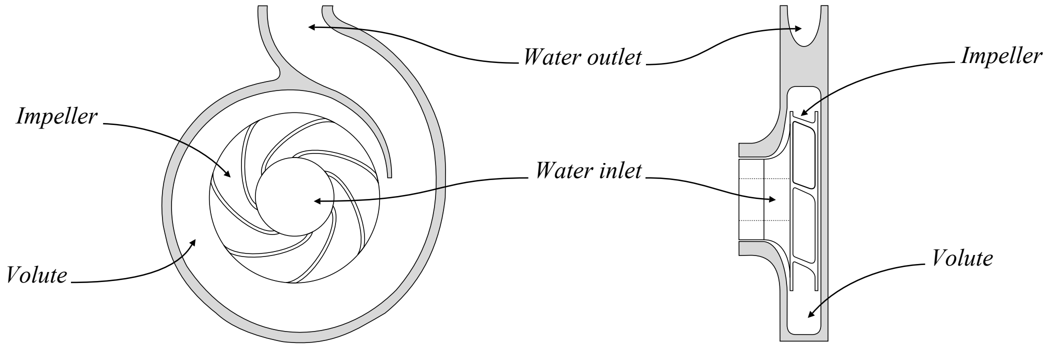
The elements of the machine described previously are more detailed on the scheme below.
Note that fresh water can be delivered to the hot water machine. However, fresh water is not used during the dives but mostly for the maintenance of the machine (Salt removal). Also, a Ultra-Violet (UV) light is added before the filter to neutralize pathogen organisms.



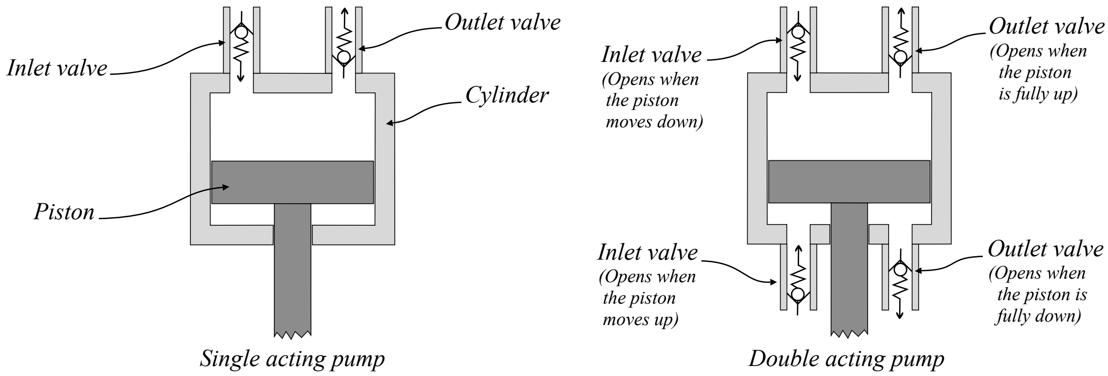
Important and not indicated previously: The control cabinet has a main and a backup electrical supply.

- Note regarding equipment that are specific to hot water machines:

- Vacuum relief valves
  Relief valves used on diving systems are generally designed to protect pressure vessels and other items against overpressure. Opposite to that, the function of a vacuum relief valve is to protect the tank from being in depression and then being crushed by the atmospheric pressure. In case the container becomes depressurized, this valve opens to equalize it with the surrounding pressure.
- Piston booster pumps
  Hot water machines are fitted with piston booster pumps instead of centrifugal pumps or of another design for following technical reasons:
  - Centrifugal pumps are commonly used in the marine and diving industries. These pumps are able to deliver high flow rates and are appreciated for their simple design that consists of an impeller that is rotated by a motor and is installed in a casing shaped in the form of a volute. The rotation of this impeller draws the fluid into the housing and transfers its kinetic energy to the liquid, which is then pushed to the discharge hose. However, due to their design, these pumps do not deliver high pressures or several stages (pumps) are necessary to achieve it, their flow rate is dependent on the delivery pressure, they may develop cavitation with warm water or low intake pressures, and they cannot auto prime if they are not pre-filled, which is the reason they are generally in the lowest parts of the boat.
    As a result, these pumps are ideal for supplying water to the machine, but not as a booster pump.



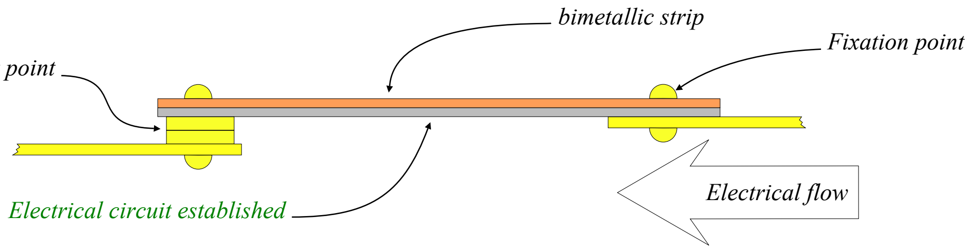
  - A piston pump is designed to draw a liquid in a cylinder and compress it using a piston that moves up and down. Inlet and outlet valves are alternatively open and close to fill the cylinder and release the liquid when it is pressurized. Thus, the principle of work of piston pumps is similar to piston compressors. Note that piston pumps can be simple or double acting. In the case of a double acting pumps, the liquid is drawn in and compressed when the piston moves up and down *(see below)*



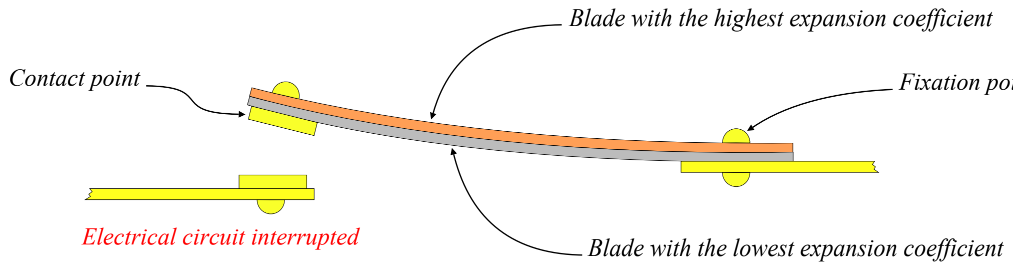
    The advantages of piston pumps are that they are less affected by variations of pressure than centrifugal pumps, they can deliver high pressures, and they are not affected by the heat. It is the reason they are also used with high-pressure water jets. Also, the pressure they deliver is not affected by their flow rate, and some models are able to auto prime.
    Their main inconvenience is that they deliver lesser flow rates than centrifugal pumps, and that this flow is pulsating. To finish, and as already said, their maintenance costs are more expensive.
    Piston pumps of the latest generation are equipped with a pulsation dampener. The system consists of a cylinder where a membrane separates a gas from the liquid that flows into it. The gas behind the membrane acts as a spring that flexes and absorbs the pulses, allowing a laminar flow downstream of the dampener. Note that this system is similar to the load limiters described in point 2.3.11.7.
    Also, to increase their durability, last generation pumps are fitted with ceramic pistons. The advantage of this material is that it has a highest resistance to corrosion, wear, and heat.
- Thermostat
  A thermostat is a device that controls the temperature of equipment by switching on or off the heating or cooling elements. On water heating machines, they are used to regulate the heat transfer from the heating elements to maintain the tank at the desired temperature.
  These devices can be mechanical and electronic and can be programmable. They work on the principle of the thermal expansion of solid materials. A lot of mechanical systems exploiting this principle can be found in the

form of strips that are coiled or not, bellows filled with gas, springs, etc. One of the simplest systems which are commonly used with thermostats is the "bimetallic strip" system:

- This mechanism consists of two pieces of different metals which have varying coefficients of expansion and are connected to form a single blade. These strips are arranged to create a bridge that can open and close in the electric circuit.
- When these metal strips are cold, the bridge is established, allowing the electricity to flow and activate the electrical elements *(see below)*.



- Depending on time and its intensity, the electricity flowing through these small pieces of metal heats them. As a result, the most conductive strip becomes hotter than the other, and because its expansion is different that the expansion of the coldest one, it bends the bridge and breaks the electrical circuit. As a result, the electrical elements are switched off.



- When the 2 strips return cold the bridge is reestablished and the electrical elements are energized again.

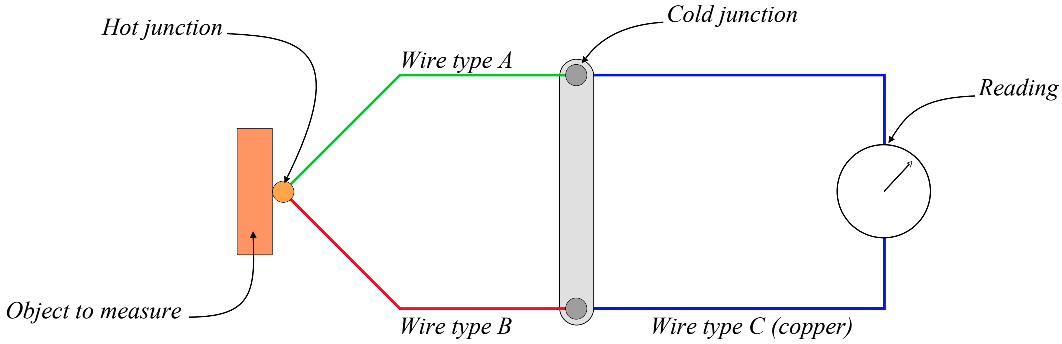
Electronic thermostats use the same principle, but they are controlled through a device called "thermistor". A thermistor is a resistor that reacts on temperature. Thermistors are also used for electronic sensors. Depending on the application two types of resistors can be used:
With a Negative Temperature Coefficient (NTC) thermistor, the resistance decreases when the temperature increases. NTC type thermistors are commonly used in thermostats, temperature sensors, or inrush current limiters.
With a Positive Temperature Coefficient (PTC) thermistor, the resistance increases when the temperature increases. This type of thermistor is generally used as a fuse.

- Temperature sensors:
  Temperature sensors measure temperature and may be used to actuate switches. They are classified into two basic types: "Contact" and "non-contact" temperature sensors
  - "Contact temperature sensors" must be in physical contact with the object being sensed and use conduction to monitor changes in temperature. They are the models commonly used with hot water machines.

    Alcohol or mercury thermometers are based on the expansion of a fluid that it is exposed to heat. They consist of a liquid that is contained in a glass bulb which is connected to an expansion bulb by a capillary. Both connected bulbs are sealed at the extremities of the device. The space above the liquid is a mixture of nitrogen and the vapour of the liquid.
    These thermometers are commonly used, and one unit is fitted on the tank of the Comanex hot water machine described.

    The "bimetallic strip" system described above for thermostats is also used to design thermometers. In this case, the deformation of the blades, which is proportional to the heat, is used to display temperatures.

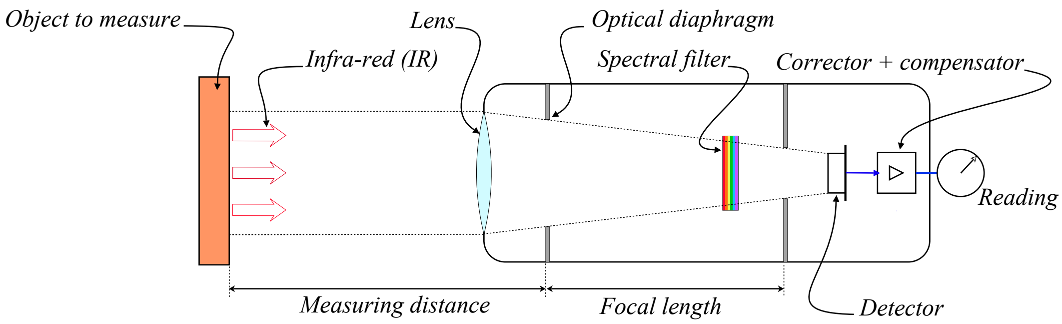
    Thermocouples and Resistance Temperature Detectors are typical examples of electrical-based contact temperature sensors.
    - A thermocouple is a device that creates electricity when heated. It is based on the thermoelectric effect that states that a temperature difference in a circuit made of two different conductors creates electricity and it does not with a circuit made of the same conductor.
      The thermocouple consists of two wires made from different metals that are welded together at one end, creating a junction called "hot Junction". This junction is where the temperature is measured. The other ends of the cables are connected in the "cold" junction which is maintained at a constant reference temperature.
      When the temperature of the "hot junction" change, it generates electricity through the loop. This electrical flow can be read using a voltmeter which reading is then translated into temperature using an appropriate formula.



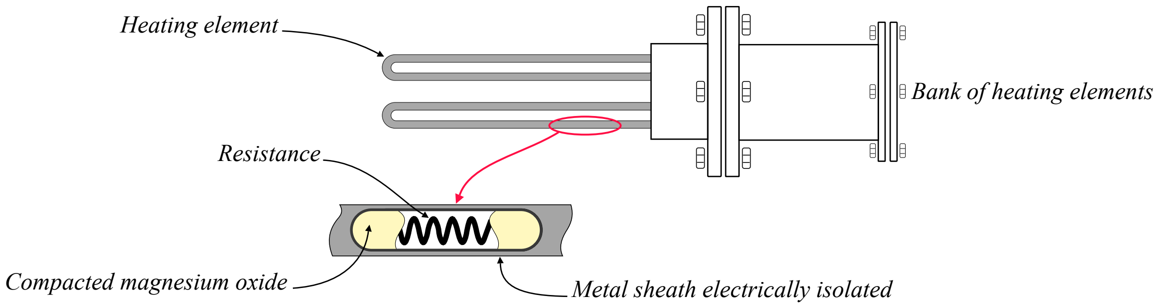
- A “resistance temperature detector” is a temperature sensor that contains a resistor that changes its resistance value as its temperature changes. The temperature sensor is made from a material whose resistance at various temperatures is documented and can be predicted. An electrical current is transmitted through this material and its resistance is measured and converted to temperature according to the resistance reading. Negative temperature coefficient (NTC) thermistors used for temperature sensing are part of this family.

◦ “Non-contact temperature sensors” detect the energy being transmitted from an organism, an object, a liquid or a gas, in the form of infra-red radiation (IR). The process is based on the fact that an element with a temperature above the absolute zero (-273.15°C = 0 Kelvin) emits an infrared radiation which is proportional to its temperature and can be measured. An infrared measurement device is composed of the following parts:

A lens that collects the emitted thermal radiation from a defined surface and a spectral filter.
A detector that converts this energy into an electronic signal
A correction system that is used to adjust the instrument according to the properties of the target.
A compensator that prevents the detector from factoring its own temperature into the output signal.



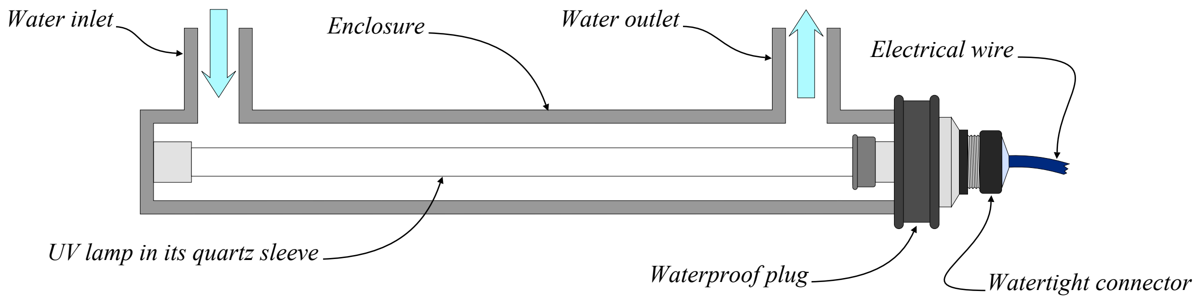
- Heating elements:
  Electrical diving hot water machines use immersed heating elements that heat the water of a tank as it is the case with the Comanex machine taken as an example for this topic. The volume of this tank and the number and the power of the elements vary according to the design of the device.
  A typical heating element is a coil, ribbon or strip of wire that gives heat similarly as a filament lamp. Thus it converts the electrical energy passing through it into heat that radiates out in all directions. The power of the heating element depends on the size and the materials used for this resistance.
  Heating elements are typically made of iron or nickel-based alloys. However, other alloys can be used. Nickel-chromium is often used with immersed heating elements because this material has a high melting point (1400ºC), a constant resistance, does not oxidize and does not expand too much when heated. This heating element is protected from the water by a metallic sheath. Also, magnesium oxide powder is widely used as a filling and isolator for electrical heating elements in contact with liquids. This material is employed because it has high thermal conductivity and low electrical conductivity.



- Ultraviolet (UV) rays:
  Divers in saturation live in a closed environment with an oxygen partial pressure of 400 mbar and above that is favorable for the proliferation of pathogens. Also, the duration of a saturation dive is up to six hours and long exposures to hot water rinses and alter the superficial layers of the skin which become more permeable to external agents like chemicals and micro-organisms. For these reasons, saturated divers are more vulnerable to

pathogens than surface orientated divers, and it is reasonable to ensure that pathogens that might have contaminated the hot water circuit are neutralized upstream to the Diver.
Ultraviolet (UV) radiations are known to alter the nucleic acids (DNA & RNA) of microorganisms and inactivate them. The effectiveness of this process is related to exposure time, lamp intensity and wavelength, as well as the number and varieties of the pathogens in the water.
Most lamps found in UV systems emit a wavelength of 254 nanometres, which is considered the optimum range for UV energy absorption by nucleic acids. The exposure time is reported in "microwatt-seconds per square centimetre" in some countries. However it is said that most scientists and engineers use units such as "millijoule per square centimetre" (mJ/cm^2) or "joule per square metre" (J/m^2). Studies have demonstrated that nearly all organisms are neutralized at doses above to 12 mJ/cm^2.

Ultraviolet lamps are generally installed in a pipe that is incorporated to the water circuit and is sufficiently narrow to neutralize the pathogens passing through. The bulb is housed in a quartz sleeve that protects it from the water. This pipe can be opened to change the bulb and being cleaned. Some installations use several units installed in series.



- Advantages of computer-controlled machines:
As indicated previously, the hot water systems studied in this presentation can be controlled from the electrical cabinet of the devices and from the dive control. However, the newest generation systems provide, more flexibility and more information than those of the previous generation. That can be demonstrated by comparing the command panels that are installed in the dive-control:

- The panel below, which is from the hot water machine of the previous generation is installed on UDS Picasso and provides the following indications and alarms:
    - #1 - Emergency stop hot water machine #1
    - #2 - Emergency stop hot water machine #3
    - #3 - Indicator heaters on
    - #4 - Water level fault
    - #5 - Heaters fault
    - #6 - Indicates that the control cabinet is on emergency power *(alarm)*
    - #7 - Buzzer *(audible alarm that switch on in the case of a fault)*
    - #8 - Indicator pump at work
    - #9 - Alarm pump
    - #10 - Alarm insufficient flow
    - #11 - Outlet temperature display
    - #12 - Adjustment outlet temperature
    - #13 - Mute audible alarm

    - With this system, the essential information is provided but it is not detailed.
    - The six 35 kW heaters are triggered and stopped at the same time by the controller, and the supervisor cannot operate them one by one.

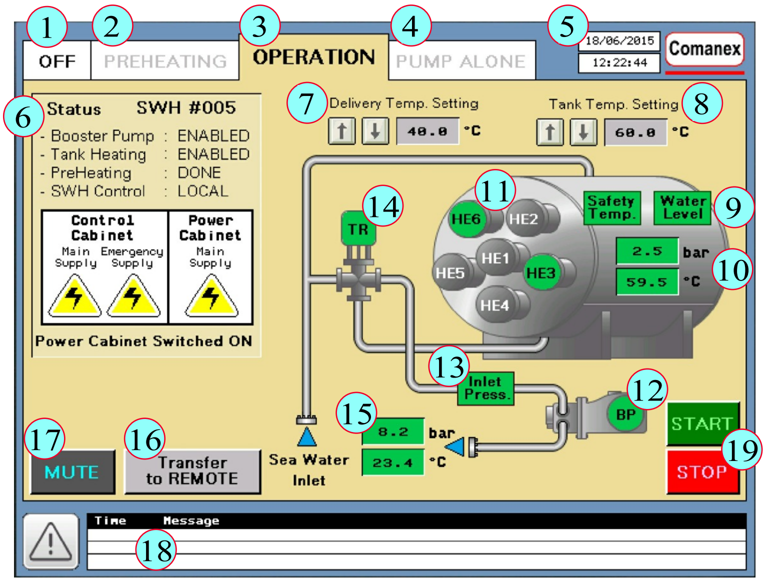
- It is true that it is possible to switch on or off some heating elements. However, in this case, the diving supervisor must ask the dive technician to do it from the panel of the machine where the six separate switches are installed *(See below and #14 in the photo of the machine on the previous page)*.
- As the commands of this machine are electrical, it is not possible to program-specific tasks that automatically optimise the functions of the device.

- As already explained, with the latest generation machines controlled by computer the electrical commands on the machine and in the dive control are replaced by Human Machine Interface (HMI) screens. These screens provide identical information on the machine and in the dive control. However, the HMI of the machine is the "master" and the one in the dive control the "slave". For this reason, to activate the screen of the dive control, the operator must enable it from the HMI installed on the electrical cabinet of the machine. In other words, the HMI in the dive control is an extension of the HMI of the machine.

UDS Picasso: Previous generation

Lichtenstein: New generation

Each HMI screen is designed as follows:



#1 - Command "off" HMI *(similar to the on/off of a computer)*
#2 - Selection "pre-heating panel" *(that is part of the pre-dive process of the machine)*
#3 - Selection "operation panel" *(it is this panel, which is used during normal operations)*
#4 - Selection "pump alone procedure panel" *(provides water from an external hot water source)*.
#5 - Date and time
#6 - Status:
    Booster pump *(enabled or disabled)*
    Tank heating *(enabled or disabled)*
    Preheating *(not done or done)*
    Status electrical supply *(control cabinet & power cabinet)*
    Sea water heater control used *("local" indicates that the control is done from the machine)*
#7 - Delivery temperature setting
#8 - Tank temperature setting
#9 - Alarms temperature & water level tank
#10 - Temperature and pressure water tank
#11 - Heating elements *(green when active and red if in fault)*
#12 - Status & alarm pump *(green when active and red if in fault)*
#13 - Alarm inlet pressure
#14 - Status/alarm 3-way valve *(hot & cold water mixing)*

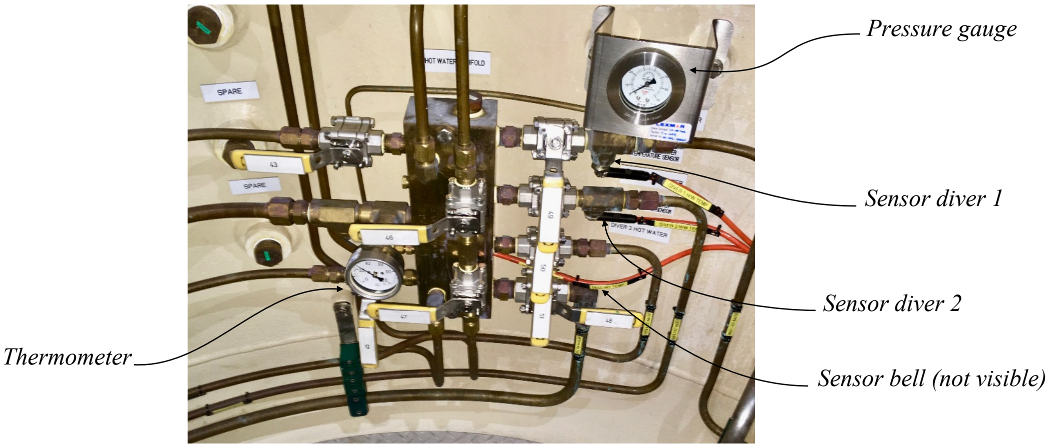
#15 - Temperature et pressure sea water inlet
#16 - Transfer to remote command *(activate the unit in the dive control)*
#17 - Alarm mute command
#18 - Alarm message records (time & description)
#19 - Machine start & stop commands

- With this system, the status of the main elements can be controlled at any moment. As a result, the operator is informed of what is performed by the machine from the water inlet to the delivery.
- The delivery temperature and the temperature of the tank, can be precisely set up
- The heating elements can be selected automatically or on demand from the cabinet or the dive control
- Alarm messages are documented and recorded

As a conclusion, computerized systems provide more flexibility and comfort in addition to the fact that the energy necessary to heat the diver is more optimised.

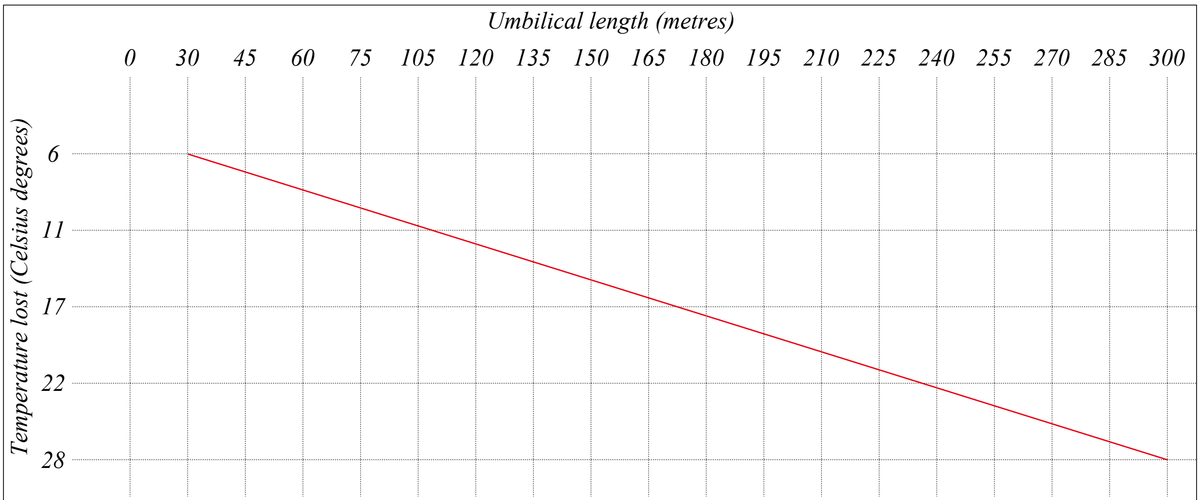
- Additional temperature controls

Already indicated with the heating system of the bell in point 2.3.2.7, sensors may be installed in the bell and linked to the dive control to alert the diving supervisor in the case of temperature, flow, or pressure change. That allows him to immediately adjust the temperature of the hot water machine to the desired temperature *(The system installed in Lichtenstein and Picasso is designed by Fathom)*. However, these sensors provide the temperature supplied at bell level and not at the end of the umbilical of the diver. For this reason, the supervisor is still obliged to extrapolate the needs of the diver according to the length of umbilical deployed from the bell.
In less advanced bells, temperature and pressure readings can be performed by the bellman using the thermometer and the pressure gauge installed on the hot water manifold. These readings are then reported to the diving supervisor.



1.1.12.3 - Settings

Before setting up the machine the necessary heat to provide, which is the addition of the desired temperature of the diver and the heat loss from the surface to the end of the umbilical, must be calculated.
Some manufacturers provide tables such as the one below to roughly evaluate the heat loss.



Approximate temperature loss through a 1/2" Synflex hose or equivalent, used with a surrounding seawater temperature of 2 - 5°C (source: Divex).

However, these tables are theoretical and cannot take into account the numerous variables that must be considered such as those listed below:

- The temperature of the surface of the sea varies according to the latitude, the season, and the weather conditions encountered. Also, note that rivers influence the temperature of the sea at the proximity of their mouth.

- The temperature of the sea is not affected by the weather conditions at deep depths but may vary according to the latitude.
- Cold currents may be encountered at any depth and speed up heat loss due to the increased convection.
- The configuration of the hot water system has an influence on the heat loss:
  - Heat loss will be different depending on whether the hot water machine and the umbilical are inside the vessel, or exposed to weather conditions.
  - The distance of the machine from the umbilical and the quality of isolation of the pipes also has an influence on the heat loss.
  - Heat loss may also depend on the configuration of the umbilicals and the quality of the hoses used.
  - As indicated in IMCA D 022 the water flow through the umbilical also influences the heat loss.

Experienced technicians and supervisors familiar with the diving system and the areas where the boat operates can establish heat loss charts more precise than those provided by manufacturers. Theoretical temperature loss can then be calculated using these tables. Nevertheless, if these charts cannot be created, the team can refer to those from the manufacturer.
Whatever table is used, some adjustments may be necessary when the bell arrives at depth. As indicated in the previous point, the water temperature and pressure can be read in the bell, and these data should be used to refine the setting of the machine. For these reasons, it is essential to set the machine in such a way that it will be available for supplying an increased demand for heat if requested.
Regarding this point, note that the manufacturer of the machine used as support for this study recommends to preset the tank 20ºC above the desired delivery temperature.
Note that the delivery temperature of the machine described is regulated by a motorised regulation valve that mixes hot and cold water to adjust the final temperature from 30 ºC to 60 ºC with a flow of 60 l/min *(see #5 & 6 in the photo)*. The temperature setting can be done and modified on the machine or in the dive control. When this setting is done, the device automatically adapts to deliver water at the temperature selected.
Similar systems can be found on other last-generation devices. However, a lot of old machines are not fitted with this option, and in this case, the water mixing must be done manually according to tables provided by the manufacturer. Also, the heating banks of a lot of modern, but less advanced machines, are not automatically switched on or off. In this case, the team will have to use the charts previously described that indicate the ideal combination of heating elements to obtain the desired temperature.
Note that, depending on the model, these machines generally require water supply at 2 to 3 bar minimum. Also, modern machines have a pressure by-pass fitted on the delivery manifold to protect the pump in the case of a blocked downstream flow. This valve can be set at the factory, or be adjusted according to the recommendations of the manufacturer.

Pre heating and “pump alone” procedure:
Hot water machines must be pre-heated prior to launching the operations. The duration of this procedure depends on the power of the device, the size of the tank to heat, the temperature of the seawater, and the desired delivered warmth.
This pre-heating phase can be speeded up or avoided with some machines that allow using the booster pump to transfer the hot water from another source. This function, which is available with the machine described as an example, also allows using this second source in the case of a breakdown of the heating system of the device.

1.1.12.4 - Oil-fired heaters

As mentioned previously, it seems that these machines become rare with built-in saturation systems and that they are more encountered with portable systems and surface orientated diving systems.

Their general design is similar to electric hot water systems except that the electrical heaters are replaced by a separate oil burner *(see #1 in the photo)* which heats freshwater or a fluid in a closed primary circuit that then heats the seawater through an exchanger. The heated seawater is then stored in a tank *(see #3)*. This process prevents salt deposits in the seawater canalizations. A separate fuel reservoir supplies this oil burner *(see #4)*.

Downstream from the tank, the delivery temperature is regulated by the 3-way regulation valve, already described with the electrical units, that mixes the hot and the cold water *(see #5)*.
The water is then circulated to the bell through the piston booster pump and the delivery manifold that is fitted with a temperature sensor, and a bypass regulator as with electrically heated machines *(see #6)*. Also, note that the mixing manifold is similar to the one described previously *(see #7)*.

Modern units such as the one in the photo on the right are provided with sensors that regulate the oil burner and allow the temperature control of the hot water machine from its panel *(see #8)* or from the dive control. Old generation units do not offer this option. As a result, the supervisor can monitor the parameters but cannot adjust the machine from the dive control and must ask the technician to do it.

The advantage of oil-fired heaters is that they can work with a limited electrical supply. It is the main reason they are appreciated by teams diving from vessels of opportunity or in cold and isolated areas.

However, due to the fact they burn fuel, these machines have numerous inconveniences that must be addressed. For this reason, IMCA D 024 / section 8, provides the following guidelines:

- Oil fired heaters must be located such that they present no risk to the dive system in the event of fire.
- Their position must also present no risk in terms of pollution or contamination of air supply intakes to the vessel or any breathing air compressors.
- They must be fitted with a spill tray which drains off to a safe area (to reduce risk of fire or pollution)
- Where possible the fuel supply should be hard piped.
- The local tank filler should be fitted with a dead-mans handle or automatic shut off valve which closes when the tank is full.
- The local tank must be fitted with an overflow system with a capacity greater than the filling supply system (i.e. capable of allowing a rate of overflow greater than the filling rate)
- The overflow system must dump to a safe area.
- The fire fighting systems are those indicated in point 2.3.13.1.

Another problem with this type of machine is that they emit a naked flame. Even though this flame is in a controlled space, that limits their use to areas that are not likely to a sudden gas release. Note that such conditions can be found on some oilfields.

2.3.12.5 - Routine maintenance and inspection

As for every device that is part of the diving system, periodic maintenance and test of the hot water machine should be carried out on a regular basis. IMCA D 024 says the following:

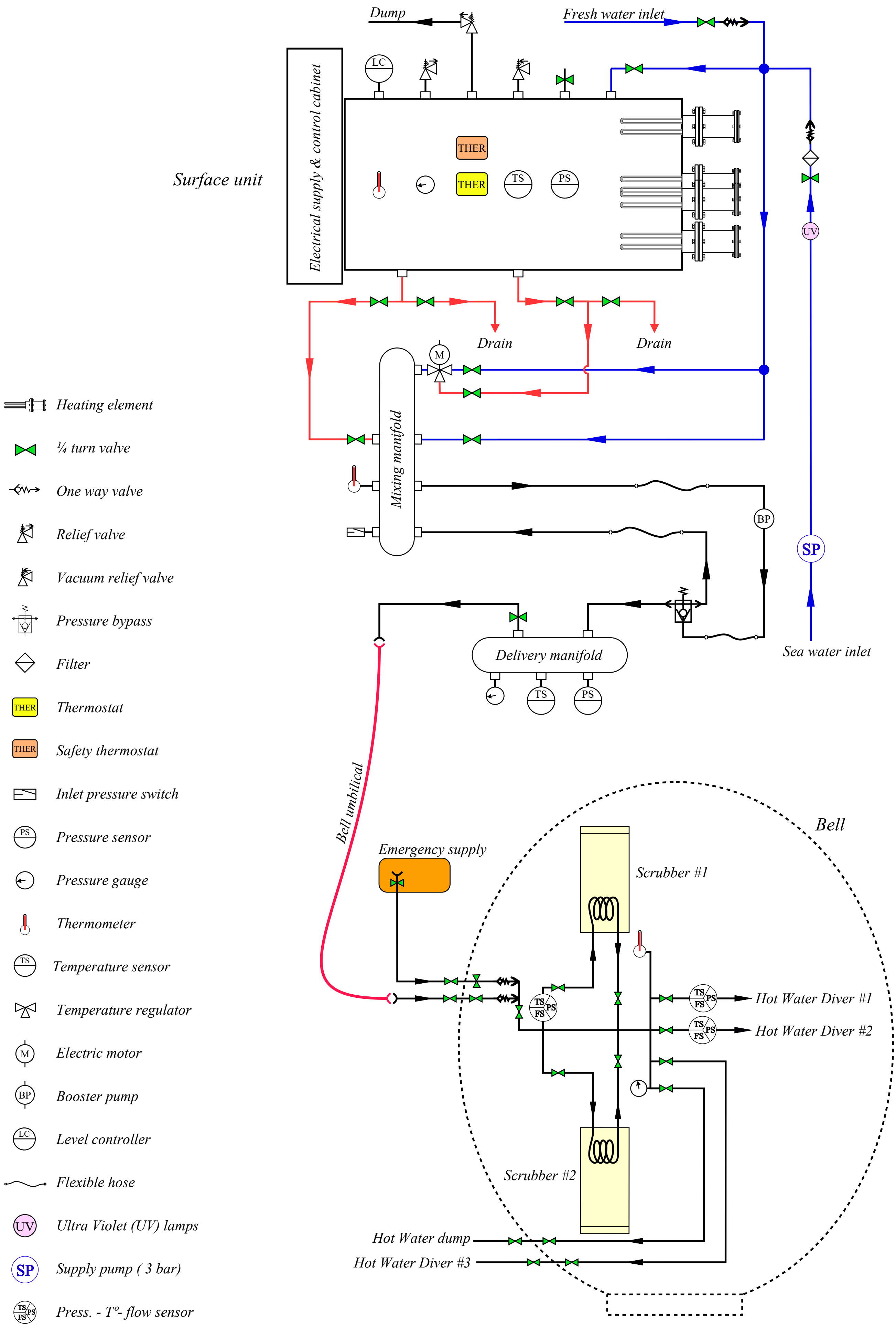
Items	*Visual external + function test , calibration*	*Visual internal + external + leak test at max. Working pressure*	*Internal + external+ leak test 1,5 max. working pressure*	*Other*
Fire fighting portable system	6 months			Manufacturer specifications
Fire fighting fixed system	6 months	12 months		Manufacturer specifications
Automatic fire detection	12 months			Manufacturer specifications
Hot water system	6 months			Manufacturer specifications
Pipework and fittings	6 months	24 months		
Gauges (calibration and test)	6 months			
Electrical systems	6 months			
Pressure vessels	6 months	15 months	5 years	
Alarms	6 months			
Relief valves	6 months	30 months		

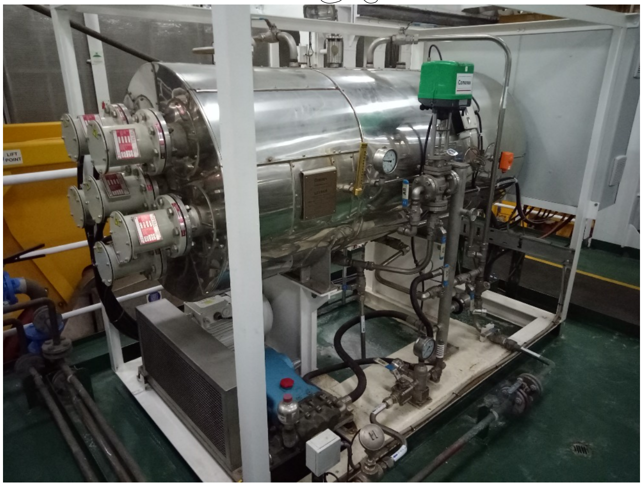
Manufacturers provide the following guidelines:

- The machine must be visually checked before starting it.
- The seawater filter must be checked and cleaned daily, or in the case of loss of pressure or flow.
- The oil level of pumps and motor outputs must be checked every day. This oil should be replaced according to the recommendations of the manufacturer.
- The tension of the belt (electric motor - pump) must be checked every week, or in the case of unusual noise or vibrations.
- The circuits and pump must be rinsed with fresh water after the bell run. In addition, in the event of an extended shut-down period, the heating tank must also be cleaned with freshwater and drained.
- The zinc anodes fitted on the machine to prevent corrosion should be checked monthly.
- Because the failure of the automaton will prevent the use of the machine, the manufacturer of the system described recommends storing a backup device with its program as a precaution.
- It may happen that some parts are more sensitive to wear than initially planned. That can be linked to numerous reasons that may be difficult to investigate and not only the machine itself. In this case, it is prudent to increase the frequency of checks and the renewal of these sensitive parts.

1.1.12.6 - Overview of the heating system

As for other systems, this drawing allows a general view of the heating system of the bell and the divers.



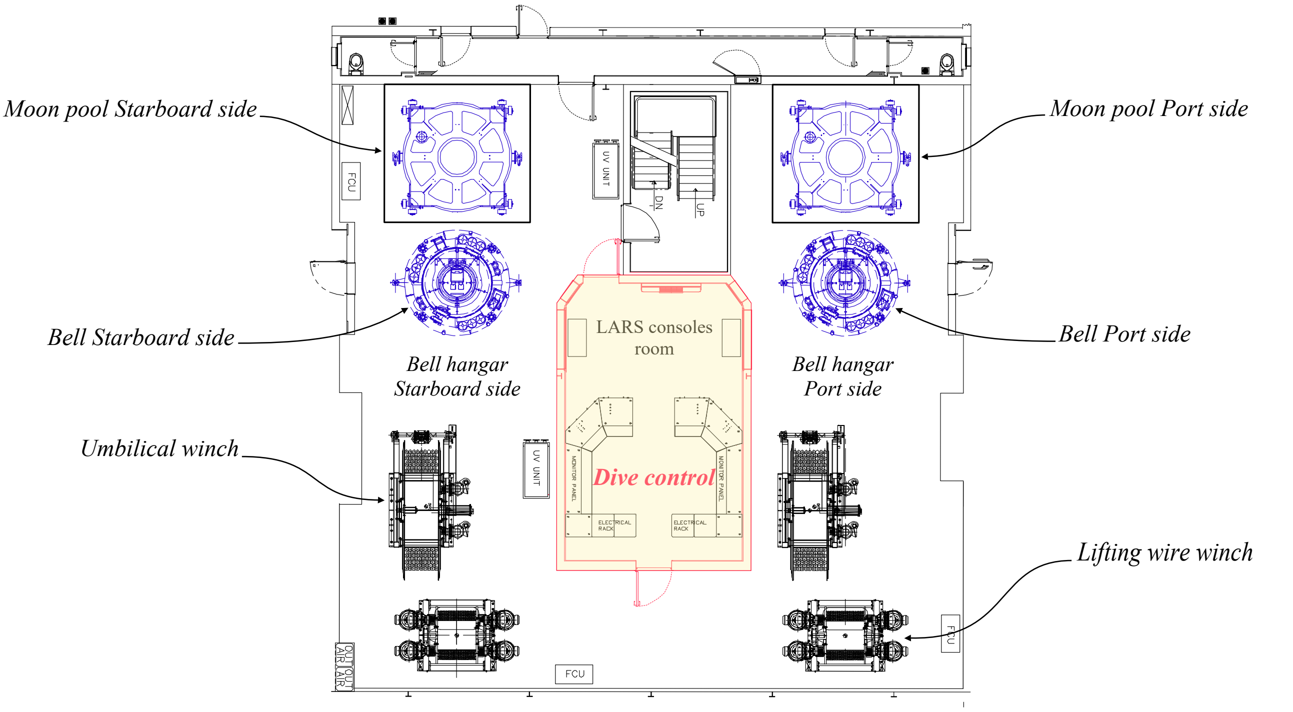


1.1.13 - Dive control

The dive control is the place from which the diving supervisor manages the diving operations. For this reason, it must be organized to allow him full control of the dive and of the elements that may interfere with it and to provide him a minimum of comfort. As a result, the commands of the systems previously described are grouped in with the communications to the essential parts of the vessel. The dive controls are generally installed above the launching area or at its level to allow a panoramic vision of the bell from the control console of the Launch And Recovery System (LARS), which is usually in a nearby room or the same room as the dive control. Their access should be comfortable and safe. IMCA D 024 provides precise guide-lines regarding the way a dive control should be organized that are followed by most manufacturers.

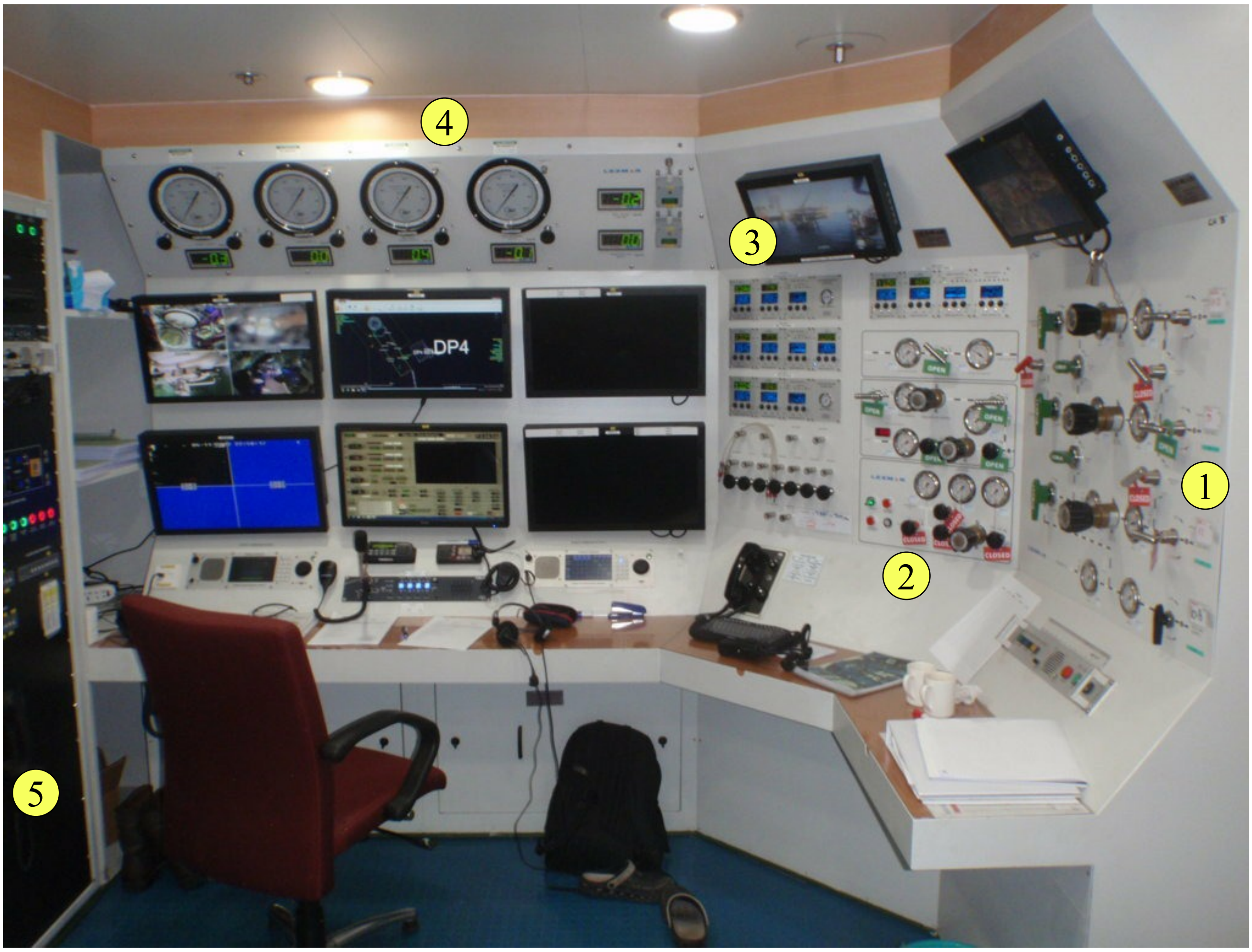
1.1.13.1 - General design

IMCA says that the diving supervisor must be protected from weather and other elements (including dropped objects) which may affect his concentration, and be kept suitably warm or cool.
Also, all gauges, displays, and relevant areas of control should be easily accessible and readable without difficulty. For this reason, the dive control and its controls must be adequately illuminated for operations during the day and night. In addition, the dive control should be suitably isolated from external noises that may disturb clear communications.
Usually, the dive controls of portable systems are organized in a dedicated 20 feet container which is protected from extreme temperatures and noises from the deck by several layers of appropriate isolation foam or wool. Also, it is warmed and cooled by relevant heating elements and air conditioning systems. However, due to their direct exposure to the weather conditions and the activities on deck, these dive controls are less comfortable than those of built-in systems that are installed in calm and weather protected areas of the vessel. It is the case of the dive control rooms of UDS Lichtenstein and Picasso which are situated between the moon pools at shelter deck level, so is inside the boat and in an area protected from external temperatures by appropriate isolating materials. As these vessels are provided with two bells, two fully separate diving panels allow controlling the starboard side bell and the port side bell. In fact, there are two dive controls grouped in one room *(see below)*.



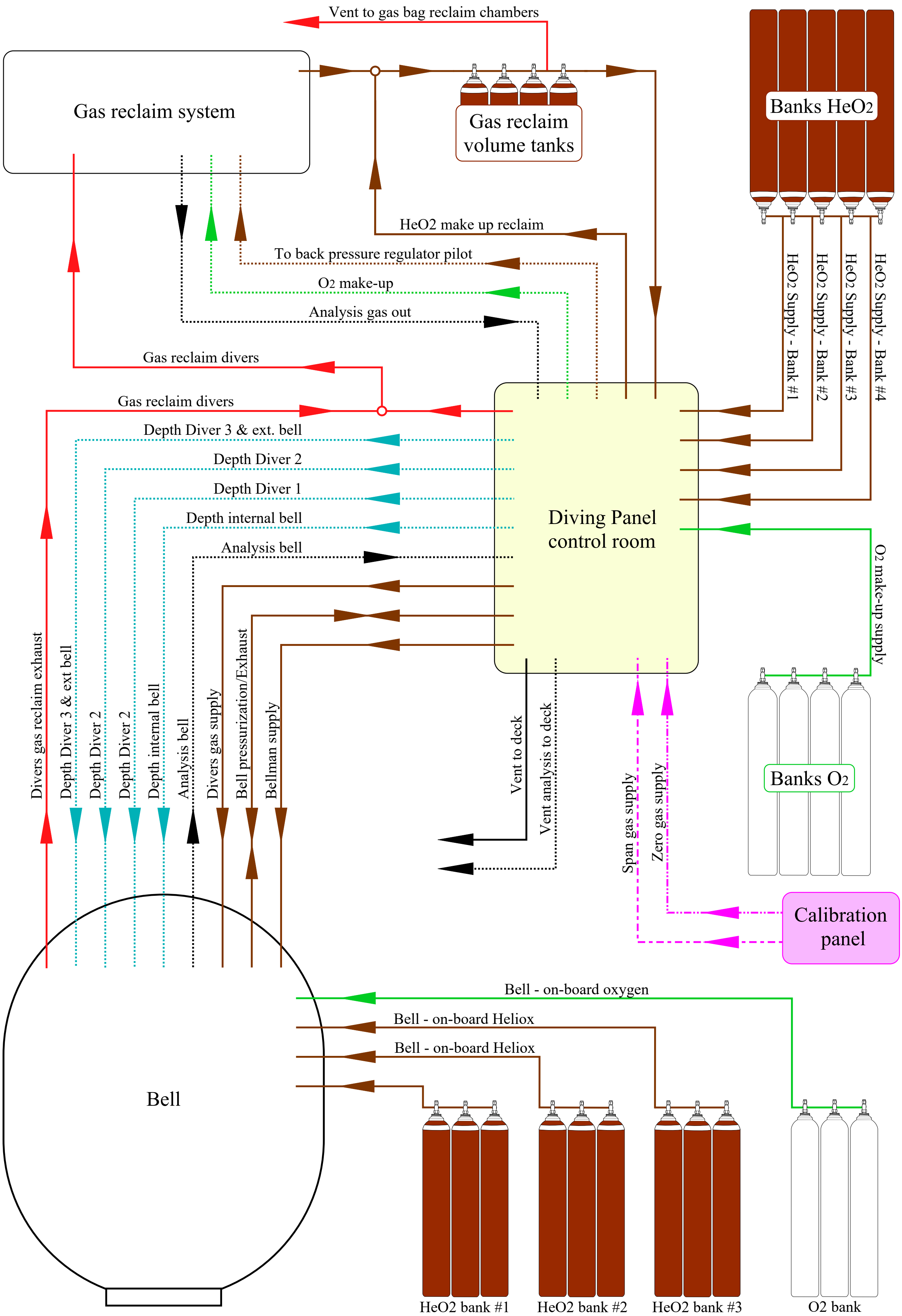
Each dive control panel is organised as follows:

1. The gas panel is already described in point 2.3.12 *"Gas reclaim system of the bell"*.
   As a reminder, the gas inlet panel is supplied with pre-mix supplies, gas reclaim make-up supply, and a supply from the divers reclaim system.
   Note that the pre-mix supplies and gas reclaim makeup are fed from the distribution panel in the gas storage room situated on the tween deck, or from the gas storage on deck. The pre-mix supplies and gas reclaim make-up supply are individually regulated to the required pressure for the diving operation.
   There is a valve system which directs the incoming gasses to the bell blow down hose, and the divers breathing hose in the bell's umbilical. The reclaim system can also be charged from this panel. The valve system prevents the reclaimed gas supply from being directed into the bell blow down hose.
2. The reclaim management panel, also described in point 2.3.12, allows the entire reclaim system to be monitored and operated from the dive control. It receives gas from the main gas supply panel. An O2 supply is also included for PPO2 control.
3. The gas analysis panel consists of the 4 x Carbon dioxide, 4 x Oxygen, analysers described in point 2.3.12. Below this panel is a patch panel fitted with quick connectors. This allows the dive supervisor to connect between the various supplies to individual analysers in order to provide calibration and zero gases, analyse the diver breathing gas, the bell internal atmosphere, the reclaim supply and any of the pre-mix supplies.
4. The diving monitoring panel accommodates the electronic depth gauges of the divers, bell (internal and external), bell trunk, and transfer lock. These gauges are readable from afar. Also, classical pneumo gauges are installed to double check the depth of the bell and the divers.
   Communication systems to the divers and the bell are in place. They are digital systems designed by Fathom systems http://www.fathomsystems.co.uk/. Also, a diver monitoring system, designed by the same manufacturer, groups all the essential information on a screen in the middle of the control panel. This system is described with others in the next points.
   Wired communications to the bridge, superintendent and client offices, and radios to contact the bridge, the personnel on deck or a boat cruising in the vicinity during the diving operations are also installed.
   A series of screens allows controlling the divers, the inside of the bell, the ROV, the position of the divers and of the vessel, the transfer lock and the strategic points of the deck are in place.
   Audible and visible alarms conforming to IMCA D 024 requirement are also installed.
5. Two side racks house the black boxes and video recording systems, the controls of the bell lights , The hot water controls, the power supply controls of the bell and diving panels with Uninterruptible Power Supply (UPS), The emergency sound powered phone, the through water communication system (wireless communications to the bell), and the intercom interface in which all intercoms are connected.



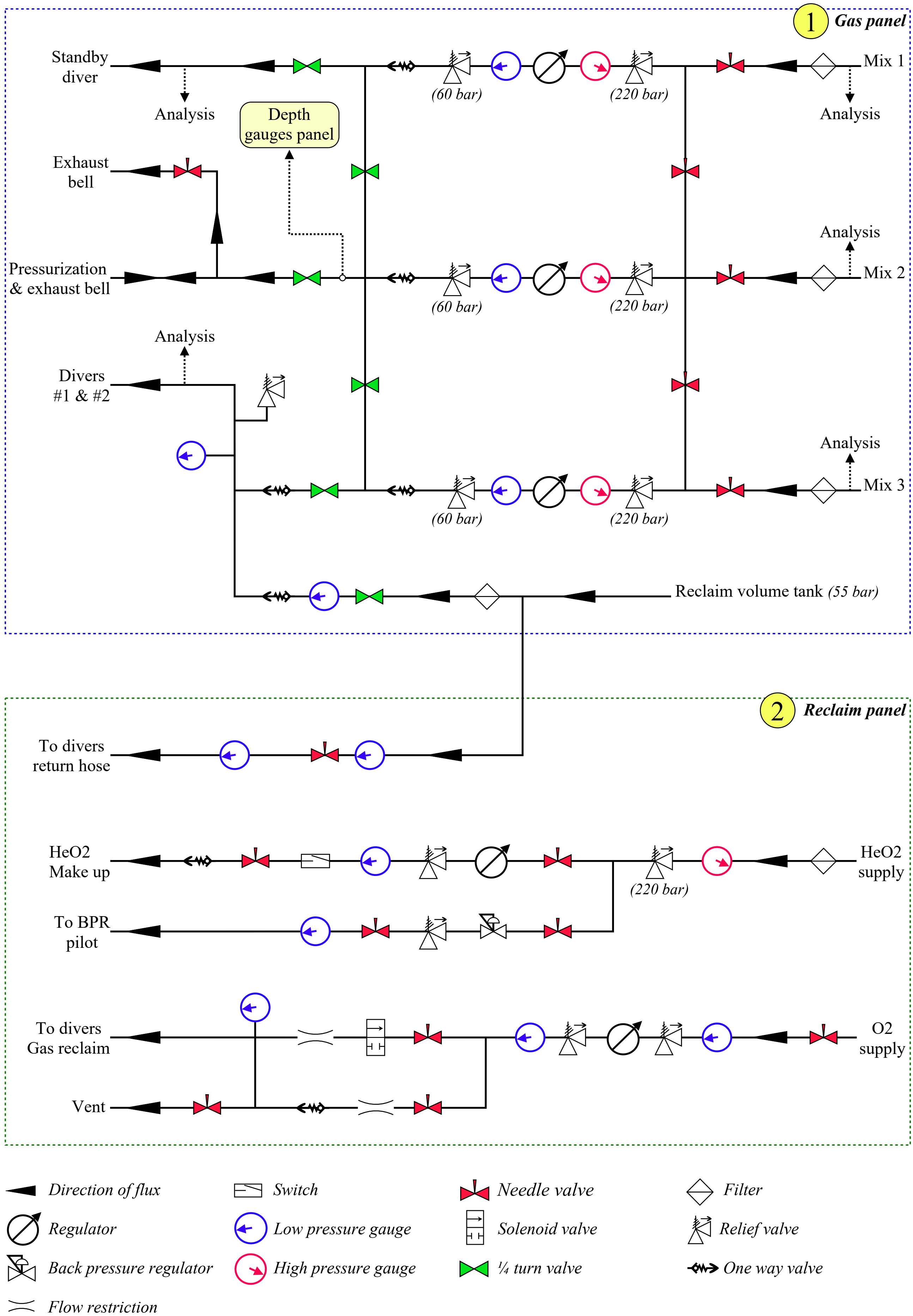
1.1.13.2 - Gas management panels

As already said, these panels control the distribution and the recycling of the gas to and from the bell. For a better understanding, it is essential to have an overview of the gas distribution to and from the dive control to provide sufficient breathing gas to the bell. It is the purpose of the scheme below.



Hyperlink Tables of contents

As a complement of the scheme on the previous page, the drawing below, which is also displayed in point 2.3.12, shows the interconnections between the gas supply and gas reclaim panels and the function of the various supply lines.

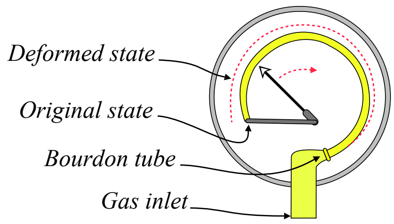


Note that the gas analysis panel is already fully explained in point 2.3.12 and is not explained again here for this reason.

Regarding gas supplies, IMCA D 024 says that sufficient sources of gas of breathing quality must be available and suitably arranged, so that if the online source to the diving bell or the diver fails an alternative source can be immediately switched on line. This point is confirmed by other organizations such as NORSOK, which also says that a minimum of two independent gas supplies is required to the panel supplying the main umbilical, and that the divers at work and the stand-by diver must have their own dedicated primary gas supply and a separate secondary gas source immediately available as a back-up.
Note that the diving systems taken as examples are widely beyond these minimum requirements as four distinct gas inlets are connected to the gas panel and should be in service in addition to the onboard gas of the bell. Also, the gas management panel of the bell described in point 2.3.2.7 is designed to open and isolate the supply lines according to the requirements indicated above.

Regarding gauges, IMCA D 024 says that there must be enough suitable gauges so that the diving supervisor is aware of the depth of the diving bell, each diver and of the supply pressures of each main and secondary breathing supply. These gauges must be protected by pressure limiting devices to avoid over pressurization that may damage them. Note indicated by IMCA, but very important, the gauges used with mixes containing more than 25% oxygen (22% with NORSOK) must be oxygen compatible and cleaned. The gauges used in last generation systems can be analogical or digital.

- Analogical gauges are usually bourdon tubes. They consist of a tube with the shape of an interrogation point and an oval cross-section which is open at one end and closed at the other one. The gas is directed inside this tube, and its pressure produces motion in the closed end of this tube, which is attached to a lever and a small mechanism that moves a needle. This needle indicates the pressure to read on a dedicated scale. The inconvenience of this system is that with the time the shape of the tube slightly change and it must be recalibrated or replaced.



- Digital pressure gauges are devices that convert applied pressure into signals which are displayed numerically. These gauges are based on various technologies that react to change in pressure such as the mechanical deflection of a specific flexible element or a diaphragm, or strain-sensitive variable resistors that are used as elements in resistance bridge circuits that perform measurements. Also, pistons, vibrating components, micro-electromechanical systems, or thin-film can be used to sense changes in pressure.

Also, IMCA divides the gauges into two categories according to their function: Depth monitoring and and gas supplies monitoring.

- Depth monitoring gauges are used for operational and decompression control. IMCA says that the scale of analogical gauges must be appropriate to their usage and large enough to be read efficiently and accurately. They should operate in the range of 25 to 75% of their full-scale deflection *(see below)*. IMCA also says that they must work in the 0 to 25% range if used for decompression and must have scale divisions of no more than 0.5 msw / 2 fsw if used for the final stages of decompression. However, the bell is not the place where decompression is usually undertaken.
  If digital gauges are used, their display must be large and clear enough to be read in all conditions and the unit used must also be marked, they must display at least one decimal point *(see below)*.

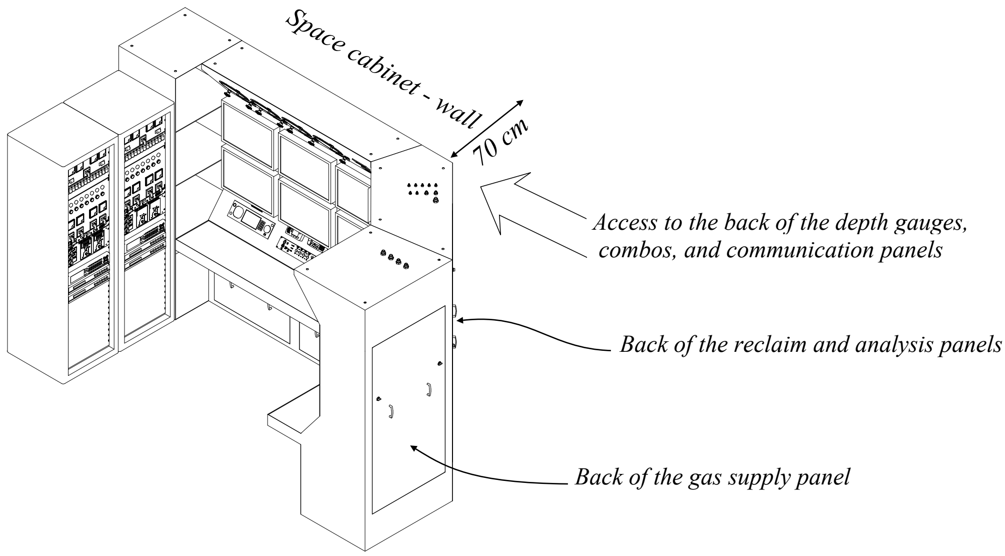
- Gas supply gauges are used for life support or as indicating gauges. IMCA says that they are not calibrated as depth gauges and must be positioned to show the line pressure of sources coming into the panel and also of any supplies leaving the panel. In addition, a system must be in place to ensure that incorrect readings cannot happen in certain valve positions. Their scale divisions must be as for depth gauges above except that they may be much smaller and with larger scale divisions. All gas supply gauges should be marked in the same unit system (imperial or metric) and dual scale marking is accepted.
  Supply gauges are usually provided with a flow restrictor that reduces the gas flow into a tiny gas trickle, so the gas leak does not affect the diving operation in case a gauge is dislodged or damaged. This item must be indicated on the panel schematic. Another system is to fit the gauges with an isolation valve providing that:
  - closing the valve does not interfere with the diver's supply.
  - the handle on the valve clearly indicates whether it is open or closed.
  - the handle is secured in the open position using light wire, tape or similar such that it cannot be inadvertently closed.

IMCA recommendations regarding valves are the same as those explained with the bell:

- The valves must be easy to operate, not be corroded, and their function must be clearly marked.

Also, when used with gas mixes containing more than 25% oxygen (NORSOK says 22%) valves and pipework Should be cleaned for oxygen service. IMCA says that “oxygen cleaning” should be demonstrated using a suitable procedure to ensure cleanliness, which is applied when any components are new or after there has been any significant alteration. Not indicated by IMCA, but very important, the materials used with these supplies must be oxygen compatible. This important requirement is explained at the beginning of this document. Also, NORSOK and classification bodies recommend to minimize to use of flexible hoses.
IMCA says that due to the depths involved in saturation diving, the pressure of such gases will often require to be above 15 bar, and that valves carrying oxygen and mixes containing more than 25% oxygen (22% with NORSOK) at a pressure higher than 15 bar must not be quarter turn. The reasons of this rule are linked to the possible ignition of oxygen that may destructs the gas circuit and injury or kill the divers. These effects are already explained in point 2.3.2.6 and at the beginning of this document. Note that the American Society for Testing and Materials (ASTM) recommends needle valves with a non-rotating stem.

- Exhaust pipework must not vent into an enclosed space. For this reason, they are generally directed to safe areas on deck *(see the general scheme)*. IMCA says that panel pressure relief valves and sampling for analysis do not constitute exhaust pipework. However, they are usually directed outside the room as well to avoid any unexpected oxygen concentration in the room.
- IMCA says that gas pipework, particularly in panels and at connection points, must be easily accessible for maintenance and repair. It is the reason that most dive controls are designed with access to the back of panels. It is the case of the systems used as support for this presentation which cabinets where the panels are housed can be opened from the back. Also, note that these cabinets are separated from the wall of the room by a space of approximately 70 centimetres that allows the technician to intervene comfortably.



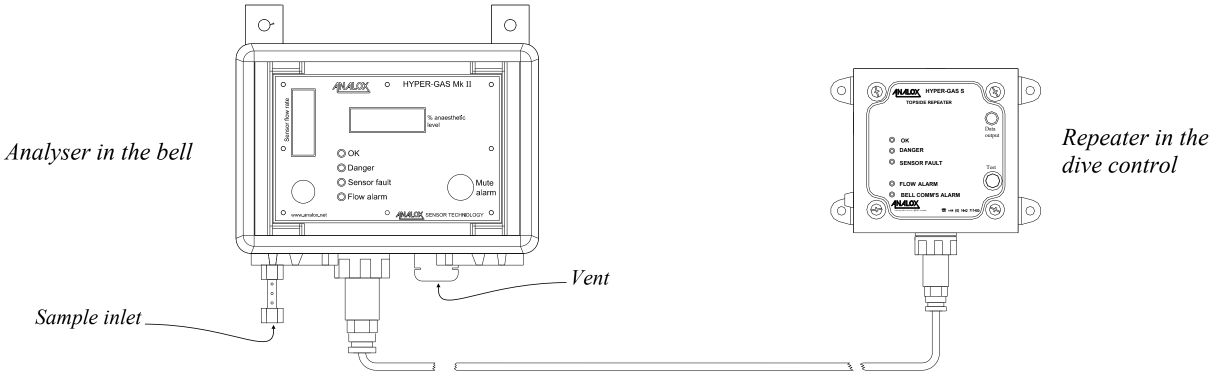
- Cross over valves are often installed on gas panels of saturation systems. IMCA says that cross-over valves should either be fixed in one position (the handles may be removed to avoid accidental changes) or should indicate very clearly which source they are connected to. In any event any gauge fitted with a cross-over valve must indicate very clearly at all times exactly what it is reading. This is particularly important if one gauge can show the depth of more than one diver.

Analysers used to control the gasses supplied to the bell and the panel in which they are grouped are already described in point 2.3.12.4 “Control console unit”. Please, remember that regarding this point IMCA says the following:

- *There must be an oxygen analyser with an audible and visible high and low alarm fitted in line on the downstream gas supply to the divers*
- *If diver gas reclaim is being used, there must be a carbon dioxide analyser with audible and visible high level alarm fitted to the down-stream side of the diver gas supply. The adjustment of gas sample flow rate must not affect any other analyser fitted*
- *There must be a means by which the diving supervisor can monitor the bell atmosphere for oxygen and carbon dioxide levels. This may be by a manual procedure carried out by the bellman or by a remote reading in dive control*

Note that a hydrocarbon analyser is often installed in the dive control. This item is optional with IMCA, which considers that it should be installed following a risk assessment. However, it is mandatory with IOGP *(international association of oil & gas producers)*. As a result, contractors working for IOGP members must have this device permanently in place. The reason for this stringent rule from IOGP is that the majority of hydrocarbons are found in crude oil and natural gas, where decomposed organic matter provides an abundance of carbon and hydrogen. Hydrocarbons can be found near the installation where the diving operations are organized and can enter the bell during the dive or soil the diving suits of the divers and then be released in the bell atmosphere. Hydrocarbons can cause pneumonitis and systemic effects such as central nervous system depression with respiratory and cardiac failure. Some other potential damages can be done to the liver, kidneys, or bone marrow. The onset of these effects is usually rapid. Note that hydrocarbons and their effects are described in the document “Diving accidents” of this manual.

In appendix 8 “saturation diving“ of IOGP 411 “Diving recommended practices” it is indicated that the bell must be equipped with a hydrocarbon analyzer similar to the “hypergas MK2” proposed by the company Analox. This analyzer has a bell monitor which will detect the presence of vapoured hydrocarbons, and the topside repeater installed on the diving panel. Both items have audible and visual alarms running before the anesthetic threshold is reached.



In addition to the analysis of the gasses of the bell, the atmosphere of the dive control must be monitored for oxygen content. The reason is that undetected leaks may happen and build a flammable atmosphere.
Note that this requirement, which is indicated in the latest version of IMCA D 024, was not in force when some old generation systems had been built. As a result, ambiance oxygen analysers must be added in the dive control to comply with this rule if they are not already installed. Such analysers are specifically designed for this purpose and must not be confused with those used to monitor the bell atmosphere. Their concept may be based on those previously described in point 2.3.12.4 which may be fitted with a fan that creates a regulated gas flow through the sensor to adapt them to this function. However, a lot of systems are using electrochemical cells similar to those used with personal oxygen analysers that need a very reduced gas flow.
Manufacturers recommend installing the air intake of such devices approximately 1 metre off the floor of the room. The reason is that when it is not yet mixed with the atmosphere of the room, oxygen is heavier than air and tends to concentrate on the lowest parts of the room.

1.1.13.3 - Communications, surveillance, recording, alarms, and electrical supplies

Communications, surveillance, and recording are of utmost importance during the diving operations. These elements can be divided into two segments: Communication and supervision of the bell and communications with the bridge and other vital parts of the vessel involved in the diving operation. Note that some elements are mandatory and some other are optional with IMCA. However, these optional elements may be required by clients or other safety organizations. For this reason, new saturation systems and Diving Support Vessels (DSV) are often fitted with them to avoid last-minute installation and improve their efficiency and safety. They can be classified into the two tables below:

Communications and monitoring bell

No	***Description***	***Requirements IMCA***	***Requirements from clients and other organizations***	***Additional information***
1	Two way voice communications divers (working divers & rescue diver)	Mandatory	Mandatory	There should be four wires into the communication cable to allow the installation of duplex communications. A duplex communication system enables all parties connected to the system to talk and listen at the same time.
2	Two way voice communications to the bellman	Mandatory	Mandatory	
3	Sound powered phone	Mandatory	Mandatory	
3	Through water communications (wireless comms)	Mandatory	Mandatory	
5	Video cameras outside and inside the bell	Not indicated	Mandatory (NORSOK and most clients)	According to NORSOK U100, all chamber compartments, bells, habitats and winch drums when necessary, shall be equipped with video monitoring system, enabling the surface support crew to visually monitor the occupants and operations. Cameras are usually installed at the top, bottom and inside the bell.
6	Video cameras divers	Not indicated	Mandatory (NORSOK and most clients)	According to NORSOK U100, a diver must be monitored by an ROV or a 2nd diver camera.

Communications and monitoring bell (continuation)

No	Description	Requirements IMCA	Requirements from clients and other organizations	Additional information
7	Diver Monitoring System	Not indicated	Not mandatory outside Norwegian waters / Mandatory with NORSOK and some clients	NORSOK says: *"A diver monitoring system shall be provided for each diver"*
8	Communications divers - supervisor recording	Mandatory	Mandatory	Retention of records is 24 hours with IMCA and 48 hours with NORSOK
9	Divers' video camera recording	Not indicated	Mandatory with NORSOK and most clients	Retention of records should be 48 hours
10	Divers' exposure data recording	Not indicated	Mandatory with NORSOK and some clients	NORSOK says that the diving contractor must have a system for recording the divers exposure data

Communications, monitoring and alarms vessel

No	Description	Requirements IMCA	Requirements from clients and other organizations	Additional information
1	Hard wired communications to and from the bridge (Intercom)	Mandatory	Mandatory	The primary link must be hard wire, immediately available and unable to be interrupted.
2	Wired secondary communications to and from the bridge	Optional	Optional	The secondary link can be hard wired, or a dedicated radio channel.
3	Hard wired communications to and from the launch and recovery console (winch operator)	Mandatory	Mandatory	These communications can be verbal if the console is in the same room as the supervisor.
4	Hard wired communications to and from the crane (Intercom)	Mandatory	Mandatory	Radio is no more accepted as main communication with the crane
5	Hard wired communications to bell trunk LARS deck (trunk connection)	Mandatory	Mandatory with most clients and contractors	There should be a clear connection between the competent person who monitors the bell on deck and the LARS operator and the diving supervisor. Hard wired communications have the advantage to be dedicated and not interrupted.
6	Hard wired communications to and from the ROVs (Intercom)	Mandatory	Mandatory	
7	Hard wired communications to and from the saturation control room (Intercom)	Mandatory	Mandatory with most clients and contractors	There should be a permanent and clear connection between the the diving supervisor and the Life Support Technician (LST) on duty . Hard wired communications have the advantage to be dedicated and not interrupted.
8	Secondary hard wired communications to and from the saturation control room (Intercom)	Nothing indicated (It can be the phone)	Mandatory with most clients and contractors	Saturation control rooms are often in places where radio communications cannot work. For this reason, secondary communications should be hardwired
9	Hard wired communications to and from the surface orientated dive control room (if the dive controls are separate)	Mandatory	Mandatory with most clients and contractors	Surface orientated divers may be involved to rescue the bell. Hard wired communications have the advantage to be dedicated and not interrupted.
10	Hard wired communications to and from the survey control room (Intercom)	Mandatory	Mandatory with most clients and contractors	See above
11	Hard wired communications (Intercom) to and from Offshore Installation Manager (OIM) office	Nothing indicated (It can be the phone)	Mandatory with most clients and contractors	See above

Communications, monitoring and alarms vessel (continuation)

No	***Description***	***Requirements IMCA***	***Requirements from clients and other organizations***	***Additional information***
12	Hard wired communications (Intercom) to and from the conference room	Optional (It can be the phone)	Optional (It can be the phone)	Onboard new vessels, this office is generally connected to the dive control by hard wired communications
13	Hard wired communications (Intercom) to and from the inspection office	Optional (It can be the phone)	Optional (It can be the phone)	See above
14	Radio communications to boats cruising within the vicinity of the vessel	Mandatory	Mandatory	
15	Radio communications to key people or used as 2nd means of communication	Mandatory	Mandatory	Can be used as a 2^{nd} means of communication with areas that have primary hard-wired communications
16	Phone (wired) communications to the areas indicated before and other parts of the vessel	Optional (It can be the intercom)	Mandatory with most clients	Onboard new vessels, office and cabins are generally connected to the dive control by phone communications
17	Video signal from ROV	Mandatory	Mandatory	The picture is the same as the pilot
18	Video signal from the launching and recovery areas and appropriate working areas	Mandatory	Mandatory	Cameras are not mandatory for the areas the supervisor has a direct view
19	Video signal from surface orientated dive control (if the dive controls are separate)	Not indicated	Mandatory with most clients	Surface orientated divers may be involved to rescue the bell. For this reason, the saturation supervisor must have a visual of what is carried on
20	Data from survey control to combo screen.	Not clearly indicated	Mandatory with most clients	A data screen indicating the position of the vessel and the divers is common today and often mandatory.
21	Video signals to bridge	Not indicated	Mandatory with most clients	A video screen showing the ongoing work of the diver to the bridge is mandatory with most clients. A similar screen from the ROV and the surface orientated dive-control is also compulsory.
22	Video signals to client office	Not indicated	Mandatory with most clients	A video screen showing the ongoing work of the diver to the client office is mandatory with most clients. A similar screen from the ROV and the surface orientated dive-control is also compulsory.
23	DP alarms	Mandatory	Mandatory	The diving supervisor must be able to mute the alarm if it is disturbing the communications.
24	Vessel emergency alarms	Mandatory	Mandatory	Fire alarm, abandon ship, personnel falling to the sea, gas release, etc. This alarm can also be muted.

Electrical supplies to and from the dive control

No	***Description***	***Requirements IMCA***	***Requirements from clients and other organizations***	***Additional information***
1	Main electrical supply 220 volts AC from generators	Mandatory (but voltage not indicated)	Mandatory (but voltage not indicated)	Dive controls are generally supplied with 220 volts AC, which is converted from the main generator(s) that provide current of higher voltages for the needs of the vessel. Note that some variations of voltages may be found such as 230 volts AC.
2	Backup electrical supply 220 volts AC from generators	Mandatory (but voltage not indicated)	Mandatory (but voltage not indicated)	See above

Electrical supplies to and from the dive control (continuation)

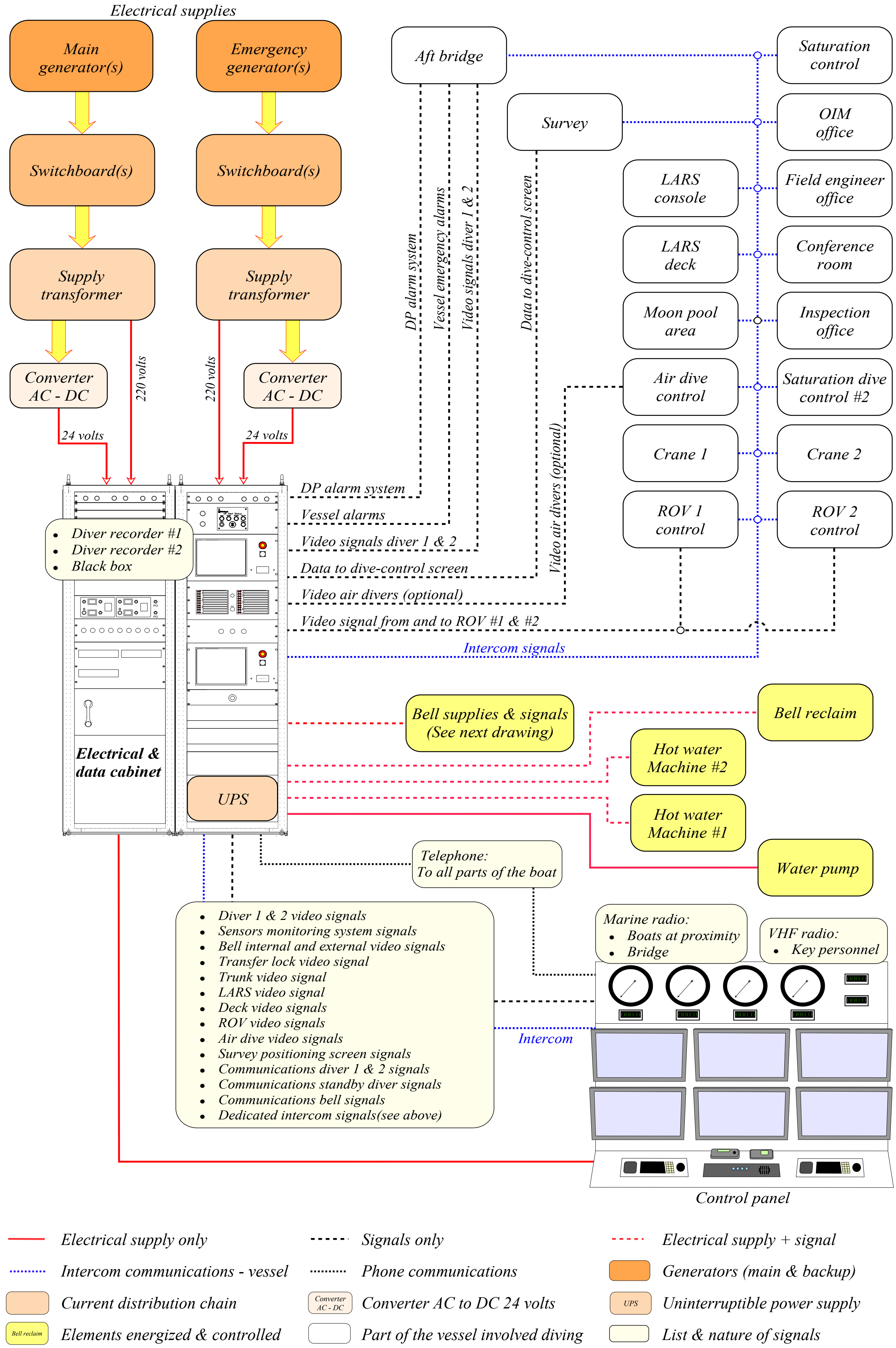
No	Description	Requirements IMCA	Requirements from clients and other organizations	Additional information
3	Main electrical supply 24 volts DC from generators	Mandatory (but voltage not indicated)	Mandatory (but voltage not indicated)	24 volts DC is generally converted from the 220 volts AC, which is converted from the main generator(s) that provide current of higher voltages for the needs of the vessel. This current is sent to the bell (24 Volts DC is not dangerous) and used to supply elements working with this type of electrical supplies. Note that some variations of voltages may be found such as 36 & 26 volts DC.
4	Backup electrical supply 24 volts DC from generators	Mandatory (but voltage not indicated)	Mandatory (but voltage not indicated)	See above
5	220 volts AC and 24 volts DC (or relevant voltage) from Uninterruptible Power Supply (UPS)	Mandatory	Mandatory	An UPS is a device that allows essential devices to keep running for at least 30 minutes (IMCA) when the primary power source is lost and the secondary supply is not yet engaged. Systems commonly supplied: - Communications systems not fitted with batteries - Recording - Emergency lights allowing to continue to manage the dive . - Video systems (optional with IMCA)
6	Current 24 volts DC to diving bell	Electrical supply of the bell is mandatory (voltage not specified)	Electrical supply of the bell is mandatory (voltage not specified)	This current is used to supply the elements of the bell for the reasons indicated in point 3. The switches of of helmet lights are in the electrical cabinet The elements usually supplied are: - Bell external cameras - Bell internal camera - Bell lights - Divers lights - Divers cameras - Scrubbers - Onboard batteries (charging) - Through water communication batteries - Sensors monitoring system - Hydrocarbon analyser (mandatory IOGP)
7	Current 220 or 110 volts AC to diving bell	Noting specified	Nothing specified	This current usually supplies the external lights only. The switches of these lights are in the electrical cabinet

Machineries controlled from the dive control

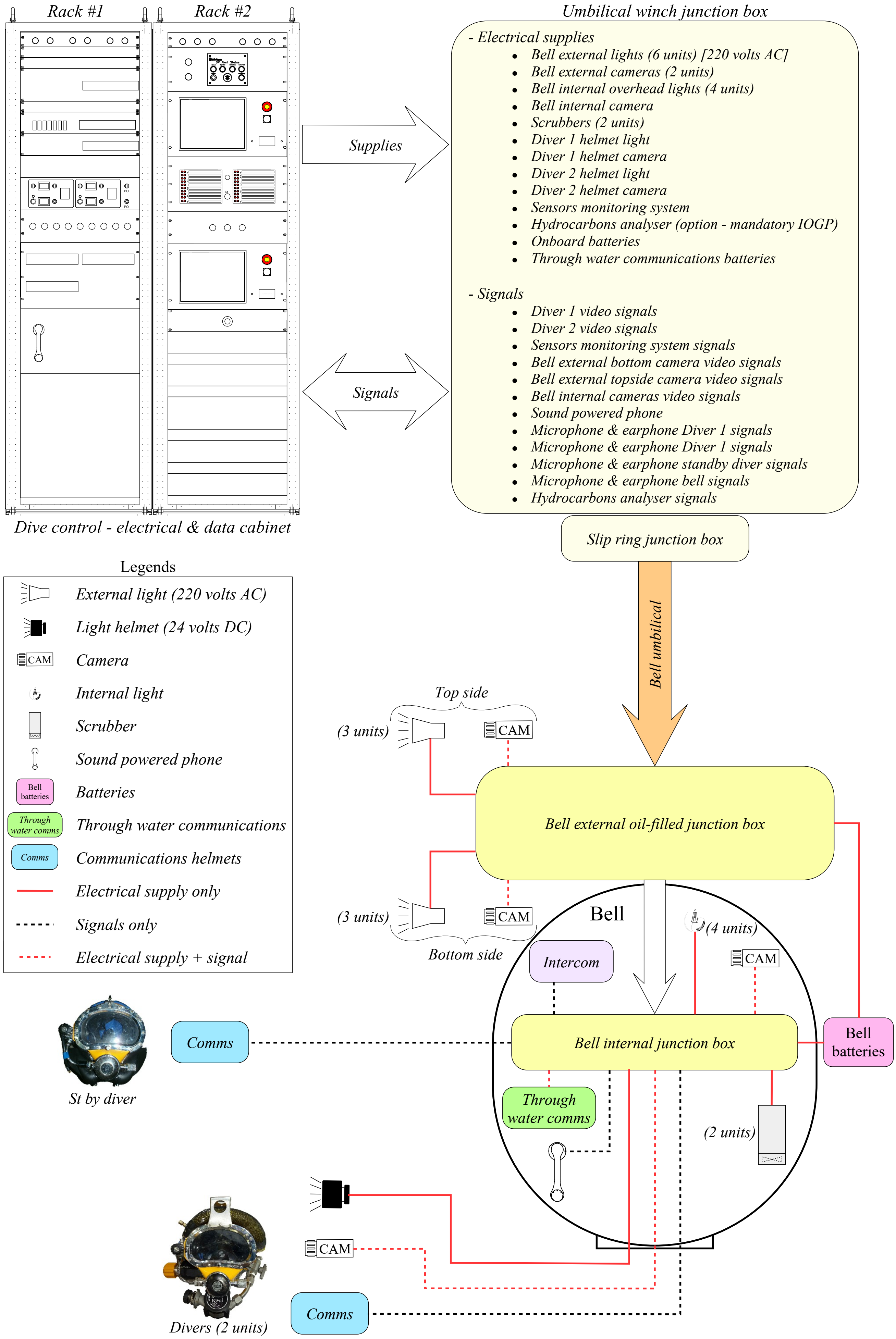
No	Description	Requirements IMCA	Requirements from clients and other organizations	Additional information
1	Bell reclaim system	Mandatory	Mandatory	Refer to the full description in point 2..3.12 An emergency stop allow to stop the unit from the dive control.
2	Hot water machine divers #1	Mandatory	Mandatory	Refer to the full description in point 2..3.13 An emergency stop allow to stop the unit from the dive control.
3	Hot water machine divers #2	Mandatory	Mandatory	See above
4	Water pump	Nothing specified	Nothing specified	This pump supplies the water to the hot water machines.

Tables of contents

The scheme below, which is based on drawings of UDS Lichtenstein, represents the main electrical supplies and wired communications of the dive control. Note that the communications and supplies to and from the bell and the client representatives office are not in this scheme and are explained on the next pages.



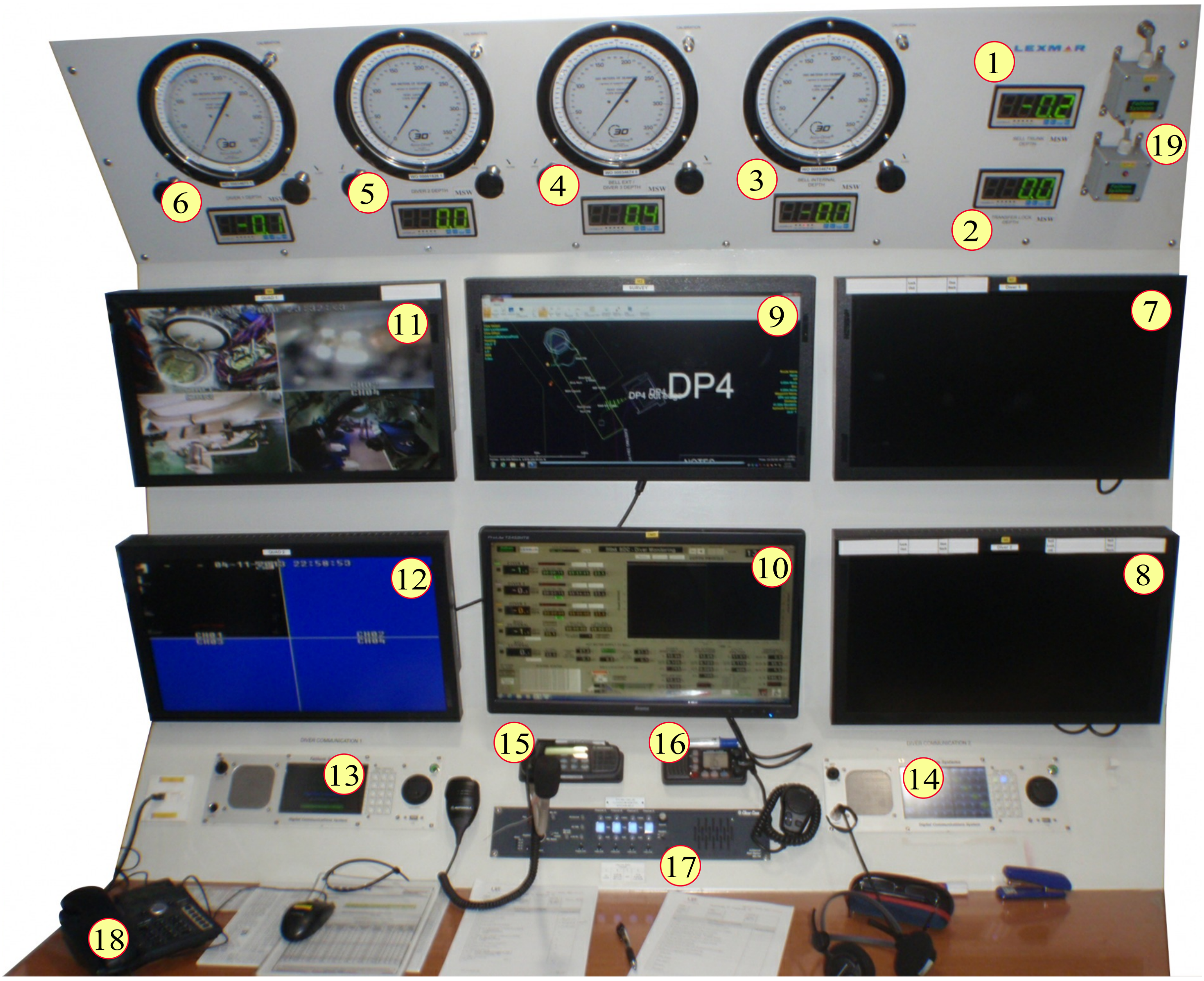
The scheme below represents the main electrical supplies and wired communications to and from the bell.



Client representatives office:
Client representatives are in charge of monitoring the performance of the contractor, report the progress of the operations and any incident, and help the contractor to achieve the planned task. However, they are not the persons the supervisor refers to directly as their action should be done through the chain of command. So, in the case of diving operations, and depending on the situation, through the Offshore Construction Manager (OIM), the diving superintendent, and the master of the vessel.
Their office is usually fitted with:

- Video screens from the dive and ROV controls showing the ongoing work of the divers and the ROV. They are mandatory with most clients.
- Positioning screen from the survey system that provides the position of the vessel, ROV, and divers.
- Dynamic Positioning (DP) alarms. They are not always in place but usually required by the clients.
- Phone communications with external and internal access. It is the minimum wired means of communication asked. However, a lot of oil and gas producers request an additional intercom that allows contacting the critical areas of the boat directly.
- A marine radio. It is in place in the client office of a lot of Diving Support Vessels (DSV), but not in all of them.
- UHF/VHF deck radios. They are commonly used. Sometimes the client provides his systems.

The diving monitoring panel allows the supervisor to monitor other parameters than the quality of the gas supplied to the bell and is already described in point 2.3.14.1 “General design”. It groups the following elements:



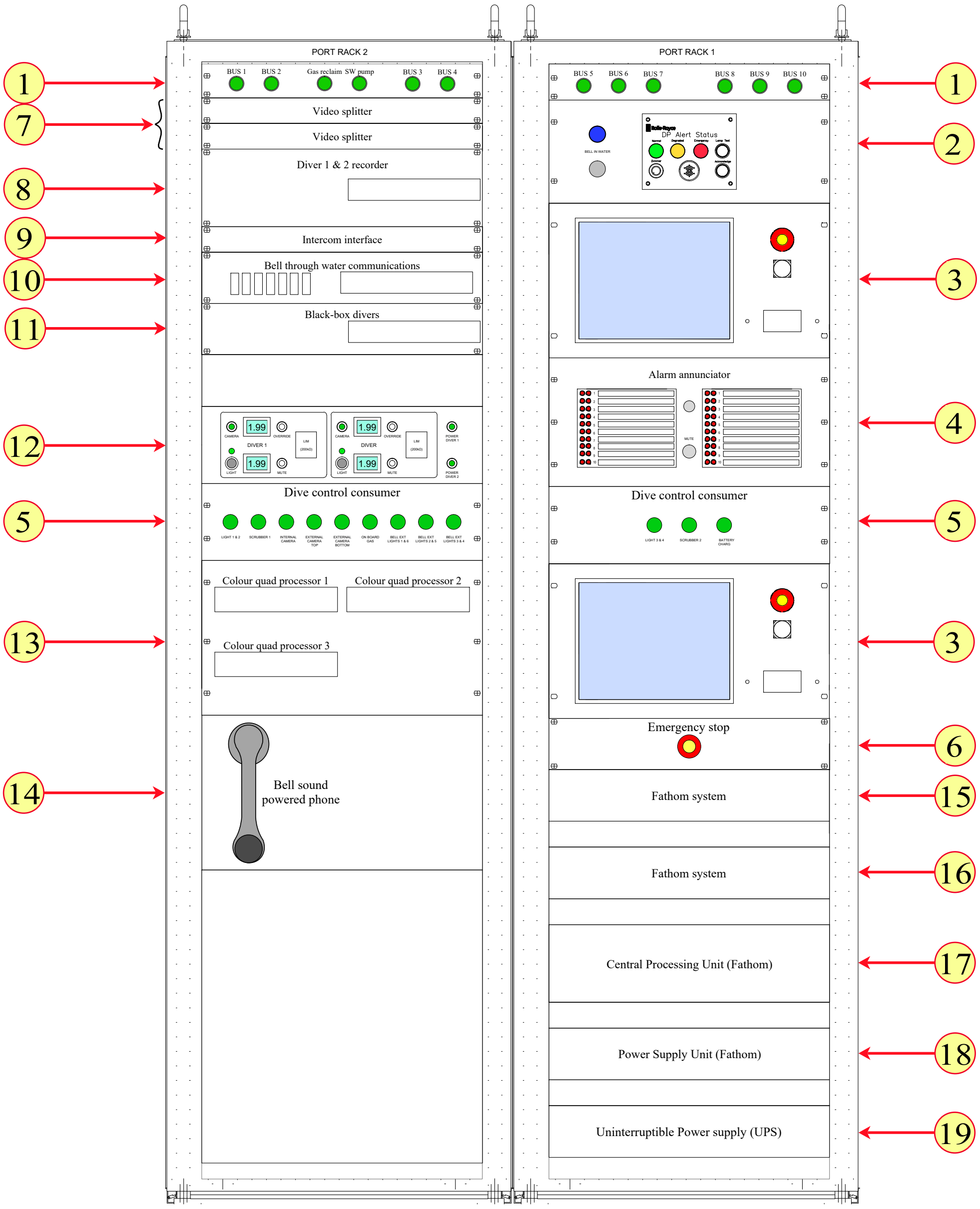
1 - Depth bell trunk	2 - Depth transfer lock	3 - Internal depth bell
4 - External bell / diver 3 depth	5 - Depth diver 2	6 - Depth diver 1
7 - Camera Diver 1	8 - Camera diver 2	9 - Screen survey
10 - Divers monitoring system screen	11 - Screen bell trunk & transfer lock	12 - Screen bell (external & Internal)
13 - Communications bell / divers	14 - Communications bell / divers	15 - Marine radio
16 - VHF radio	17 - Intercom system	18 - Phone

19 - Master base-stations of wireless communications to divers *(See more details in the next descriptions)*

Notes:

- Divers monitoring system *(see #10 on the previous page)* is a specific electronic system which is optional with IMCA, but mandatory inside some national waters. It is explained on the next pages.
- The communications bell/divers *(see #13 & 14 on the previous page)* are digital systems of the latest generation. They are also explained on the following pages with more classical systems.
- Screens to monitor the transfer of the divers to and from the bell and the entry lock and the screen to monitor the external and internal of the bell *(see #11 & 12 on the previous page)* are divided in four. Other screens are above the gas panels and are used to control what happen on deck.

The electrical and data transfer cabinet groups some elements that cannot be integrated into the diving monitoring panel and is also the interface of the electrical supplies and the various video and data signals. Depending on the complexity of the system, it can be limited to one rack or be composed of several units where the following items can be found:



1 - Electrical inlets	2 - Dynamic Positioning (DP) alarms	3 - Hot water machines interfaces
4 - Alarm annunciator	5 - Dive control consumer	6 - Emergency stop gas reclaim
7 - Video splitter	8 - Video recorder divers	9 - Intercom interface
10 - Through water communications	11 - Black-box comms divers	12 - Cameras and lights divers
13 - Colour quad processors	14 - Bell sound powered phone	15 - Intelligent acquisition unit *
16 - Intelligent Network Logger *	17 - Central Processing Unit *	18 - Power supply Unit Computer *
19 - Uninterruptible Power Supply		

* = Elements of the Divers Monitoring System *(See the notes above)*

Notes:

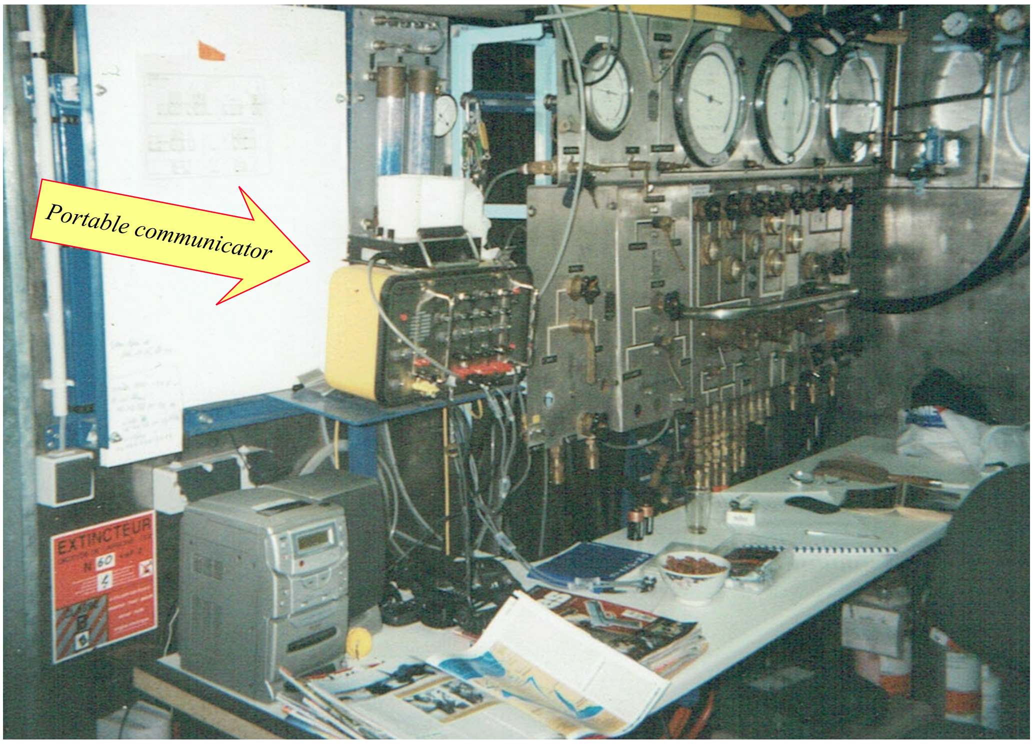
- The definition of an interface is a connection between two pieces of electrical or electronic equipment, or between a person and a computer.
- The dive control panel incoming power supply arrangement groups several "BUS" at the top of the cabinet *(see #1)*. In a power system, a "BUS" is defined as the vertical line at which the several components of the power system (generators, switchboards, transformers, etc.) are connected.
- DP alert status panel *(see #2)* is mandatory and provides visual and audio alarms. Note that last generation systems are provided with a "blue status" when the bell is in the water
- Interfaces with hot water machines *(see #3)* are described in the relevant topic on the previous pages
- Alarm Annunciator Panel *(see # 4)* displays the status of alarm signals using lights and sound features.
- The dive control consumer *(see #5)* groups the several switches of the bell that are illuminated when activated.
- A video splitter *(see #7)* is a device that takes one signal from a video source and replicates it over multiple monitors.
- Intercom interface *(see #9)* is a device in which all intercoms are connected and from which the signal emitted from one unit is routed to the selected intercom.
- The cameras and lights of the divers are switched on and off from the dive control *(see #12)*. A resistor allows dimming the lights of the divers when needed.
- A "colour quad processor" *(see #13)* turns any monitor into a quad monitor with security features and allows to connect up to four cameras and view all four locations simultaneously in real-time.
- An Intelligent Acquisition Unit *(see # 15)* is a system that acquires and processes measurement signals and convert them for the control of the applications of the system. In the Divers Monitoring system, it collects data from the various sensors and provides precise system diagnostics through the use of multiple status Light-Emitting Diodes (LED) which indicate the condition of input signals from sensors and the state of power supplies and telemetry links.
- An intelligent network logger *(see #16)* is a device that collects the "messages" emitted by network devices, operating systems, applications, and all manner of intelligent or programmable devices, and classify them in such a way that they can be accurately stored and interpreted.
- The Central Processing Unit (CPU) of a computer is a piece of hardware that carries out the instructions of a computer program *(see #17)*. It performs the basic arithmetical, logical, and input/output operations of a computer system.
- A Power Supply Unit (PSU) converts mains AC to low-voltage regulated DC power for the internal components of a computer *(see #18)*.
- Uninterruptible Power Supply (UPS) is described previously in the list of power supplies to the dive control. Note that in addition to the devices described in the list, this model is also designed to supply the Divers Monitoring System, which is mandatory in some national waters. Also, note that the batteries are housed in an open-air area outside the room.

1.1.13.4 - Communications with divers breathing heliox

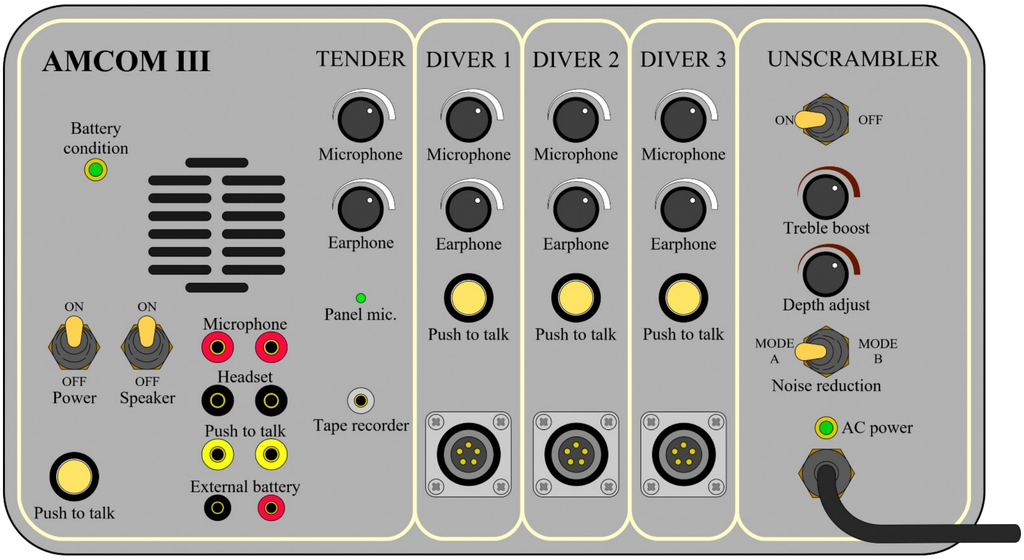
Heliox mixtures are used in saturation as they alleviate the effects of narcosis and dyspnea (respiratory difficulty) which otherwise occur at depths deeper than 30 m with air.
However, the main disadvantage of such mixtures is that they increase the velocity of sounds and generate acoustic impedances with are altering the speech emitted by the diver to such an extent that its intelligibility is heavily impaired. Also, it has been established that trying to change the voice characteristics and slowing down the speech to adapt to the new environment generally results in a less intelligible conversation. As a result, severe mistakes in comprehension may occur that can lead to fatal errors. For these reasons, corrective systems have been created and implemented.
The first speech unscramblers were based on studies related to the general structure of vocal tracts and assumed that the voice distortion depended mainly on the physical and chemical parameters of the breathing mixture. Thus, the distortion of the voice in a helium-based atmosphere was supposed to be a linear process. As a result, these systems were not perfect, and the supervisor needed to be familiar with deformed voices to understand the divers fully.
More detailed researches on the emitted frequencies and the structure of vocal tracts demonstrated that the intelligibility of a conversation varies from one person to another and that the distortion of the voice of a diver breathing a helium-based mix is a non-linear process. However, the first systems based on these studies were limited by the available technologies and were not capable of independent manipulation of frequency bandwidths and amplitudes, which resulted that the modification of one parameter impacted the others. These problems demonstrate that the comprehension of a conversation also depends on the restitution of the bandwidth emitted by the equipment used, and thus, is directly linked to the quality and the technical possibilities of the material used.
The latest generation of unscramblers makes a profit of the progress of the quality of the materials and of the computing technologies that allow treating any problem separately without affecting the other parameters. However, despite the tremendous improvement, the results are not yet 100% perfect and research to improve the next generations continue.

Helium speech unscramblers used in diving and saturation control rooms are generally designed to be inserted in the control panel *(see the previous point)* with their electrical and communication wires connected to their back, thus not visible and protected from shocks and inappropriate manipulation.
However, portable units are sometimes found with some small saturation systems. They are usually inserted in a

solid waterproof shell that is designed to protect their back from shocks and moistures. As a result, the communication wires that link the divers to the dive control must be connected to their front panel with the microphone and the headset. Also, the majority of portable models are based on systems designed for surface orientated air diving to which an unscrambling device is added. The advantages of mobile devices are their robustness and the possibility to replace them, in case of a breakdown, quickly. Also, most devices provide duplex communication allowing to speak and listen at the same time. However, their unscrambling performances are inferior than those of panel mounted models initially designed for heliox diving.



A lot of efficient portable communication systems designed for heliox are available on the market. However, it is impossible to describe all of them in detail. It is the reason the AMCOM III heliox communicator, which is often seen in dive controls (see above) and is a representative example of such equipment is described.
This model is a three diver communicator to which an optional unscrambler is fitted. It is designed with independent volume controls of the microphone, and earphone of the diving supervisor and each diver. Also, a connection to the tape/DVD/HDD recorder is available and can be connected to the video system. In addition, an external microphone with a push to talk command and a headset can be installed, so the supervisor can isolate from external noises when needed. This diving communicator is usually powered with Alternative Current (AC) 220 volts, but it is also fitted with an internal battery and can also be supplied by an external 12 volts battery or transformer. The internal battery condition can be checked through a light that is green when the battery is full and red when it is empty or out of order.
Note that the optional unscrambling system converts the analog audio information to digital, store these digital data, and recombine them to reconstruct the audio without the frequency shift caused by the helium gas.
The model represented below has a "noise reduction" function which reduces background sounds such as hum and whistling which are increased by the concentration of helium. Mode A is usually for shallow depths and mode B for deeper depths. This function is completed by the "Depth adjustment" command which modifies the correction made by the algorithm according to the depth. "Treble boost" control enhances the frequency from the microphone of the diver.

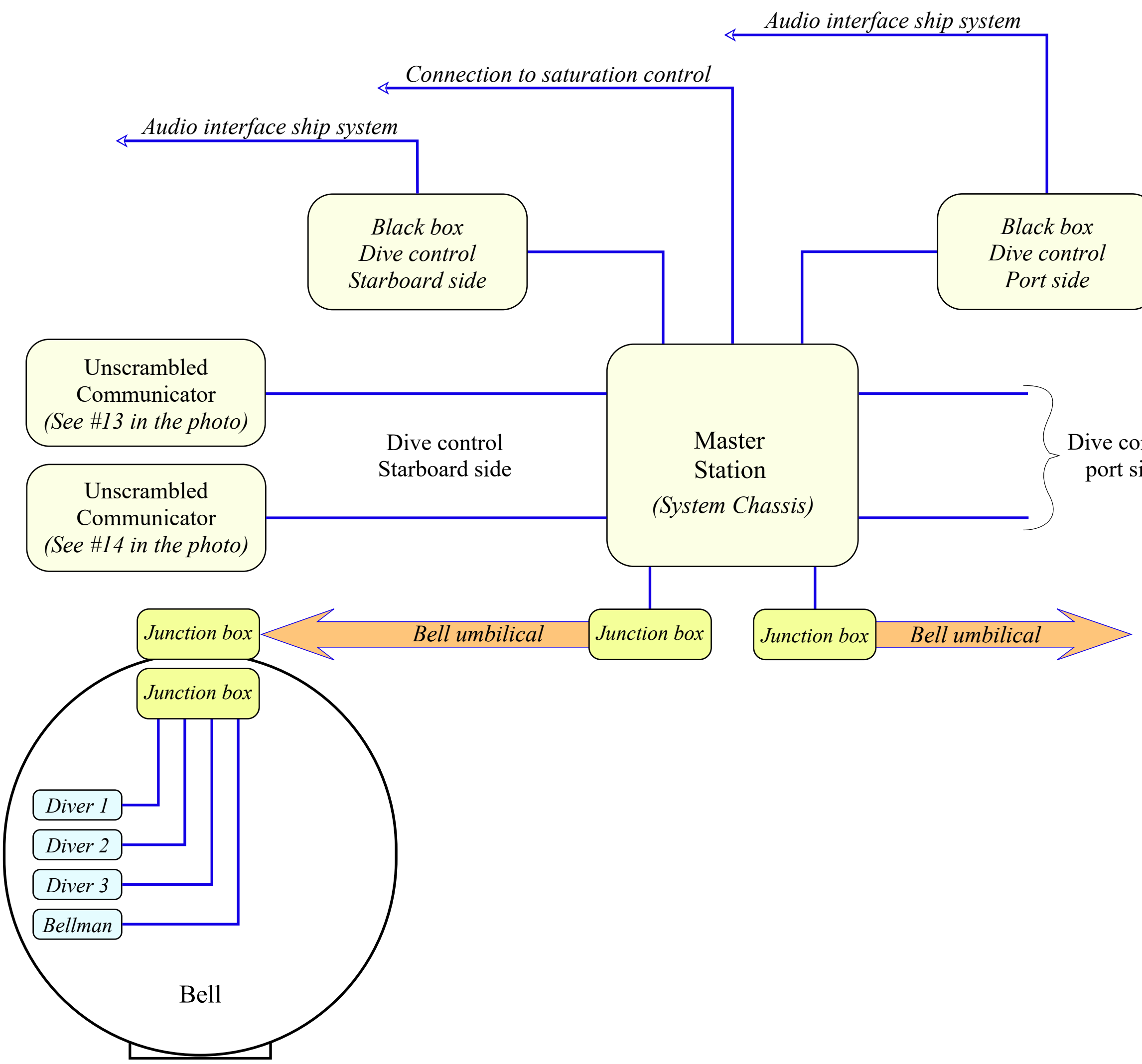


The portable communicator described above is based on reliable technologies that have evolved over the years and continue to be updated by small touches. Nevertheless, it is based on a concept from the nineties in which the quality of the sound is optimised using a series of potentiometers, and that limits the communications channels to those that are visible on the facade of the device. As a result, any new channel requires the installation of a corresponding module or the use of another unit.

Such inconvenience can be avoided with the latest generation of diver communications products that are based on a fully digital signal processing and routing. These systems that make a profit of the most recent progress of the computing industry can be configured for a wide range of applications ranging from a simple 3-channel stand-alone comms system up to a complex multi-channel system spread over a number of separate interconnected units. The advantages and possibilities provided by this new technology can be listed as follows:

- Improved audio performance which result from the fully digital audio processing (volume controls and channel mixing / routing) and the improved quality of the audio codecs and low-noise analogue signal paths;
- Fully isolated diver interfaces;
- As a result of the improved initial audio performance, the helium speech unscramblers allow for more intelligibility of conversations. Also, they are configurable on multiple channels.
- Their architecture provides more flexibility with the possibility to link multiple units together through a digital fibre-optic network, allowing any channel to be accessible from any communications unit. That avoids the installation of additional modules or units.
- Similarly to tablets and computers, there is the possibility for the supervisor to use a wireless communication system, allowing him to be always in communication with the divers when moving in the dive control and performing tasks such as adjusting the gas panels.
- Another advantage that is similar to those offered by last generation computers, tablets, and smartphones is that the supervisor can store his preferred system settings and organize for automatic standby redundant operation for mission-critical applications.
- Not normally used with bell management but in the saturation control room, a telephone interface allows the divers dialling internal or external numbers from within chambers and to speak to others in an unscrambled voice.

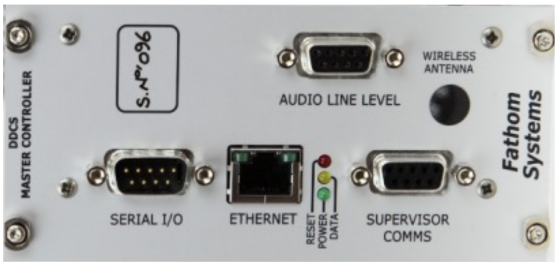
The drawing below, which shows the organization of the communications of the dive control that is taken as an example in this presentation *(refer to the photo of the monitoring panel)*, illustrates some of the possibilities offered by such new systems. Note that in this example, the interconnections have been limited to the dive and saturation controls.



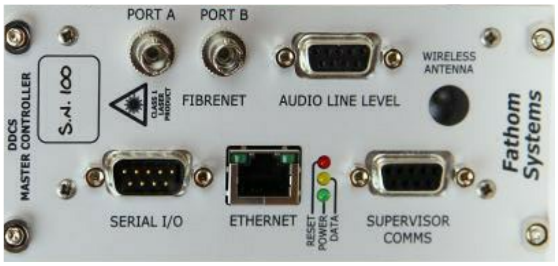
In addition to the extensive possibilities of interconnections, one crucial element to take into account with this new generation of communicators is that their control is based on series of menus that are accessed from the touch screen of a terminal that is linked to a master station which is installed in the dive control. That is a significant change compared with the previous generation systems to which most supervisors are familiar. For this reason, a description of the devices that are installed in the dive control taken as a reference is necessary. Note that the manufacturer of this system is Fathom.

As it can be seen in the scheme on the previous page, operation of the communicator, which is called "Digital Diver Communication System (DDCS)" by the manufacturer, requires a "master user", who is usually the diving supervisor, who controls one or more comms units which link to the various "remote devices". The remote devices can be a diver's helmet, the intercom of the bell, the saturation control room, or an outstation in a chamber if the system is configured for this purpose.
The system is composed of a chassis that can be mounted in any suitable location and does not need to be installed in the control panel, as is the case with classical communicator systems. This chassis is equipped with modules designed to provide sufficient channels to perform the operational requirements expected such as:

- The power supply module that provides Alternative Current (AC) 90-265 volts to Direct Current (DC) 24 volts.
- The Master Controller module in with a Digital Signal Processor (DSP) performs all signal routing, switching, mixing, level adjustment, multi-channel parallel helium speech unscrambling, breathing rate extraction, and filtering to reduce breathing noise levels.
  This module can be equipped with an optional fibre optic interface module that allows the audio channels to be available on any connected unit.



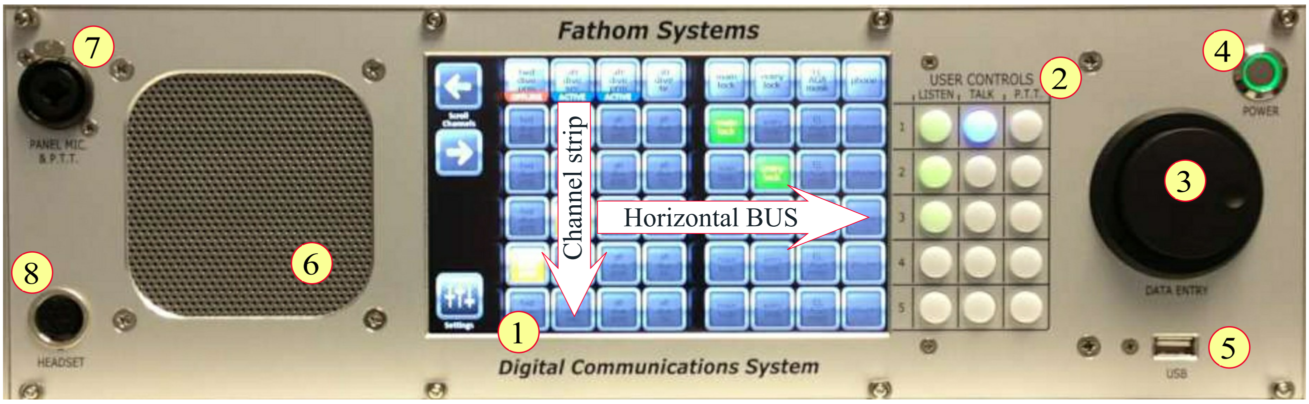
Master controller module (rear)



Master controller module with fibre optic interface (rear)

- A module provides galvanically isolated audio channels to the divers and the bellman in the bell, and if configured for, to chamber outstations or other remote stations. Note that "galvanic isolation" is a principle of isolating the functional sections of electrical systems to prevent current flow and provide safety from fault conditions in wired communication between devices that regulate their electrical supply. Each channel is designed with a configurable interface supporting various power and signalling technologies.
- A module provides input and output (I/O) channels that are used for connections of recording equipment, entertainment systems, and third-party equipment. When configured for, such module can also support a telephone interface that allows unscrambled telephone calls between the divers and any location in the vessel or onshore.

The modules described above are controlled from an "Operator Control Panel (OCP)" unit which can be installed in the chassis or remotely on a separate user's control stand. With the system taken as an example, the supervisor can use two "Operator Control Panels" *(see #13 & #14 in the photo of the control panel point 2.3.14.3)*.
Note that several versions of operator control panels are available and that the model in the dive control taken as an example is the "version 3" *(see the picture below)*.

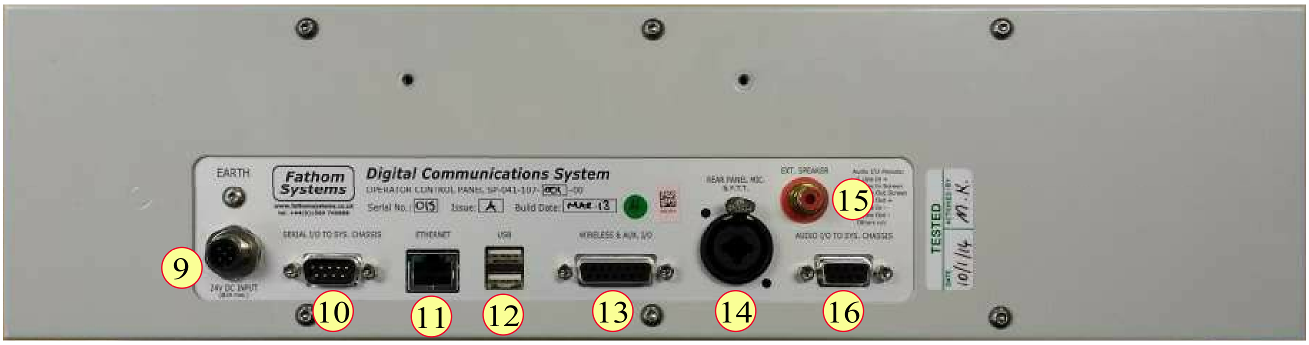


- This Operator Control Panel (OCP) is composed of a touch-screen display which is connected to an internal embedded computer card that manages its functions *(see #1 above)*. This touch-screen provides information about the connected channels and the settings of the system. Also, it allows the user to adjust the setup and navigate through several configuration pages.
  The main display is the "communications matrix" that represents various channels which are arranged in vertical columns that are identified by "tiles" and are divided into five horizontal rows or 'buses'. Each horizontal "bus" is a common connection that runs across all remote user channels in the vertical strips *(In computing, a "bus" is a communication system that transfers data between components inside a computer, or between computers)*. As a result, when touching the "channel tile" on the desired bus, the user can select any channel of this particular bus.

- Three “User controls” buttons are provided on the right side of each of the five horizontal buses *(see #2)*. These buttons provide the following functions:
    - “Listen”, which illuminates green when it is pressed on, allows the supervisor to listen to all the selected channels on the corresponding “bus”.
    - The “Talk buttons” allow the supervisor talking on a latching mode to remote users who are connected on the selected bus. These buttons illuminate blue when they are pressed on. Also, if the “listen” button is not already pressed on, this function is switched on automatically as it is assumed that the operator wants to receive an answer.
    - The “Press to Talk” buttons which are labeled “P.T.T.” are only functional when the Supervisor is not in latched talk mode *(the "talk button" is off, and the corresponding blue light is not illuminated)*. In this condition, the supervisor can use the "Press to Talk" button to call or answer to the user(s) connected through the corresponding bus.

- Situated further to the right of the touch-screen, the “data control wheel”, which is marked “Data Entry”, can be rotated either clockwise or counterclockwise *(see #3)*. It is a digital encoder knob that allows adjustments of parameters and the selection of controls on the particular touch-screen display page selected.
- The power button of the unit is installed in the corner above the “data control wheel” *(see #4)*. This button is illuminated in green when the power is on.
- A Universal Serial Bus (USB) socket is visible below the “data entry wheel” *(see #5)*. It allows connecting various devices such as a keyboard, a mouse, or a memory stick for software updating or other maintenance activities.
- A loudspeaker which is protected by a stainless steel grille is on the left of the touch-screen *(see #6)*. It can be used to listen to the person the user is talking with without a headset or headphones. It is switched on or off via the relevant configuration page in the software.
- A 3-pin XLR / ¼” mono jack combination socket is available at the top left of the panel and identified as “Pa Mic. P.T.T” *(see #7)*. This connector is used for either a panel microphone, such as a goose-neck microphone, or another type of wired microphone, or a “press-to-talk” wired switch.
- In the corner below the “PANEL MIC. & P.T.T.” connector described above, there is a screw-locking type 7-pin DIN socket that is labeled “Headset” *(see #8)*, which is designed for connecting a wired headset to allow for private communications. This connector also allows a remote “press to talk” switch to be used.

The rear of the “Operator Control Panel” allows noticing that this system is very different from the communicators of the previous generation and is, in fact, a network of computers.



- Similarly to the modules in the System Chassis the “Operator Control Panel” is supplied with Direct Current (DC) 24 volts, through a power connector (see #9) that is linked to an external power supply module.
- The “Operator Control Panel” communicates with the modules of the System Chassis via a dedicated RS232 serial link for its control functions *(see#10)*. In computing systems, Recommended Standard 232 (RS-232) refers to a standard for serial communication transmission of data which defines the signals connecting between a data terminal equipment (DTE) such as a computer terminal, and a data circuit-terminating equipment or data communication equipment (DCE) such as modems, printers, computer mice, data storage, uninterruptible power supplies, and other peripheral devices. RS232 serial link is found on any desktop.

- An Ethernet connector is provided to link to other Digital Diver Communication System (DDCS) components and share information *(see #11)*. In computing technology, “Ethernet” refers to a system that connects computers together in a local area network or LAN. Dedicated cables connect to boxes called hubs or switches. Several standards exist that allow multiple computers to send data at any time. Such connection is commonly found on any desktop or laptop.

- In addition to the one provided on the facade, two utility Universal Serial Bus (USB) are provided on the rear panel *(see #12)*. USB is a standard that has been developed to simplify and improve the interface between personal computers and peripheral devices. It establishes specifications for cables and connectors and protocols for connection, communication and power supply between computers, peripheral devices and other computers.
- A D-sub (also called D-subminiature) connector is in place to provide power, audio interfaces and telemetry signals to the wireless master station *(see #13)*. Such connectors ensure correct orientation and screen against electromagnetic interference.

- An XLR connector is in place to install an external microphone *(see#14)*. XLR connectors are circular electrical connectors primarily found on professional audio, video, and lighting equipment. They are most commonly associated with balanced audio interconnection, including digital audio, but are also used for lighting control, low-voltage power supplies, and other applications.
- There is also a connection for an external speaker *(see#15)*. Note that this connection is similar to those used with communicators of the previous generation.
- Another D-sub connector is in place to provide additional power, audio interfaces and telemetry signals to the wireless master station *(see #16).*

As indicated before, a 2.4 GHz wireless communication system that provides an audio link in both directions can be used by the supervisor. Note that for several years, wireless systems at a frequency of 5 GHz are available. The differences between the two frequencies are that 5 GHz band transmits data at a faster speed but provides less coverage. The more reduced coverage is due that the fact that high frequencies cannot penetrate solid objects, such as walls and floors. That explains the choice of many manufacturers of Wi-Fi controlled equipment not to use this frequency for their applications.

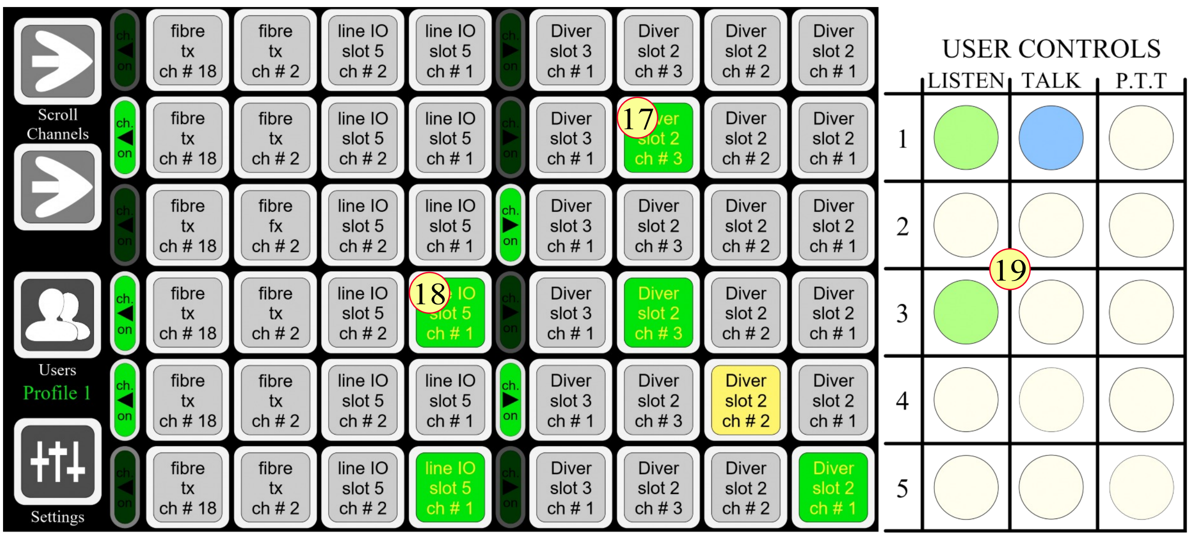
The supervisor connects to the system through a battery supplied hand-held or belt-worn unit which contains the wireless interface in addition to a headphone and a microphone interface. The battery that powers the device can be refilled with a phone USB charger. A keypad allows selecting one of three of the buses, and a press-to-talk button is used to communicate with the selected Bus. A failsafe system informs the user in the event of a link failure. Additional wireless units can be configured in the system for other users such as an example the person responsible for checking the bell on deck.

The wireless pack communicates with an interface module in the Operator Control Panel. It must, therefore, be paired with it to operate correctly. Note that in the networking process, “pairing” is the procedure to set up a dedicated linkage between devices, allowing them communicating together and not being affected by other communications. This process allows multiple wireless packs to operate in the same area.
Note that the latest Operator Control Panel version of the system described can be fitted with an external base station which is wired to it to improve the connection. These base stations are visible on the photo of the diving monitoring panel of the dive control taken as an example in point 2.3.14.3 (see #19).

Hand-held unit

belt-worn unit

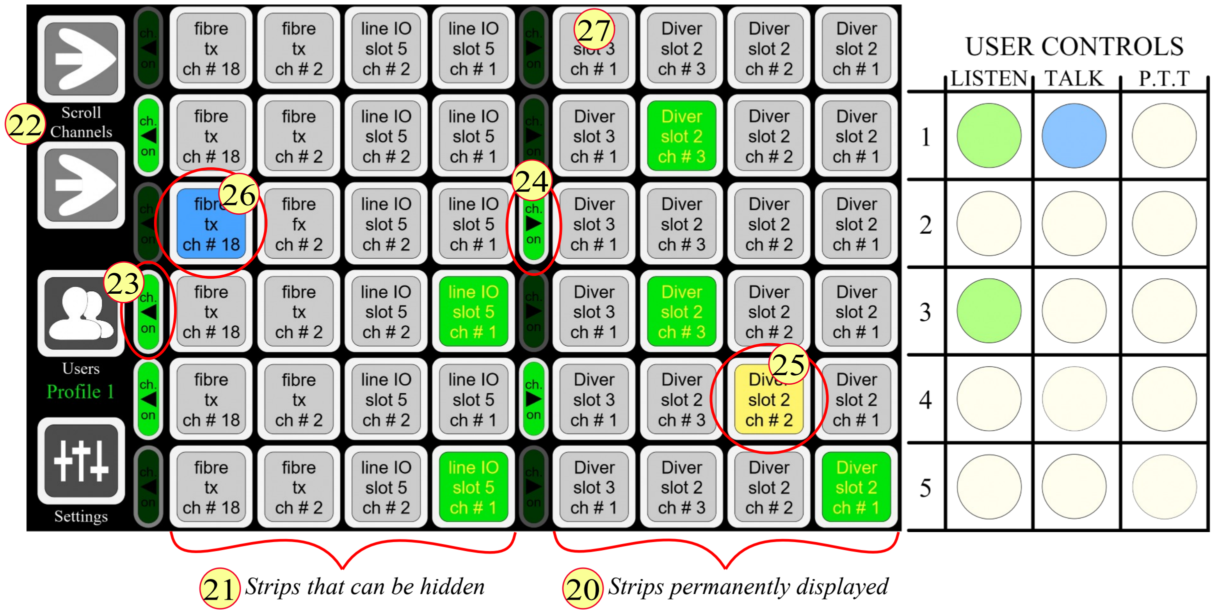
The presentation above shows that the setting up and control of this new generation of communicators are very different from those of more classical systems where the adjustment is made through a series of switches and potentiometers. However, People familiar with computers and tablets will not be disturbed with such a new design.
As explained previously, this concept considers that the horizontal buses displayed on the touch screen are a common connection that runs across all remote user channels in the vertical strips.
The user can select any channel of a particular bus to be connected through it. To do it, he touches the channel “tile” on the desired bus. As a result, the channel’s tile on the bus is illuminated *(see #17 &18 below)*, and the channel is connected to the desired bus. To disconnect the channel from the bus, the user touches the illuminated tile again, and the tile returns to the dark grey colour. There are 5 Buses on the model presented that are numbered from top to bottom on the “User Controls” keypad which is directly on the right-hand side of the touchscreen *(see #19)*. This keypad, which has been previously described *(see #2)* allows to listen or listen and talk, depending on the button selected.



If the user wishes to talk to a location, he places the location's channel on a bus (any bus will do), and then selects the corresponding button(s) on the keypad at the right of the touch-screen to be connected on that bus.

The space on the matrix screen is limited to eight (8) strips at one time. Also, it is organized with four static strips that are dedicated to the communications with the divers and are always visible. These essential strips are grouped to the right-hand side of the screen *(See #20 below)*.

To accommodate additional channels, the left-hand side section of the matrix screen is configured so that some channels are not always visible *(see #21 below)*. They can be accessed using two tiles in the topside left-hand side corner that allow scrolling to the left and the right *(see #22)*. To inform the user that there are active channels on a particular bus which are hidden due to the scrolling function, a small "activity indicator" is displayed for the involved bus pointing in the direction where an active channel is located *(see #23 & 24)*.



Fifteen "local channels" are available on the "System chassis" that can be connected to the "Operator Control Panel" and be visible on the matrix display if the corresponding modules are installed. Local channels are those limited to the modules in the "System chassis". They are connected through connectors which are specific to link several printed circuit boards together within the computer system.

Also, if the hardware configuration of the system includes the fibre-optic interface modules described previously, there is the possibility of communicating with remote stations in the ship through eight additional channels. In this case, a total of twenty-three (23) channels strips that can be visualized on the matrix display. Note that the remote fibre channels assigned to an "Operator Control Panel" have an indication on their tile that shows their status and whether the station is active or offline.

As a result of the numerous possibilities of channels, the supervisor may request that the function or the location of each channel is precisely indicated for a more suitable display and a better ergonomic. For this reason, the channel strips are configurable and can be named by the technician.

Diving communicators must be fitted with a connection to the safety recording system (Black box). Several channels can be configured for this purpose so that they are included in the "black-box" recording output group. This function is used to collect a number of audio comms channels and send them on a particular channel so that the audio can be recorded on a separate digital audio/video recorder. The selection of which channels are recorded is set up by the technicians, and all channels that are being recorded have a small red Light Emitting Diode (LED) on their title tile.

When the supervisor calls another station, both users can talk and listen at the same time without the need to press any buttons. It is the default setting for conversation, which is based on an algorithm called "Round-Robin Mode" that uses scheduling techniques to assign processing time slices, and transfer queued data packets. However, the supervisor can modify this setting using the functions of the "user controls" keypad.

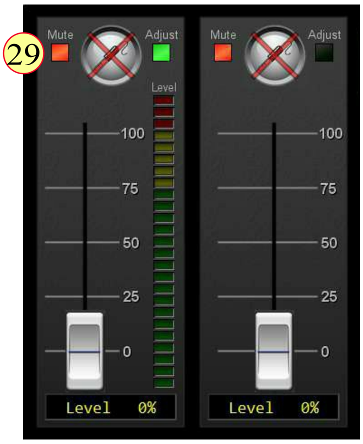
"Cross-talk mode" which is commonly used with classical communicators to allow the divers in the water to talk to each other can be implemented. To do it, the channel strip tiles are merely selected onto the same bus.

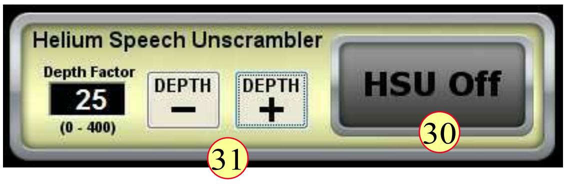
Also, the supervisor can reduce the connection of one or several remote users to listen only. As an example, he wants the bellman hearing to the divers in the water but does not want him intervening in their conversations. In this case, the tile corresponding to the station is held pressed for a couple of seconds. As a result, it becomes yellow (amber) which indicate the new status of the station *(see # 25 in the drawing above)*. Also, the supervisor can talk to this station using the "press to talk mode. In this case, the yellow tile becomes light blue when the supervisor is talking *(see #26 in the drawing above)*.

Note that there are theoretically no limits to the number of remote users connected on the same bus. However, the manufacturer recommends limiting to two or three connection on a single bus as it can get quite confusing trying to understand who is talking if there are too many stations connecting at once.

Adjusting the volume of the channels is performed through the touchscreen: The user press first the 'title tile' at the top of the vertical channel strip he wants to adjust *(see #27 in the drawing on the previous page)*. As a result, the display changes to the channel adjustment page where two linear adjustment controls, also called "sliders", for the volume of the microphone and the speaker/headset are displayed with the name of the channel and the commands of the unscrambler.

The volume of each device can be adjusted using a finger on the touchscreen or using the data wheel *(see #3 in the photo of the OCP's facade)*. In this case, the operator must touch the adjustment control of the device to be adjusted on the touchscreen to select it. When an adjustment control is selected, a green light labeled "adjust" is illuminated *(see #28 above)*. If the volume of the device is set to 0%, the symbol above the slider shows a red X, and a red indicator below the label "mute" lights to note that the function is turned off *(see #29 below)*.





The helium speech unscrambler (HSU) can also be turned on or off from this page *(see #30 above)* and the depth of the diver adjusted to provide the best intelligibility *(see #31 above)*. To do it, the operator presses the corresponding tiles on the touchscreen.
When the adjustments are completed, the operator presses the tile "done" to close the page.

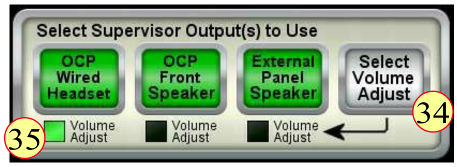
In addition to the settings of the several remote stations, the supervisor must adjust his microphone and speaker/headset settings. To do it, he presses the "Settings" button on the matrix display to obtain the adjustment page. The page displayed is similar but provides more options than the one described above.

The sliders for the adjustment of the microphone and the earphone are similar to the one of the user channel described previously. For this reason, they are adjusted using the same procedure.
However, four possible microphone inputs can be used *(see #32 above)*:

- Wired headset
- Front panel microphone
- External panel microphone

- Wireless belt-pack

They are selected by touching the relevant button on the touchscreen to provide the supervisor with the desired functionality. Nevertheless, only one microphone input can be selected at a time. As a result, choosing a new microphone via the touch-screen turns off the previously selected input *(see #33 below)*.
Note that each selected microphone input has its volume/gain setting that is displayed on the adjustment control of the slider. Choosing a different microphone input causes the adjustment control to show the volume setting for the selected microphone automatically. Thus, if these adjustments were previously satisfactory, the supervisor does not need to touch them again.



Three possible speaker/ears outputs can be selected for use with the Operator Control Panel.
Wired headset
Front speaker
External panel speaker
They are selected to provide the desired functionality of the "Operator Control Panel". The system allows multiple outputs to be active together, and therefore the three buttons are used to toggle the particular output on and off. As there are three possible speaker/ears outputs, a "Select volume adjust" button allows the user to select which of the outputs is being adjusted *(see #34 above)*. In this case, the chosen output "Volume Adjust" indicator is illuminated in green *(see #35 above)*.

Note that if the wireless belt-pack system is in use, the headphone output on the wireless belt-pack is automatically enabled. However, such a device must be "paired" to the "Operator Control Panel" the 1st time it is connected. To do it, the operator presses the button "wireless outstation". When the device is successfully paired, the red status indicator becomes green.

The supervisor can place the "Operator Control Panel" into standby mode by pressing the relevant button. In this case the station is powered down and disconnected as it is the case with every computer. When the button is pressed, a confirmation pop-up asks the user for confirmation of this request.

As with the menu for external users, pressing the button "done" returns the display to the main matrix view.

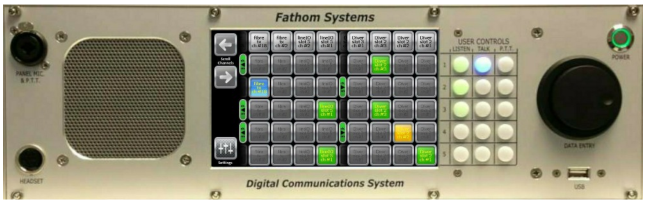
Phone communications:
The "Digital Diver Communication System (DDCS)" can be configured to provide one or more telephone interface channels through a module that connects to the host vessel phone system.
The purpose of the telephone system is to allow the supervisors or chamber occupants in saturation to talk to people such as doctors, family members, company managers, and others. That can be done with the benefit of the helium speech unscrambler if needed. Note that satellite phone communications in the dive and saturation controls are mandatory with the majority of the IOGP members and other clients.
The telephone page is displayed when the title tile for the phone channel at the top of the vertical channel strip is pressed. This page provides a dial pad that is used to compose the number to call and the sliders to adjust the volume of the microphone and the speaker that are similar to those used with the other setting up pages.

Operating the telephone is similar to using any smartphone. The supervisor dials the number to call or selects it from the list, and then presses the button labeled "call" to make the call. If the vessel telephone exchange requires an outside line, the relevant digit is to be dialed first.
Depending on the reason for the call, the supervisor places the telephone channel on a bus in round-robin mode and selects talk & listen to that bus. He can then talk to the party being called and handle the transfer to the diver in the chamber if needed. In the case of a private conversation, the supervisor then deselects his channel from the bus once the call is underway. The call can be ended by pressing the red button as with a smartphone.
The system also allows incoming calls to be handled. In this case, the system rings and flashes the channel title tile on the matrix view. The supervisor can choose to answer or reject the call.

When there are two identical “Digital Diver Communication Systems (DDCS)” operating side by side and interfacing to the same group of users, but with only one system being used at a time, they can be configured to operate in dual redundant mode. This function provides a backup system that can be used immediately in the event of a failure or problem with the primary system.
In this case, the primary “Digital Diver Communication Systems (DDCS)” must be powered up and the backup DDCS in standby mode. As a result, the unit standing by displays a “splash screen” that indicates its condition *(see below)*.

If the Operator Control Panel (OCP) is a member of a redundant pair, this status is shown for both Operator Control Panels in the redundant pair, allowing the user to check that the two units are operating correctly.
Note that when a redundant pair of Operator Control Panels is first powered up, the two units are into standby mode. For this reason, the operator must press the button “Switch to duty mode” of only the OCP that is going to be used. When the selected Operator Control Panel is placed into duty mode, the button “Switch to duty mode” is disabled on the screen of the second unit as long as the selected Operator Control Panel is on duty *(see the photos below)*. We can see that it is the case with the photo of the control panel taken as an example in point 2.3.14.3.

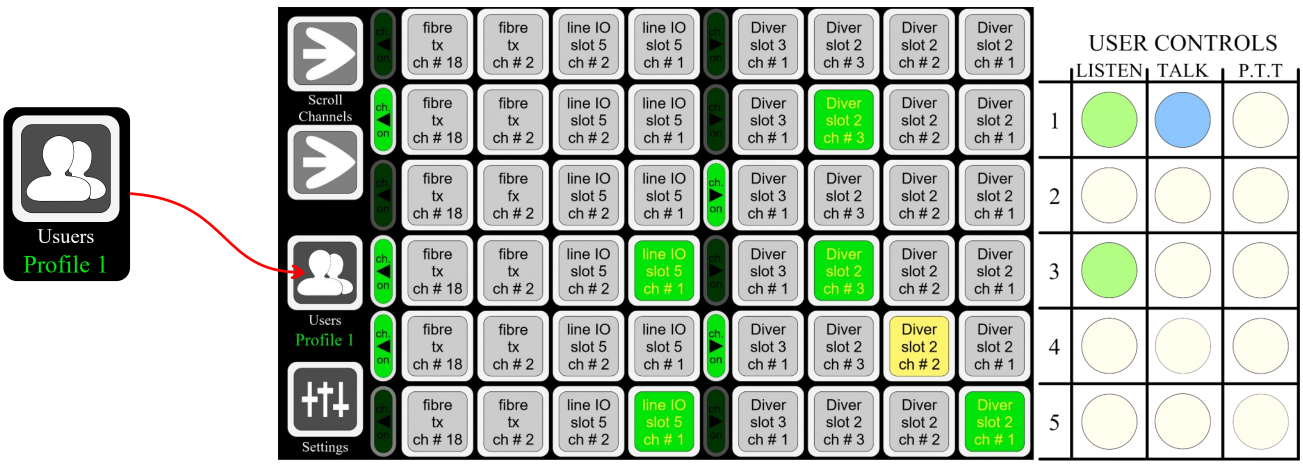
Operator Control Panel standing by



Operator Control Panel on duty

The manufacturer recommends that the duty and standby “Digital Diver Communication Systems’ are alternated on successive dives / bell-runs to ensure that both systems are maintained fully functional and tested regularly.
To swap the Operator Control Panel on duty, the unit in service must first be placed into standby mode. Then the unit to be used can be implemented. In the event of a fault or critical problem, it can be done by switching off the power to the defective unit.
Note that the systems described above can also be configured to operate in concurrent mode. As a result, the two master users can communicate with the same group of remote users at the same time (as an example, divers). In this case the stations used are on “duty mode”
This configuration is commonly used when inspection activities are carried out by one diver who needs to be in close communication with the inspection coordinator at the same time as the other diver continues to focus on other tasks under the diving supervisor’s instructions. In this case, it is vital that the diving supervisor can monitor all the diving activities he is responsible for, and this mode allows him doing it.

When the system is adjusted according to his preferences, the supervisor can save hi settings. The system provides twelve profiles that can be stored in the machine or the possibility to save profiles on memory sticks that can be connected to the USB port of the facade. To do it, the supervisor touches the button labeled “Profiles” on the matrix screen *(see below)*



The selection page that opens displays the twelve buttons of the profiles that can be saved *(see below)*.

To save his profile, the supervisor presses the button he selects to store it and then presses the button labeled "Done" *(see above)*. Note that the stored profile should be recorded on a document that is easily visible to avoid another supervisor from erasing it by accidentally.
If the supervisor prefers saving his profile on a memory stick, he inserts it into the USB slot of the active OCP and presses the tile labeled "Save". Then he follows the instruction provided by the machine. Note that the manufacturer says that memory stick provided must be compatible, not contain other files, and be certified virus-free.
To load a profile, the supervisor inserts a relevant memory stick into the USB slot and presses the button labeled "Load" *(see above)*. As a result, the machine prompts him to confirm the operation. When the procedure is confirmed, the profile settings saved on the USB stick replaces the settings for the currently active profile.

To conclude on diver communication systems:
The presentation above shows two types of communicators that are based on technologies that are not from the same generation and coexist with their advantage and inconvenience. Both systems provide a Modified Rhyme Test (MRT) score above 0.91 *(see below)*, and so, can be used to manage a conversation in a pressurized heliox atmosphere.

Communication requirement	***MRT score***
Exceptionally high intelligibility; separate syllables understood	0.97
Normally acceptable intelligibility; about 98 % of sentences correctly heard; single digits understood	0.91
Minimally acceptable intelligibility; limited standardized phrases understood; about 90% sentences correctly heard (not acceptable for operational equipment).	0.75

It must be noticed that the fully digital system presented is one of the most advanced that can be found on the market, and its MRT test scores 0.97 and above. Such last generation computing technology systems can replace all the communication systems present in the dive control, as in addition to the communications from and to the divers, the system is designed to replace the intercom and the phone and interact with them if necessary. Also, the latest developments of the computing industry allow navigating through the menus as easily as with a smartphone. That enables the supervisor to refine and save his selected settings, which is not possible with devices from the previous generation.
Nevertheless, we can see that this system is not exploited in full in the dive control taken as a reference in which a separate intercom and a phone are provided for the communications outside the diving area *(see #17 & #18 in the photo of the control panel point 2.3.14.3)*. As a result, we can say that the choice of the features offered by communicator systems depends not only on the design of the system but also on the working and safety philosophy of the diving system owner.
Note that most manufacturers propose fully digital systems that give good results but often have less advanced functions as those described here.

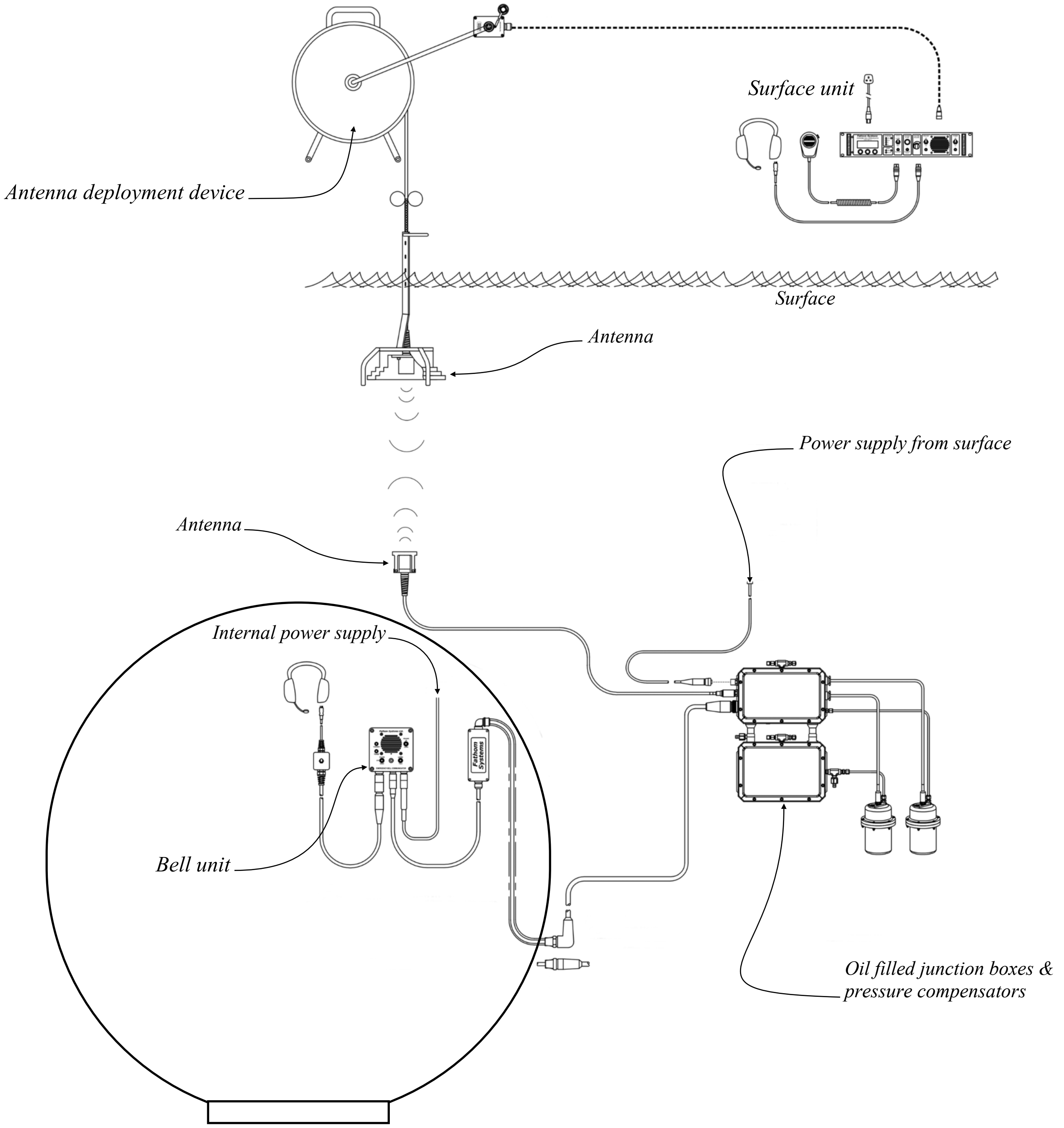
1.1.13.5 - Particularities of emergency communications to the bell

In point 2.3.14.3 it is indicated that A "sound powered phone" and "through water communications (wireless comms)" are mandatory in the dive control. It is also indicated in point 2.3.2.7 "Bell internal equipment". Both systems are located in the "Electrical & data cabinet".

- A sound-powered telephone is a communication device powered by the sound pressure of the voice of the user rather than batteries or an electrical power source.
  When the user speaks into the mouthpiece, the sound waves of his voice cause a diaphragm to vibrate. The vibrations are transferred from the diaphragm through a drive rod to an armature centered in a wire coil that generates an electrical current. The current then is transmitted to the earpiece of the receiver, where the process is reversed. As a result, the person at the other end of the circuit hears the sounds transmitted. Note that the earpiece and the mouthpiece can be used interchangeably. As a result, the user can talk into the earpiece or hear through the mouthpiece, which allows continuing a conversation if one of these two elements fails. Ringing is accomplished by a manually activated magneto producing sufficient electrical power to operate a howler at the called station. This system is

robust and was already used during the 2nd war. However, the communications performed with this device are not unscrambled. Thus, a conversation with divers in a pressurized heliox atmosphere will be difficult to understand. Nevertheless, it can be used to transmit a message from the surface and verify that the divers are well.

- “Through water communications”, also called “Emergency bell communicator”, are wireless communications that must be available to allow the supervisor to talk to the divers inside the bell when it is in the water and communications through wired systems are no more possible.
  The system operates by using high-frequency ultrasonic sound waves that are passed through the water between the bell and the surface vessel. As an example, the set installed in the dive control taken as a reference, which is built by Fathom, uses a frequency of 25kHz. This frequency is also used by other manufacturers. However, 30 to 35 kHz are also very common frequencies.
  The set installed in the bell is powered by the onboard electrical supply of the bell and a dedicated battery pack allowing a conversation during approximately 5 hours. The set installed in the dive control is supplied through the Uninterruptible Power Supply (UPS). There is an output from the topside transceiver for a black-box recorder and also for the helium speech unscrambler. Also, the unit that is in the bell of the system taken as an example has a pinger function that repeatedly sends an “S.O.S.” morse code.
  The emitter/receptor (antenna) is usually deployed in the water when the bell left the surface and is recovered when it is close to the surface. The manufacturer says that the transmission range is about 3 Km, depending upon the underwater conditions. It is true that previously reported experiences have shown that sometimes teams were obliged to deploy the emitter very close of the bell.



Note that the wireless communication systems used with scuba divers are based on the same principle.

1.1.13.6 - Diver monitoring system

This system, which is also designed by Fathom in this example, is integrated into the dive control taken as a reference. It is a computing tool that provides accurate information from the dive system through a dedicated monitor to the diving supervisor *(see #10 in the photo of the diving monitoring panel* *point 2.3.14.3**)*. A similar display is available for the Life Support Supervisor (LSS) . It is also designed to be easy to operate and maintain for both operations and maintenance personnel. Such systems are gradually adopted in the diving industry as they allow for better controls of the operations ongoing. Another reason for the implementation of these systems is that they are mandatory with NORSOK standard U100 which says in point 7.11.3.3 that a diver monitoring system must be provided for each diver. As these standards are to be applied in Norway, the company working in this country are mandatory to use such equipment.

The system is designed to display, record, and provide alarms for at least the following parameters:

- Divers depth (Diver 1 & 2 and standby Diver 3 in the bell).
- Bell internal depth.
- Bell external depth.
- Bell internal temperature.
- Divers' breathing gas PO_2 and ppm CO_2.
- Sampled bell internal gas PO_2 and ppm CO_2.
- Hot water temperature supply to the bell measured at the surface
- Hot water supply flow rate supply to the bell measured at the surface
- Hot water temperature supply to each diver measured at the bell
- Duration of each bell-run.
- Duration of the "in-water time" of each diver.
- Depth of each chamber lock in the saturation system.
- For each chamber lock in the system:
  - PO_2
  - ppm CO_2
  - Temperature
  - humidity

NORSOK standards also request to display the temperature at the divers' suit, and the hot water flows of the divers measured at the bell in case of dives deeper than 200 m.

The manufacturer can also provide additional optional features such as:

- Personnel management features (tracking Divers, Dive supervisors, and LSSs/LSTs)
- Remote access for maintenance
- Secondary / system status alarms and alerts
- Provision of Diver's Gas temperature, measured at the Diver.
- Scheduled data archiving and management

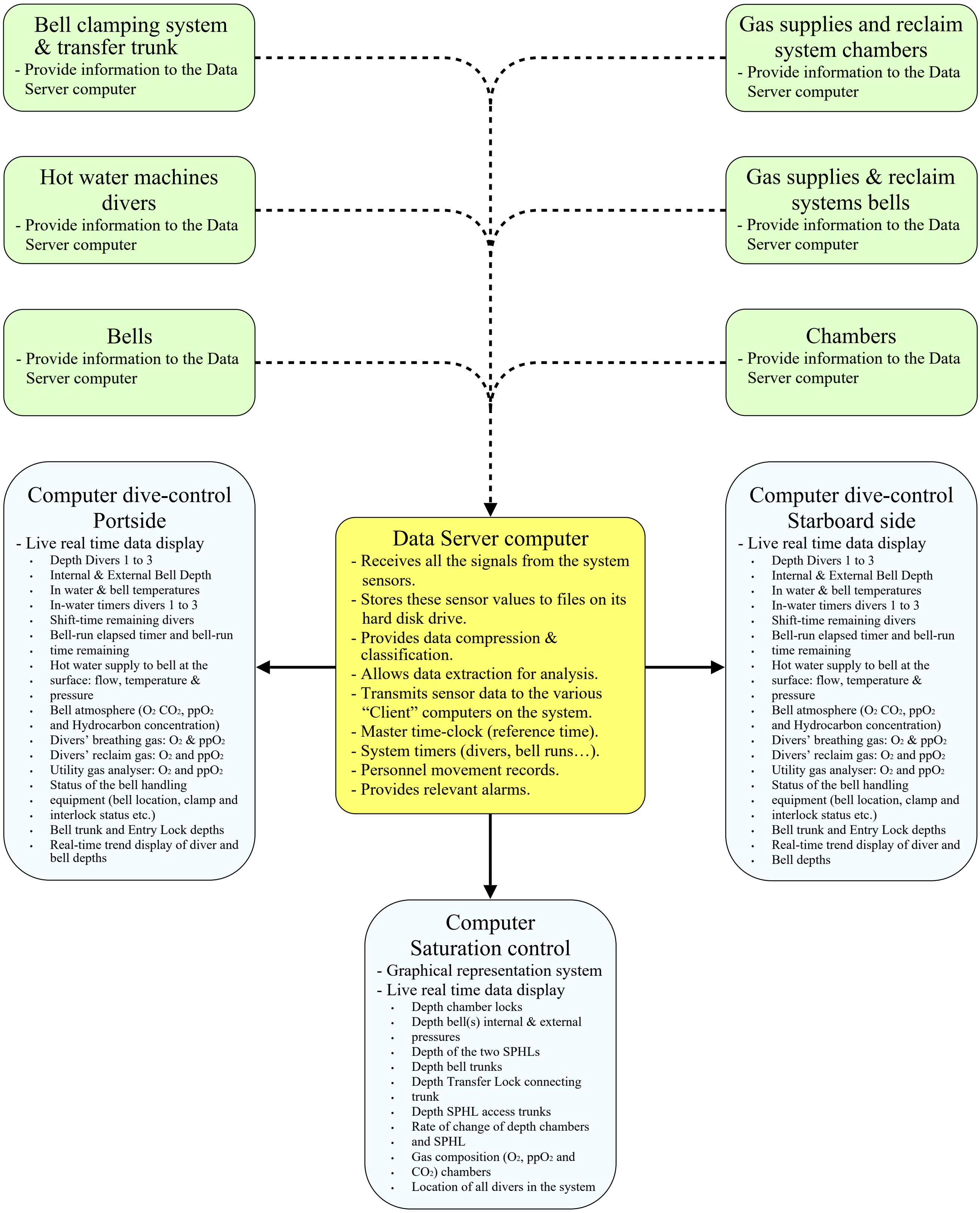
The Diver Monitoring System (DMS) is composed of networked computers which communicate with bespoke hardware devices that acquire data from sensors fitted to various parts of the dive system. These sensors measure parameters such as depths, temperatures, gas compositions, hot water flow, humidity, etc. The primary function of the system is to measure these physical parameters and store the values on a computer disk file for archiving and subsequent analysis. In addition to recording the sensor values, there are a number of computers that provide operators with real-time graphical displays of the sensor values to assist in the management of diving operations.

- The "Data Server computer" is the "Master device" of the Diver Monitoring System. It receives signals from various sensors over a dedicated Ethernet network via multiple interfaces, and stores these values to files on its hard disk drive. One data file being created every hour. There are therefore 24 separate files recorded to disk every day, with their filename identifying the start and end times. These saved files can be copied to CD/DVD ROM for off-line examination and analysis, and long-term archival.
  This computer is also fitted with the "master time-clock", which is used to provide a universal system time for all computers on the network. As a result, the various system timers that are used to measure the in water durations and bell-run times, and provide relevant clock alarms thresholds are provided by this unit and synchronized with this clock.
  The server also displays the data stored in real-time to the computers in the dive and saturation control rooms, and even various utility or maintenance computers. That allows the supervisors and technicians managing the dives and the maintenance of the saturation system to react proactively.
  Also, the server records personnel movements such as the status and identity of the supervisors on duty and the identity and location of the divers in the dive system.
- There is one Diver Monitoring System "Client computer" for each diving bell. It is situated in the control panel with a display located in front of the supervisor. As the saturation system taken as a reference has two bells, two units are installed in the dive control. These displays have been designed to be ergonomically correct and straightforward to read. They provide a full range of relevant information, so the supervisor has an accurate view of the condition of the divers and the dive system during the operations.
- Another Diver Monitoring System "Client computer" is located in the saturation control room. This computer runs an application that displays a graphical representation of the chamber complex, which is overlaid with live real-time data values for the Life Support Supervisor (LSS) and Technicians (LST). In addition to sensor parameters, the names of the

divers in each chamber lock or at work in the bell are indicated. For convenience, because the saturation control panel is extensive, this computer is fitted with two monitors that provide the same information at opposite ends of the saturation control panel. Note that the procedure for managing the information provided by this computer is not described here, but in the chapter that explains the saturation control.

- The manufacturer also says that other "Client computers" *(not indicated in the scheme below)* can be used for maintenance purposes.

The scheme below summarizes the computer network of the Diver Monitoring System.

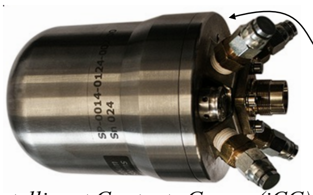


The data from the bell that are collected are sent to the Master Unit through an "intelligent Acquisition Unit (iAU)" that acts as the local interface. This unit, which is visible on the side of the bells of the system taken as a reference is a stainless steel oil-filled enclosure that is pressure compensated to the ambient depth. An acrylic window on the front of the unit allows technicians to diagnostic the status of each interface channel. This intelligent Acquisition Unit communicates through a communication protocol that is designed to transmit signals over long distances to the intelligent comms router (iCR) in the dive control, where the data from the bell sensors are converted and transferred to the server across the network. Note that similar "intelligent Acquisition Units" are provided for the other components of the dive system. However, as they are located at the surface, they do not require a pressure compensated oil-filled enclosure.

Pressure compensator

intelligent Acquisition Unit

A lot of sensors are permanently installed on the dive system to provide various signals to the central computer of the Diver Monitoring System, giving immediate information on the physical parameters and conditions of interest.
Also, specific sensors, such as those designed for measuring the depth of the divers, give a substantial advantage. These depth sensors that are installed at the far end of the excursion umbilicals are of similar technology as those used with ROVs. They measure the divers' depths at regular intervals and are as small as possible so as not to disturb the divers. Their signals are sent to the local "intelligent Acquisition Unit' and then to the central computer that interprets and records the data coming from them and draws diving excursion curves in nearly real-time.
As a conclusion, this system offers significant advantages over the conventional pneumo gauges. It is also a helpful tool to progress in the comprehension of saturation procedures when coupled with other information such as the temperature at the diving suit, the composition of the gas breathed and its consumption. We can imagine that in the near future other sensors, which technologies already exist for surface activities, may be adapted to inform the supervisor of the heart rate, blood pressure, and other parameters in real-time.
Another specific sensor fitted to the bell that provides significant progress is the "intelligent Contents Gauge (iCG)". This unit contains four specially designed pressure transducers and a custom interface circuit that monitor the pressure of the three HeO2 banks and the O2 in real-time and displays them on the monitor of the diving supervisor. With systems where this device is not installed, such information can be provided by the bellman only.



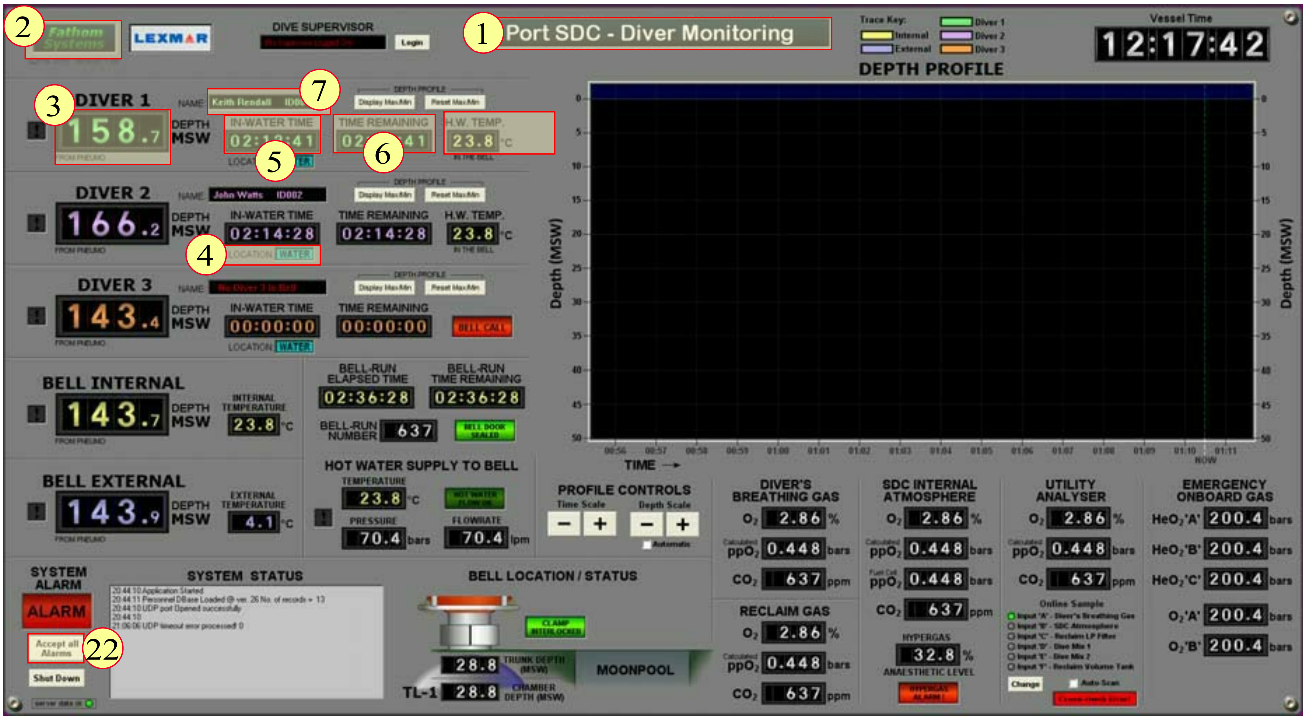
Ø = 99 mm

intelligent Contents Gauge (iCG)

Ø = 26 mm

Depth sensor

The "real-time data" of the dive system are displayed as in the drawing underneath on a monitor that is on the control panel. Their description allows a better understanding of the possibilities of the Diver Monitoring System.

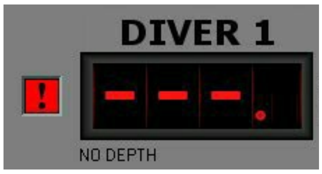


Note that the reference numbers of the elements described are those in the drawing on the previous page.

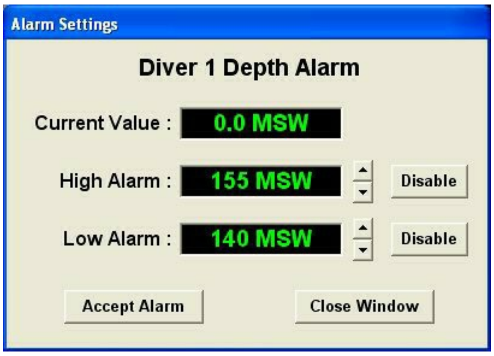
1) - Display screen title:
This title shows which bell, also called Submersible Decompression Chamber (SDC) is being viewed *(see #1)*.

2) - Software revision *(see #2 in the drawing on the previous page)*:
Details of the software revision status of the Dive Control display client. Clicking on the Fathom logo provides more details.

3) - Diver depth displays *(see #3 in the drawing on the previous page)*:
Three colour-coded digital display readouts show the current divers' depth in metres of seawater (MSW), with an accuracy of 0.1 MSW. The colour coding is green for Diver 1, purple for Diver 2 and orange for Diver 3. When the diver's depth signal is either unavailable, in a fault condition or out with the preset alarm limits, the digital display changes from its standard colour to red. A signal fault is represented as a row of red dashes *(see on the side)*.



Normally, the signals for these readouts come from the divers' depth transducers attached to the end of the excursion umbilical (at the D-ring) and connected back to the "intelligent Acquisition Unit (IAU)" mounted on the outside of the Bell. In this case, a small label under the depth reading shows "FROM iAU". If for some reason the intelligent Acquisition Unit depth signal is unavailable, the system automatically reverts to the surface Pneumo depth transducer reading. In this case, the depth value is displayed in red and the label beneath shows "FROM PNEUMO". When no valid depth signal is available, the label shows "NO DEPTH".
Clicking on the depth display readout for a particular diver opens up the window of the depth alarm settings:



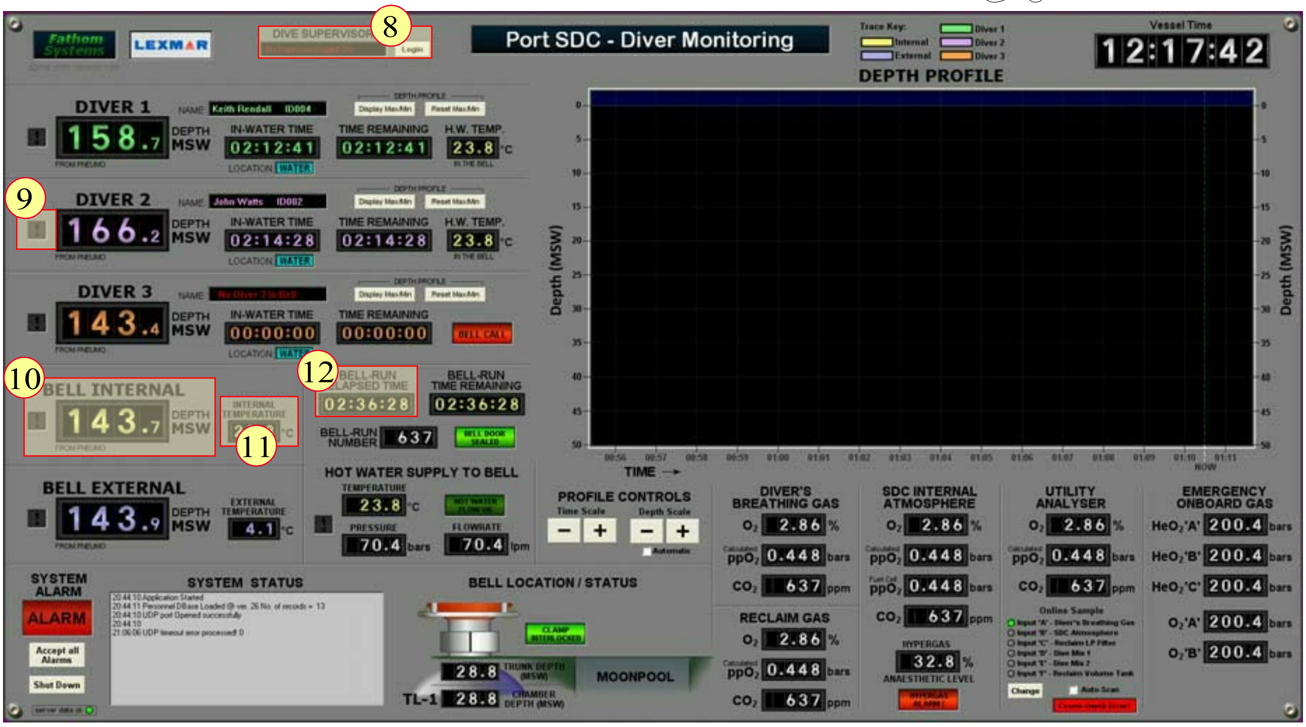
Using the up and down arrows and the buttons on this window allows the diving supervisor adjusting the diver's minimum and maximum depth alarm set-points.
When a Diver's depth signal is in an alarm condition, this is initially presented as an 'Active' alarm, where the depth value flashes red, and the audible alarm sounds every 10 seconds. The Supervisor can click the button "Accept Alarm" on the alarm setting window to accept this alarm or click on the global "Accept Alarms" button *(see #22 in the drawing on the previous page).*

4) - Diver location indicator *(see #4 in the drawing on the previous page)*:
This status display panel shows the current location of the diver, either in the bell or in the Water. The information displayed here comes from the pushbutton switches operated by the dive supervisor. This information is also stored in the master data file on the server to allow dive profiles to be recorded for each dive.

5) - Diver in water timer display *(see #5 in the drawing on the previous page)*:
A digital display is provided for each diver to show the duration that he has spent in the water (his in-water time). This display is colour-coded the same as the depth displays and automatically increments every second so long as the supervisor has pressed the pushbutton on the panel to indicate that the diver is actually in the water. When the pushbutton is returned to the off state, the timer stops but continues to display the last total time figure.
This display indicates hours, minutes and seconds as follows: HH:MM:SS
The dive supervisor can reset the in-water accumulated time to zero via the timer configuration window (accessed by clicking on the "in-water" or "time remaining" time displays).
The in-water timers have an alarm system which results in a red alarm indicated on the screen when the elapsed in-water time exceeds the alarm threshold. Configuration of the alarm thresholds is made via the timer configuration window.

6) - Diver shift-time remaining display *(see #6 in the drawing on the previous page)*:
A digital display is provided for each diver to show the time remaining for his current operational shift. This display is documented every second so long as the supervisor has pressed the pushbutton on the panel to indicate that the diver is actually in the water. When the pushbutton is returned to the off (in Bell) state, the timer stops but continues to display the last total time figure. This display also indicates hours, minutes and seconds (HH:MM:SS).
As with the in-water timer, the shift timers have an alarm system which results in a red alarm on the screen when the shift time remaining is less than the alarm threshold. The alarm thresholds are configured though the timer configuration window.

7) - Diver Identification (name and ID number) *(see #7 in the drawing on the previous page)*:
Before starting the bell run, the Life Support Supervisor (LSS) logs the names, identification numbers(ID), and the function (Diver 1, 2 or bell-man) of the divers transferred to the bell. As a result, their names and ID numbers automatically appear in this display window.



8) - Dive supervisor name, identification (ID) number, and login/log off button *(see #8 above)*:
This display window shows the name and ID number of the dive supervisor currently on shift. The supervisor logs on or off using the pushbutton

9) - Alarm indicator *(see #9 above)*:
The alarm indicator is grey when all alarm conditions for a particular diver depth or bell depth are within limits and healthy. The alarm indicator is illuminated red when a depth alarm condition for a diver or the Bell are outside the boundaries, or the signal is faulty. The alarm indicator flashes until the supervisor accepts the alarm through the Alarm Settings window.

10) - Bell Internal depth display *(see #10 above)*:
This colour-coded digital display provides the bell internal depth in metres of seawater (MSW) with an accuracy of 10 centimetres. If this signal is faulty or unavailable, or the bell is outside the preset alarm limits, the digital display changes from its standard yellow colour to red.
The signal for this readout comes from a depth transducer mounted external on the bell and connected to the bell internal depth sample pipework. The signal from this transducer is connected back to the “intelligent Acquisition Unit (IAU)” mounted on the outside of the Bell. In this case, a small label under the depth reading shows "FROM iAU". If for some reasons the iAU depth signal is unavailable, the system automatically reverts to the surface Pneumo depth transducer reading. In this case, the depth value is displayed in red and the label beneath shows "FROM PNEUMO". When no valid depth signal is available, the label shows "NO DEPTH".
When the supervisor clicks on the display readout for the bell internal depth, he opens up the alarm settings adjustment window (similar to the Diver depth alarm settings window described above)

11) - Bell internal temperature display *(see #11 above)*:
This display indicates the current ambient temperature inside the diving dell in degrees Celsius. The sensor for this display is mounted on the bell internal Diver Monitoring System junction box. Its signal is converted to run over long distances with minimal signal losses (4 to 20 mA type) and connects through the penetrator to the “intelligent Acquisition Unit (IAU)” on the outside of the Bell.

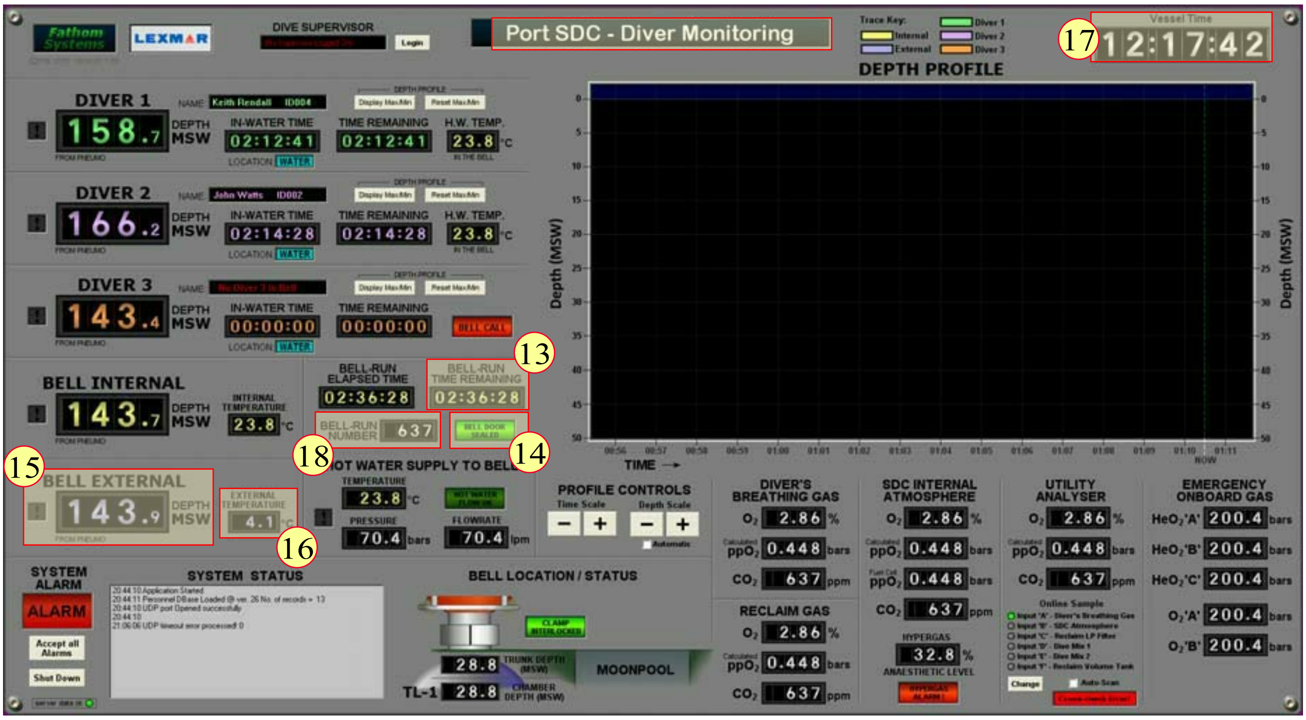
12) - Bell-run timer display *(see #12 above)*:
Bell-run timers are started and stopped automatically from the status of the bell transfer trunk pressure sensor (a difference in pressure between the trunk and the bell internal implies that the bell is locked off and bell-run timer running). Three modes for the bell-run timer are available:

- Normal mode – where the timer is started and stopped automatically based on the “bell seal” status from the trunk pressure sensor. This mode requires a manual reset of the timer at the start of each bell-run.
- Automatic reset mode – where the system works the same as in Normal Mode, except the bell-run timer is reset to 0 when the bell locks back on to the trunk.
- Don’t Stop mode – where the bell-run timer continues to run even if the bell is locked back on to the trunk. This mode is used where the bell is required to be returned to the system and then launched again all within a single bell-run.

Bell door seal status is implied automatically from a pressure (depth) difference between bell internal and bell external depth readings.
A digital display shows the total elapsed duration of the bell-run. This display is yellow colour-coded and automatically increments every second whenever the bell-run timer is running. The bell-run timer is running when one of the following sets of conditions are satisfied:

- The bell is located on its mating trunk, and the bell internal depth is more than 5 metres sea water (MSW) deeper than the trunk and there are one or more divers in the bell;
- The bell is not above the bell trunk and there are one or more divers in the bell;
- The Dive Supervisor has selected the “Don’t Stop” bell-run timer mode;
- There is a fault / logic error with any of the signals that are used to control the bell-run timer.

The dive supervisor can reset the accumulated bell-run time to zero at any time via the bell-run timer configuration window (accessed by clicking on either the bell-run timer display or the bell-run time remaining display). This reset function is provided automatically by the trunk pressure signal when the "Automatic Reset/ timer mode" is selected. The Bell-run timer is fitted with an alarm, which triggers a red signal on the screen when the elapsed bell run time exceeds the alarm threshold. The setup of the alarm thresholds is made via the bell run timer configuration window.



13) - Bell-run time remaining display *(see #13 above)*:
This function displays the time remaining for the bell run ongoing to ensure that the maximum legal duration of the bell run is not exceeded (strictly 8 hours seal to seal). This display is documented every second as long as the bell-run timer is running. The target time and the alarm threshold are set using the relevant configuration window.

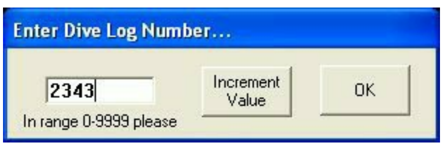
14) - Bell door seal status display *(see #14 above)*:
This display indicates whether the Bell door is sealed. This tool compares the bell internal depth with the Bell external depth to provide a status. When the difference of two depths is 3 metres of Seawater (MSW) and above, the system assumes that the door of the bell is sealed. As a result, the indicator is illuminated in green.

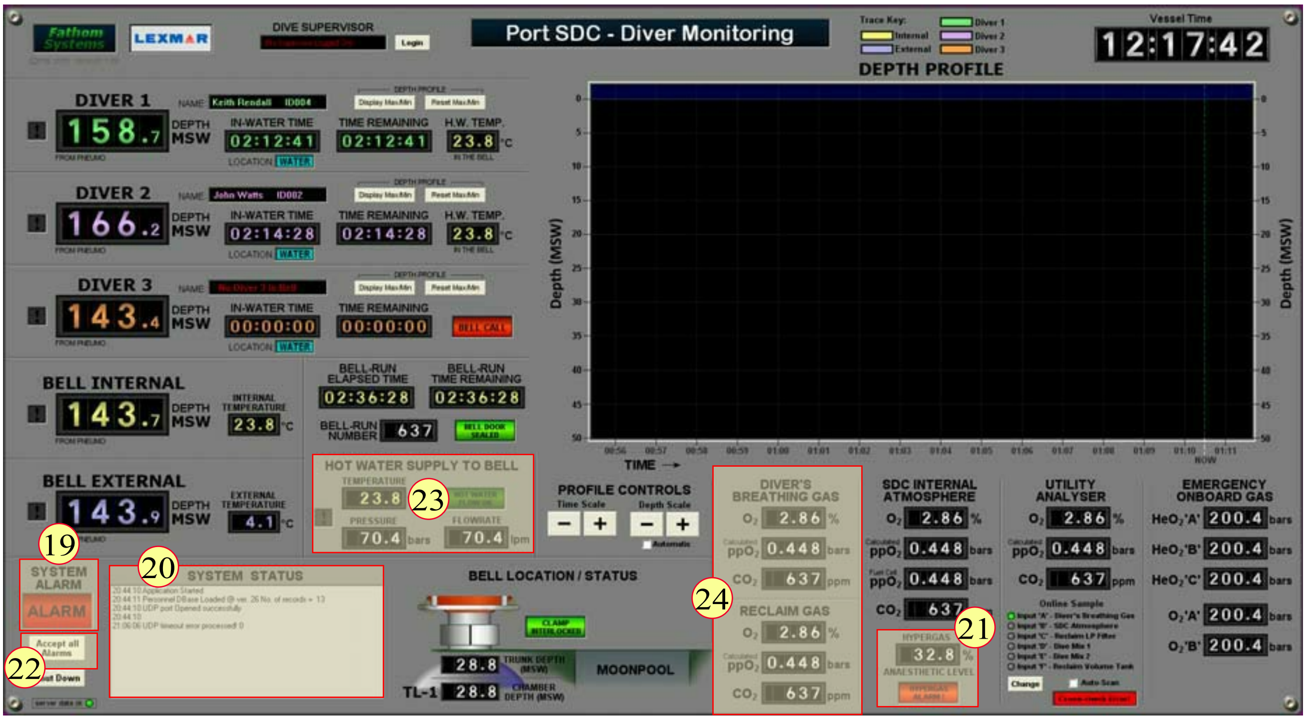
15) - Bell External depth display *(see #15 above)*:
This colour-coded digital display provides the bell external depth in metres of seawater (MSW) with an accuracy of 10 centimetres. If this signal is faulty or unavailable, or the bell is outside the preset alarm limits, the digital display changes from its standard blue colour to red.
The signal for this readout comes from a depth transducer mounted inside the “intelligent Acquisition Unit (IAU)” on the outside of the bell. In this case, a small label under the depth reading shows "FROM iAU". If for some reasons the iAU depth signal is unavailable, the label shows “NO DEPTH” (there is no bell external Pneumo signal to use). When the supervisor clicks on the display readout for the bell external depth, he opens up the settings adjustment window (similar to the Diver depth alarm settings window described above).

16) - Bell external temperature display *(see #16 above)*:
This display indicates the ambient temperature outside the diving bell in degrees Celsius. The sensor for this display is mounted on the bell “intelligent Acquisition Unit”.

17) - Vessel time display *(see #17 above)*:
This function shows the time on the bridge of the vessel which is the reference for all vessel operations. The vessel time is synchronized to the real-time server clock of the Diver Monitoring System. If for some reasons, the server is unavailable, this display can be used as reference time. However, it is not synchronized, and for this reason, it is displayed with red numbers.

18) - Bell run ID display *(see #17 above)*:
This window shows the dive log reference number that should match the one used for the dive records hand-filled by the supervisor. This tool allows correlating the recorded data against the manual dive logs. Clicking on this display opens a small pop-up window that is used to set the dive log number.



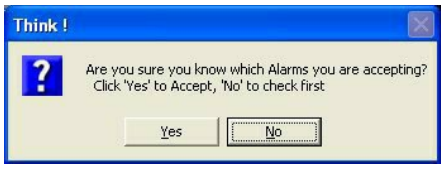


19) - System Alarm Indicator *(see #19 above)*:
This indicator panel is illuminated in red and flashes whenever there are one or more active alarms on the system, or is illuminated steady red when there are one or more accepted alarms (and no active alarms).

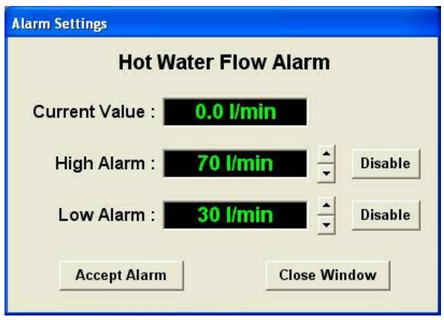
20) - Status display *(see #20 above)*:
This window provides diagnostic information and status of the Diver Monitoring System. As a result, the alarms are also documented in this window. Over time, this list of status messages increases and the oldest logs will not be visible in the window. For this reason, the previous messages can be accessed using the vertical scroll bar at the right-hand side of the window.

21) - Bell "Hydrocarbon analyser" display *(see #21 above)*:
This alarm status panel indicates the hydrocarbon concentration inside the bell and illuminates red when the alarm is active. This function uses the data from the "Analox hypergas MK2" analyzer which are updated every 10 seconds. It is merely a repeat of the sensor values displayed on the relevant display inside the bell.
Note that the alarm threshold is adjustable which allows setting a low alarm limit for an early warning in case of hydrocarbons building up in the bell.

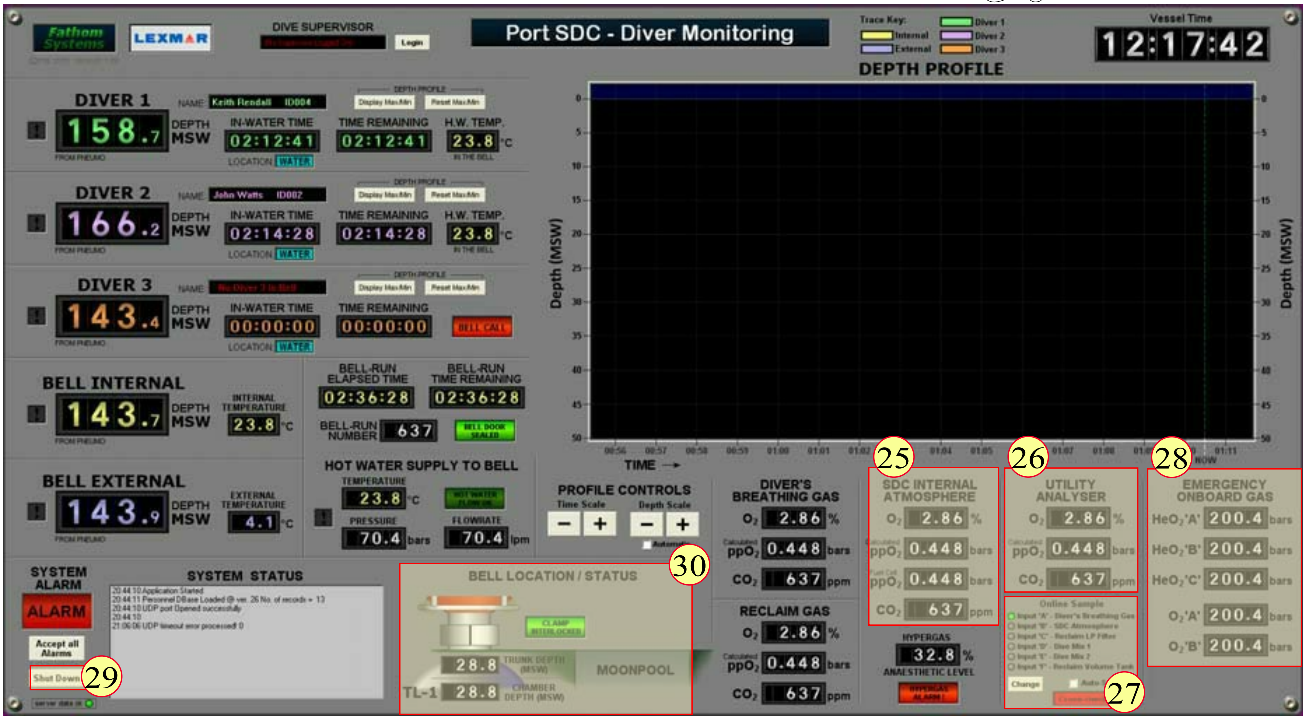
22) - Accept all Alarms Button *(see #22 above)*:
This button allows the Supervisor to accept all active alarms at once. Of course, he must be sure that he understands them, as this button does not require that each alarm condition be viewed prior to accepting. The System status window *(see #20 above)* does, however, provide a list of active alarms to assist in this operation. The system requests confirmation from the supervisor that he acknowledges his responsibility for accepting all alerts at once with a relevant dialog box.



23) - Hot-water supply to the Bell displays *(see #23 above)*:
Three digital readouts provide details of the hot water supply to the bell (temperature, flowrate and pressure), measured at the surface. The relevant sensors are located at the hot-water machines and interfaced via the "intelligent Network Logger (INL)". The hot-water flow is measured by an ultrasonic non-invasive flowmeter attached to the outside of the supply pipework of each bell. These sensors connect to the "Intelligent Network Logger" in the dive control using a signal that is designed to run over long distances with minimal losses (4 to 20 mA type).
The supervisor can adjust the alarm of each hot-water sensor. That is performed by clicking on the particular digital display. As with other warnings, the test in the window flashes red when an alarm is activated or is steady red when it is accepted.



24) - Diver Breathing Gas composition displays *(see #23 above)*:
This window shows the composition of the breathing and reclaimed gasses before they enter the gas hoses of the main umbilical of the bell. The PO2 and ppm CO2 values are generated by the gas analysers in the dive control that are connected to the "intelligent Network Logger (INL)". These values are measured at surface-equivalent pressure and therefore are based on 1-atmosphere concentrations.
Note that the system displays the values of the deepest Diver. The reason for using the most profound depth is to indicate the most critical condition.



25) - Bell atmosphere composition display *(see #25 above)*:
These displays provide details of the composition of the atmosphere of the Bell (internal). The partial pressure O2 and parts per million CO2 values are those from the gas analysers in the dive control that are transmitted to and read by the “intelligent Network Logger (INL)”. These values are measured at surface-equivalent pressure and therefore, are based on 1-atmosphere concentrations.
The ppO2 is calculated from the surface-referenced partial pressure O2 sample reading and the bell internal depth (pressure) reading from the “intelligent Acquisition Unit (IAU)” sensor.

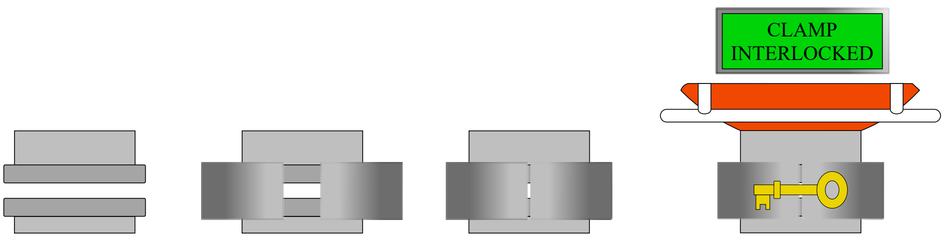
26) - Utility analyser display *(see #26 above)*:
This window provides the PO2 and ppm CO2 values that are generated by the utility gas analyser in the dive control whose Ethernet data is transmitted to the server of the Diver Monitoring System. These values are measured at surface-equivalent pressure, and therefore are based on 1-atmosphere concentrations.
The ppO2 is calculated from the surface-referenced partial pressure O2 sample reading and the bell internal depth (pressure) reading from the “intelligent Acquisition Unit (IAU)” sensor.

27) - Utility analyser sample selection display *(see #27 above)*:
The online sample to the Utility Analyser (one from six possible inputs) is shown, and the supervisor can select this online sample. An auto-scan function is provided that cross-checks the primary gas analyzer readings against the Utility analyzer automatically and is enabled with the check-box.

28) - Bell Onboard Gas displays *(see #28 above)*:
These displays show the pressure in the bell onboard gas banks (HeO2 and O2). The signals for these displays come from the “Intelligent Content Gauges (ICG)”, that has been previously described, and is mounted on the outside of the bell and send the data from the sensors to the “intelligent Acquisition Unit”.

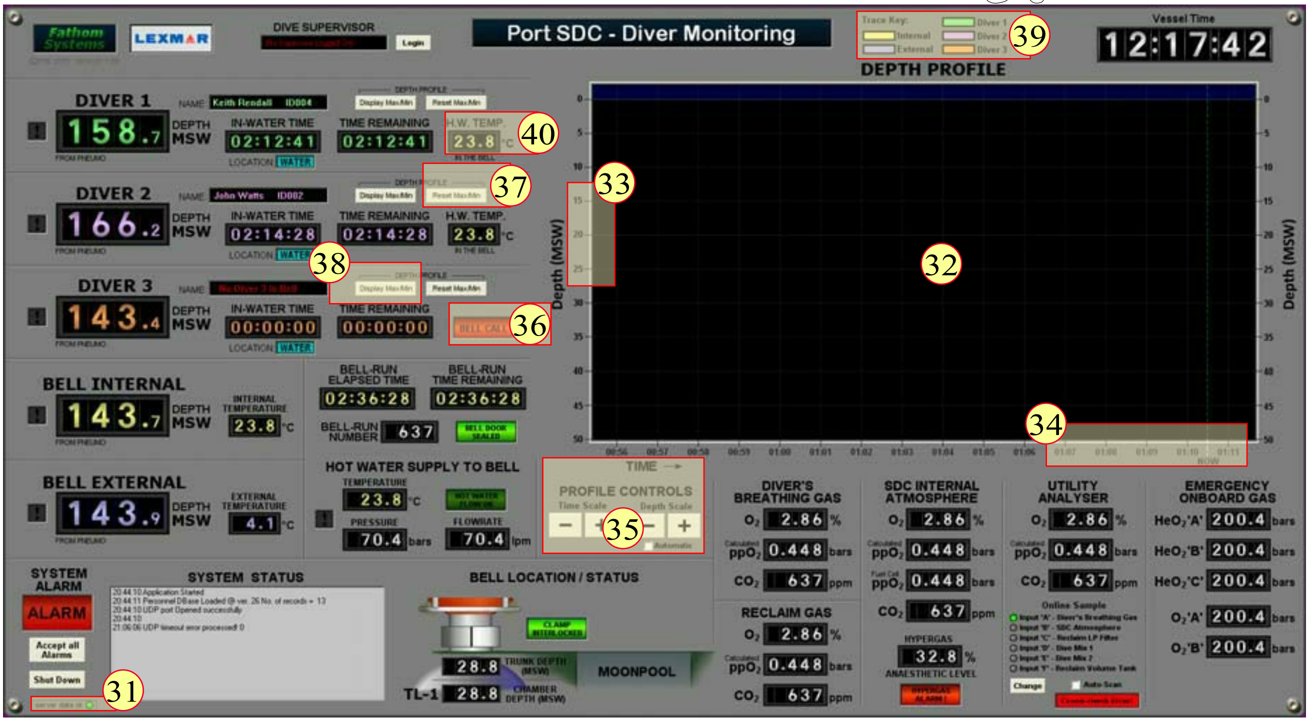
29) - Shut Down pushbutton *(see #29 above)*:
This button is used to shut down the dive control client display screen. A prompt dialog appears to check that this action is required before the application is shut down.

30) - Bell position, clamp and trunk status displays *(see #30 above)*:
This area of the display screen shows the status of the clamp that secures the bell to the trunk when it is under the control of the diving supervisor. This is done using several mimic drawings. Note that when the bell is not above the trunk, there is no mimic picture of the bell shown. The display indicates the four possible states below:



Clamp fully open — *Clamp between Open & closed* — *Clamp fully closed* — *Clamp fully closed & interlocked*

A digital indicator for the depth (pressure) of the bell mating trunk is visible below the drawing of the clamp. This value comes from the pressure transducer located in the dive control.
In addition, there is another digital indicator for the depth of transfer lock below the the trunk depth display. This value comes from the pressure transducer located in the saturation control.



31) - Server status indicator *(see #31 above)*:
This indicator is illuminated green when the data server computer runs correctly and provides the dive control client display with correct information. If the server is down or unavailable, this indicator illuminates red.

32) - Depth profile display *(see #32 above)*:
This large display shows a real-time plot of the five key depth signals against time. It is updated automatically and provides a graph of depth (on the Y-axis) against time (on the X-axis), and uses colour-coded traces to represent each of the following depth sensor signals:

- Diver 1 Depth (Green)
- Diver 2 Depth (Purple)
- Diver 3 Depth (Orange)
- Bell Internal Depth (Yellow)
- Bell External Depth (Blue)

A graticule allows reading the scales easily. Clicking on the main graph area selects various (alternate) display scaling modes. The depth range of the display area automatically re-scales to suit the desired display settings
The data visible on this display are held locally in the dive control display application and is retained in the client computer memory for 12 hours. Data older than 12 hours are discarded, so if a review of older data is required, the "Report Generator application" should be used.

33) - Profile depth scale *(see #33 above)*:
The depth profile is scaled vertically in metres of seawater (MSW).

34) - Profile time scale *(see #34 above)*:
The depth profile is scaled horizontally in time. The timescale for the data is either 1, 4, or 12 hours, and the actual time of day (Vessel time) is shown on the horizontal display.

35) - Profile time and depth scale selector buttons *(see #35 above)*:
These buttons allow selecting the different profile time scales and adjusting the depth range shown on the graph. Checking the "automatic" check-box scales the depth to the most suitable range automatically.

36) - Bell call indicator *(see #36 above)*:
This display indicates that there is a pending call from the bell to the supervisor (taken from the bell call system status signal). This indicator illuminates red and reads "BELL CALL" when a call is pending. This condition is cleared by the Supervisor

37) - Profile maximum and minimum depth cursor reset buttons *(see #37 above)*:
The horizontal colour coded dashed lines show the limits of excursion of Divers 1 to 3 within the previous 12 hours. These cursors can be reset with the three buttons, one for each diver. That would typically be done before starting a bell run.
Note that when reinitialised, these cursors only track depth changes from this time onwards and not historically over the past 12-hours.

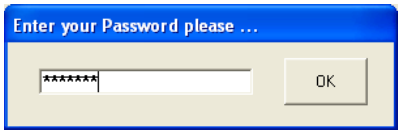
38) - Profile maximum and minimum depth cursor enable buttons *(see #38 above)*:
These horizontal colour coded dashed lines show the limits of excursion of Divers 1 to 3 within the previous 12 hours. These cursors can be turned on or off using the dedicated buttons (one for each Diver).

39) - Profile trend key *(see #39 above)*:
This key shows the colour coding used for the profile display traces.

40) - Diver's hot water temperature at bell level *(see #40 above)*.

Diver monitoring system preparation:

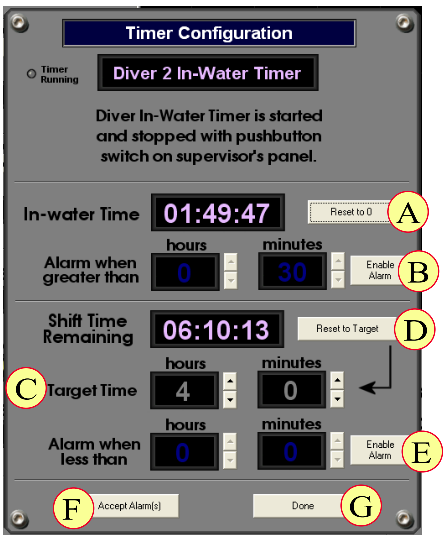
The diving supervisor is required to log onto the system at the start of his shift. To do it, he clicks the “Dive supervisor Login” button on the Main screen display *(See #8 in the drawings on the previous pages)*, and then selects his name from the list provided. A prompt is then presented to the supervisor to enter his password before login is permitted.



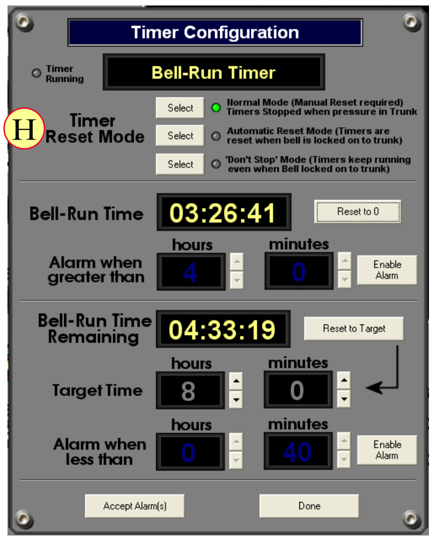
If the Supervisor has never worked on the vessel where the Diver Monitoring System is installed, he must enter his details at first into the Monitoring System database. It is usually performed from the client computer of the saturation control. It can also be done by the dive technician using a remote saturation control client session.
Note that when the supervisor is logged on, the text displayed on the button changes from “Dive supervisor Login” to “Dive supervisor Log off”. At the end of his shift, the supervisor must log off the system. To do it, he clicks the “Dive supervisor Log off” button on the Main screen display and follows the menu.

When the supervisor is logged in the system, he must reset the timers before starting the bell run.

- To access the menu of the “Diver in-water timer”, the supervisor clicks on the particular diver’s timer display *(see #5 in the description of the monitoring screen)* to open the configuration window. Then he clicks on the button “reset to 0” *(see #A below)*. Also, he configures the alarm time using the scrolling arrows to adjust the time as required *(see #B below)*.
 The Supervisor should adjusts the duration of the shift of the diver by clicking the up and down the scrolling arrows of the boxes “target time” *(see #C below)*. When the desired target time for the shift has been entered, the supervisor clicks the tile “Reset to Target” *(see #D below)* to transfer the values entered to the “live timer”. The alarm is configured as for the in-water time *(see #E below)*. When both alarms have been setup their displays flash in with red digits until the setup is accepted through the dedicated button *(see #F below)*. The widow is then closed by clicking the button “Done”*(see #G below)*.
- The “bell run timer” must be also configured. To access the menu, the supervisor clicks on the bell internal or external depth readings *(see #10 & 15 in the description of the monitoring screen)*. He can also open this window by clicking on the bell-run timer displays *(see #12 in the drawing of the monitoring screen)*. The configuration of the bell run timer is similar as the divers in-water timers, but there are three additional buttons which relate to the operating modes*(see #H below)*.
    - “Normal mode” : Based on the “bell seal” status from the trunk pressure sensor, the timer is started and stopped automatically. This mode requires a manual reset of the timer at the start of each bell-run.
    - “Automatic Reset mode” : The system works the same as in Normal Mode, except the bell-run timer is reset to 0 when the bell locks back on to the trunk.
    - “Don’t Stop’ mode” : The bell run timer continues to run even though the bell is locked back onto the trunk. This mode is used where the bell is required to be returned to the system and then launched again all within a single bell-run.



Diver in-water timer



The bell run timer

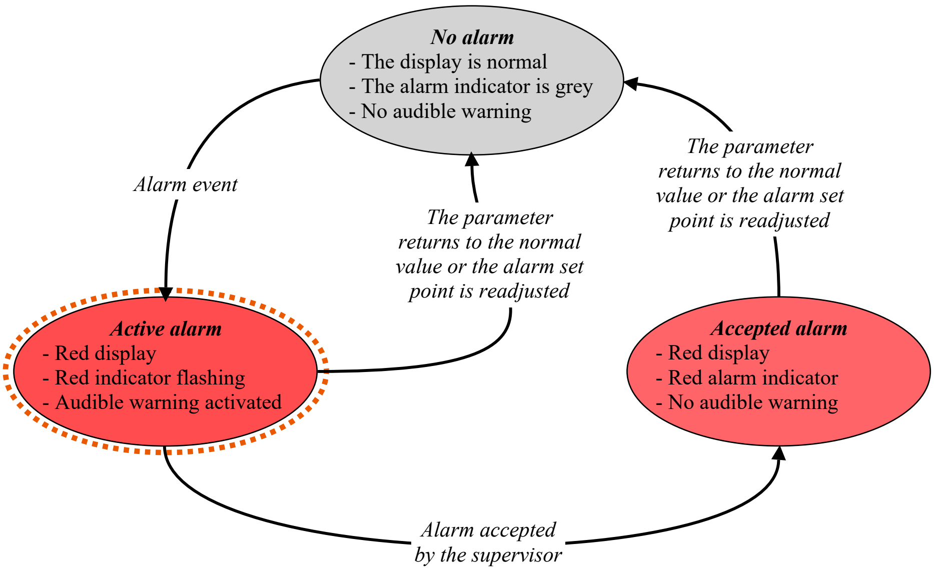
- Prior to transfer the divers to the bell, the supervisor ensures that their names are those indicated in the relevant displays and that their function during the planned bell run is correctly logged (Diver 1, Diver 2, and bellman).

If the diver's names are incorrectly logged, the diving supervisor informs the life support supervisor (LSS) who rearranges the assignment of the divers in the Bell.

- During pre-dive checks, the diving supervisor must ensure that the values on the Diver Monitoring System display conform with the primary instrumentation. If a displayed parameter disagrees with a primary instrument reading, the reason for the discrepancy should be investigated and the problem solved before commencing the dive.
- The diving supervisor does not need to interact frequently with the software, except for adjusting the alarm settings, selecting alternative display modes, or logging on or off the system. However, he must enter the names of the divers moving from the bell to the water and vice versa. To do it he presses the pushbutton switches on the control panel of the Diver Monitoring System computer monitor *(see #4 in the drawing of the monitoring screen)*. As a result, the indicator lamp is illuminated, which signifies that the diver is in the water. When the switch is in "out" position, the light is not activated, which means that the diver is in the Bell.
- During the operations, the Diver Monitoring System may raise an alarm that can be a repeated display of a diving system alarm, or an alert relating directly to one of its features. As a reminder, the warning generated by the system can be one of those listed below:
    - Diver in-water timer alarm for each diver (target duration has been exceeded)
    - Diver shift remaining timer alarm for each diver (time remaining is less than the alarm set point)
    - Bell-run timer alarm (target Bell-run duration has been exceeded)
    - Bell-run time remaining timer alarm (Bell-run time remaining is less than the alarm set point)
    - Diver depth alarm for each diver (maximum or minimum depth alarm set point has been exceeded)
    - Bell internal or external depth alarm (maximum or minimum depth alarm set point has been exceeded)
    - Hot water supply to the Bell flow alarm (water flow is below low flow alarm set point)
    - Hot water supply to the Bell temperature alarm (water temperature is above or below alarm set point)
    - Hot water supply to the Bell pressure alarm (water delivery pressure is below or above the alarm set points)
    - Hypergas anaesthetic level percentage (high alarm).
    - Onboard gas bank pressures (high and low alarms).

  This alarm status results in:
    - The digits of the element affected turning red
    - The alarm indicators are illuminated red and flashing *(see #9 & #19 in the drawing of the monitoring screen)*.
    - An audible warning generated every 10 seconds
    - A description of the problem published in the status box *(see #20 in the illustration of the monitoring screen)*.
    - In case of a system error or fault alarm is generated, the display changes to a row of red dashes.

  Remember that the active alarm must be accepted by the supervisor to stop the indicator from flashing and the audible warning from being repeated.
  Clicking on the red numeric display of the parameter in the alarm state opens the "alarm settings window" for the particular sensor *(see #9 in the drawing of the monitoring screen)*.
  Once accepted, the alarm indicator remains illuminated red and the digital parameter display remains red also.
  When the alarm returns within the setpoint(s), the display returns to its normal display colour and the alarm indicator returns to grey.
  Also, the Supervisor can accept all the active alarms at once through the button "Accept all alarms" *(see #20 in the illustration of the monitoring screen)*. As already said, he must be sure that he understands them, as this button does not require that each alarm condition be viewed prior to accepting it.



In case of a system error alarm or a warning from a part of the diving system, the manufacturer recommends informing the technician who is the competent person to investigate the error remotely and effect a repair as necessary.

1.1.13.7 - Fire fighting

IMCA D 024 says: *"Suitable firefighting arrangements must be made for dive control. It may be by means of permanent ship or platform provided equipment or by means of portable extinguishers etc. It should be capable of dealing with any type or size of foreseeable fire hazard"*.
IMCA D 024 also says: *"Whether fixed or portable the fire fighting system should be in accordance with manufacturer's specification and fit for the purpose it will be used for"*.
Also, NORSOK standard U100 says that facilities for human-crewed underwater operations must have fire detection and firefighting equipment covering the entire plant both internally and externally and that the material must have adequate capacity to put out fires that might occur. Classification societies confirm this requirement.
In addition to the above, in chapter II-2 of SOLAS (*International Convention for the Safety of Life at Sea*), it is said that a vessel must be equipped with fire detection and firefighting systems. As a result, all built-in saturation systems are protected with the detection and firefighting system of the boat. In addition to portable extinguishers, this system is composed of smoke, heat, and flame detectors, and a water mist system that is fed by two fire pumps 140 m3/h each is installed in the dive control. The operating panel, control unit, and power supply of this system are contained in a central cabinet on the bridge.
However, some transportable saturation systems are not equipped with fixed firefighting installations, and in this case, portable systems have to be provided. Also, as said above, built-in control rooms are equipped with hand-carried systems in addition to the firefighting system of the boat. The following extinguishing agents can be used:

- Water:
  Water is used to cool and protect from heat or flame impingement. Water properly applied (in the form of fog or spray and in sufficient quantity, generally estimated at 10 litres per m 2) can absorb the heat and prevent damage (throwing streams 20 litres per m²). Water does its most effective job of cooling when it is converted into steam.
  Available water should be used to cool the most critical areas of the fire engulfed equipment and the equipment in the radiation zone.
  Water may be used in two principal forms: Spray or fog and straight streams. Each has its particular advantages, disadvantages, and scope of application.
  In general, the straight stream has the greatest range of driving force, the wide angle spray (fog) has short range and affords the maximum protection for the fire fighter; and some in between position, which combines the two, will in most cases be the most desirable. The objective is to get the water in the right form and on the place where it will have the most effect as a cooling or extinguishing agent.
- Foam:
  Fire extinction is normally achieved by the use of fresh or salt water, because of its good cooling characteristics. However, with oil, which has a lower specific gravity than that of water, effective extinction can best be achieved by smothering the burning fuel with foam, thus cutting off the oxygen feeding the fire.
  - Mechanical air foam is a mixture of water under pressure, foam concentrate and air combined in set proportions to provide stabile foam.
  - Foam concentrate is a liquid foam making chemical that will normally be one of two types:
    - Protein Concentrate — manufactured from natural or organic products.
    - Synthetic Concentrate — manufactured from detergent based material

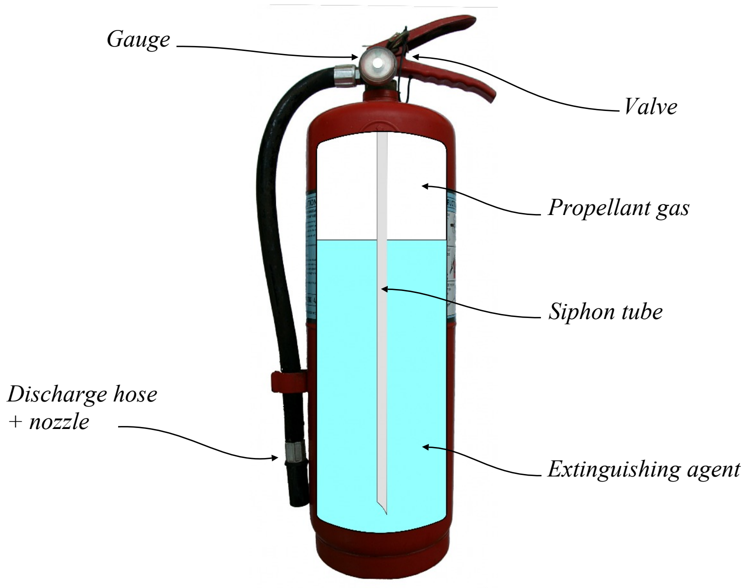
  Foam is not generally used in the dive control room as items filled with oil are usually not present in it. However, depending on the design of the saturation system, such extinguishing agents may be present outside the room and at its direct vicinity.
- Carbon dioxide (CO_2):
  Carbon dioxide dilutes the air surrounding the fire until the oxygen content is too low to support combustion. It has a very limited cooling effect and does not conduct electricity. Also, carbon dioxide does not support combustion in ordinary material. However, it reacts with magnesium and other metals.
  As a result of its characteristics, CO_2 is considered a "clean extinguishing agent" by fire combat specialists who recommend it for the protection of computer server rooms as it can be used to combat electrical fires while preserving the delicate electrical and electronic equipment.
- Halon:
  Halon is made up of carbon and one or more of the following elements: Fluorine; Chlorine; Bromine; or Iodine. Two halons are used in fire fighting:
  - BTM (Bromo Trifluoro Methane) known as HALON 1301 is stored as a liquid under pressure. When released in the protected area it vaporises to an odourless, colourless gas and is propelled to the fire by the storage pressure. Halon 1301 does not conduct electricity.
  - BCF (Bromo Chlorodifluormethane) known as HALON 1211 is also colourless but has a faint sweet smell. Halon 1211 is stored as a liquid and pressurised by a nitrogen gas. Pressurisation is necessary since the vapour pressure of Halon 1211 is too low to convey it properly to the fire area. Halon 1211 does not conduct electricity.

  For the same reasons as Carbon dioxide, Halon is considered a "clean extinguishing agent" by fire combat specialists and recommended to combat electrical fires.
- Dry Chemical Powders:
  They are considered multipurpose extinguishing agents. Dry chemicals may be used in fixed systems or portable extinguishers. They extinguish a fire by shielding radiant heat and to the greatest extent by breaking the

combustion chain. Class D dry powder is the only extinguishing media, which will successfully extinguish metal type fires. However, note that powders are generally limited to electric fires below 1000 volts. Also, this extinguishing agent is not considered a “clean extinguishing agent” and is very corrosive. Note that the manufacturer proposes several types of dry chemical extinguishing agents.

Extinguishers are the most common portable fire extinguishing devices in dive controls. The reason is that they are easy to use and can be stored near the strategic points without the need for a specific installation.
Note that there are two main types of extinguishers:

- “Stored-pressure extinguishers” contain the extinguishing agent at the bottom, and the rest of the vessel is filled with a propellant gas which is usually nitrogen. The propellant gas at a pressure between 12 and 17 bar, and this operation is usually performed in the factory. A gauge is installed on the device to ensure that the gas pressure in the reservoir is still adequate. The advantage of this design is that it is very simple with a minimum of parts. Its main disadvantage is that it cannot be opened on site and must be returned to the factory or a specialist for this operation

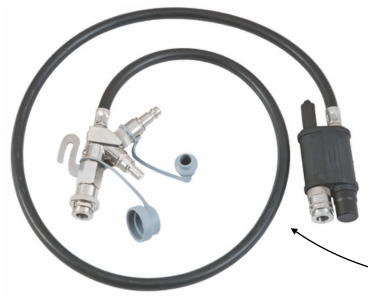


- “Cartridge-operated extinguishers” have the fire extinguishing agent not stored under pressure and the propellant gas that is in a separate small sealed cartridge. Depending on the design, this cartridge is operated by a specific mechanism triggered by the valve that pushes a plunger or by pressing a dedicated built-in squeeze lever. The advantage of such a system is that the extinguishers can be opened on-site as the reservoir is not under pressure. Their disadvantage is that their mechanism is slightly more complicated.

Note that IMCA says that portable systems must have an external visual examination and check that any indicating device reads within the acceptable range at least every six months.
Also, nozzles, valves, pipework, and other elements of fixed systems must be visually examined every six months. Besides, the system must be function tested or have a simulated test using air or gas as the test medium every year. IMCA also recommends that automatic detection and activation systems are tested at least every 12 months

1.1.13.8 - Emergency breathing apparatus

IMCA D 024 says: *“Emergency breathing apparatus fitted with communications must be available for the supervisor (and winch operator if relevant) so that he may perform his duties in a smoky or polluted atmosphere”*.
The breathing apparatus must also allow the supervisor and the Launch and Recovery System (LARS) operator to escape with the rest of the team when they have completed their duty. For this reason, the breathing apparatus must be fitted with a bottle that allows doing it.
Also, new models enable connecting to a gas reserve without using the bailout bottle during the time the people finish the ongoing diving operation. As an example, Drager, a well-known manufacturer, proposes an “Automatic Switch Over Valve” that is designed for this purpose and connects automatically from the external supply to the bailout if this supply fails *(see below)*.



Note that the breathing apparatus must never be connected to a compressor as the air intake may be in a polluted area. For this reason, the air provided must be from a gas reservoir only.
In addition to the emergency breathing apparatus, several escape sets should be provided to allow the not essential personnel present in the dive control to escape. These items are composed of a small bottle and a hood or a breathing mask and do not allow any other activities than moving to the muster station.

MCA D 024 says that Emergency breathing apparatus (and escape sets) should be function tested (including voice communications) at least every six months and at the same time their cylinder is fully charged. Also, the bottle should be tested for leaks at its maximum working pressure of and externally examined every two and a half years. The same inspection increased with an internal examination has to be performed every five years.

1.1.13.9 - Documents to be provided in the dive control

IMCA Says that the following documents must be present in the dive control:

- Copies of the diving contractor’s manuals and diving rules.
- Emergency procedures (Generic procedures supplemented by project-specific addendums).
- Diving logs or pre-printed sheets and other relevant documentation.
- Copies of the diving bell internal and external pre-dive checklists.
- A photographic record that clearly identifies the bell valves, internal and external, should be available to allow the supervisor to guide the divers in an emergency.
- Plan to deploy a surface standby diver in emergency, unless a robust alternative plan (proven through exercises) has been developed to ensure assistance can be rapidly given to a stricken or fouled bell at all depths within the working range of a surface diver, including the period while the bell is close to or in a moonpool.
- A layout of the vessel thrusters and other obstructions must be displayed if the ship operates on Dynamic Positioning mode, with also a diagram of the maximum permitted lengths of the umbilicals of the working and standby divers for each depth at the specific dive location(s). This should include the umbilical ranges for the emergency surface standby diver.

Not indicated by IMCA, but very important, the following documents should also be available:

- The list of the divers in saturation, their function, and working periods.
- The list of the personnel on deck, their function, and working periods.
- The phone numbers of the key persons.
- Emergency communication channels and the emergency response plan chart should be displayed at the direct vicinity of the supervisor.
- The task plans and risk assessments for the project.
- Tool box talk forms.
- Safety observation cards & stop cards.
- Incident report forms.
- Equipment manuals and implementation procedures.
- A plan of the diving system where the important elements linked to the management of the dive are highlighted must be displayed.
- The list of the gasses in line with their % oxygen.

1.1.13.10 - Summary of the maintenance of the elements in the dive control room

There is no change of the rules of certification of the mechanical and electrical components present in the dive control compared with those of other parts of the diving system.

Items	*Visual external + function test , calibration*	*Visual internal + external + leak test at max. Working pressure*	*Internal + external+ leak test 1,5 max. working pressure*	*Other*
Communications	6 months			Manufacturer specifications
Alarm testing	6 months			Manufacturer specifications
Analysers	6 months			Manufacturer specifications

Items	*Visual external + function test , calibration*	*Visual internal + external + leak test at max. Working pressure*	*Internal + external+ leak test 1,5 max. working pressure*	*Other*
Gauges	6 months			
Valves and pipework	6 months	2 years		
Relief valves	6 months	2 ½ years		
Electrical	6 months			
Fire fighting portable system	6 months			Manufacturer specifications
Fire fighting fixed system	6 months	12 months		Manufacturer specifications
Automatic fire detection	12 months			Manufacturer specifications
Emergency breathing apparatus	6 months	2 ½ years	5 years	Manufacturer specifications
Remote bell contamination control *(hydrocarbons +H 2 S)*	6 months			Note: Mandatory with IOGP

The computing systems described in the previous points are perfect tools for the observation of the diving system during the operations. However, that does not replace the classical planned maintenance system promoted in IMCA D 024 and described in the previous texts and the table above. Also, these tools need particular maintenance that is not yet taken into full account by IMCA and other professional organizations.
Computing systems can be subject to errors, faults, or flaw in programs or hardware systems. Such problems that are commonly called "bugs" produce unexpected results or cause a system to behave unexpectedly.
A lot of bugs are due to errors made by developers designing the source code of a program, or within components and operating systems used by the program in question. Also, malicious users can exploit potential bugs or weaknesses of an application to bypass access controls to obtain unauthorized privileges. Nevertheless, note that it is well known that most viruses are implemented accidentally through access to corrupted programs.
For this reason, the updates published by the manufacturers that correct the errors and vulnerabilities of software or the exploitation system should be installed on time. Also, memory sticks are identified as a significant source of transmission of bugs and viruses. For this reason, the manufacturer of the systems described in this presentation recommends not connecting such devices that contain other files and programs than those from the system. Considering that the price of such an item is negligible, the best procedure is to provide a new one to each supervisor arriving on board and ensure that these devices are always stored in the control room.

1.1.13.11 - To conclude with the latest generation dive controls

The latest generation of dive controls have their ergonomics improved compared to systems of the previous generation. Also, they provide additional tools that can be used for the management of the gasses, the condition of the divers, and the tasks performed. Nevertheless, note that dive controls from the previous generation can be upgraded to this latest standard by the addition of these new tools.

The dive control of Seven Pelican that has been built 35 years ago is an example of an old system upgraded to the latest standards.

The implementation of technologies from the computing industry allows significant improvements in the communications and the management of the conditions of the diver health and of the system his life depends on during the bell run. As a result, and even though new technologies such as the Diver Monitoring System are not mandatory with IMCA *(International Marine Contractor Association)*, IMO *(International Maritime Organization)*, and ADCI *(Association of Diving Contractors International)*, we can say that such equipment should be used.

The implementation of such technologies with divers is merely the continuation of their use in many industries, and particularly the space, aviation, and maritime activities for more than 40 years.
However, we can see that the manufacturer of the system taken as an example acts prudently and that the classical control systems are still present and ready for immediate use. It is probably the best philosophy for systems that are designed to protect the life of people working in a dangerous surrounding, which is the case of saturation diving activities. Several accidents that have happened in the aviation industry prove that fully computerized systems may lead to catastrophic events. As a result, despite clear menus, the management of such new systems requires the supervisor to be familiar with them, and the owner of such a system should organize a specific formation before the beginning of the operation. This formation should be anyway mandatory with all saturation systems, even those that do not provide electronic tools as each system has its specifications and the supervisor must keep his knowledge regarding the use of the classical commands.

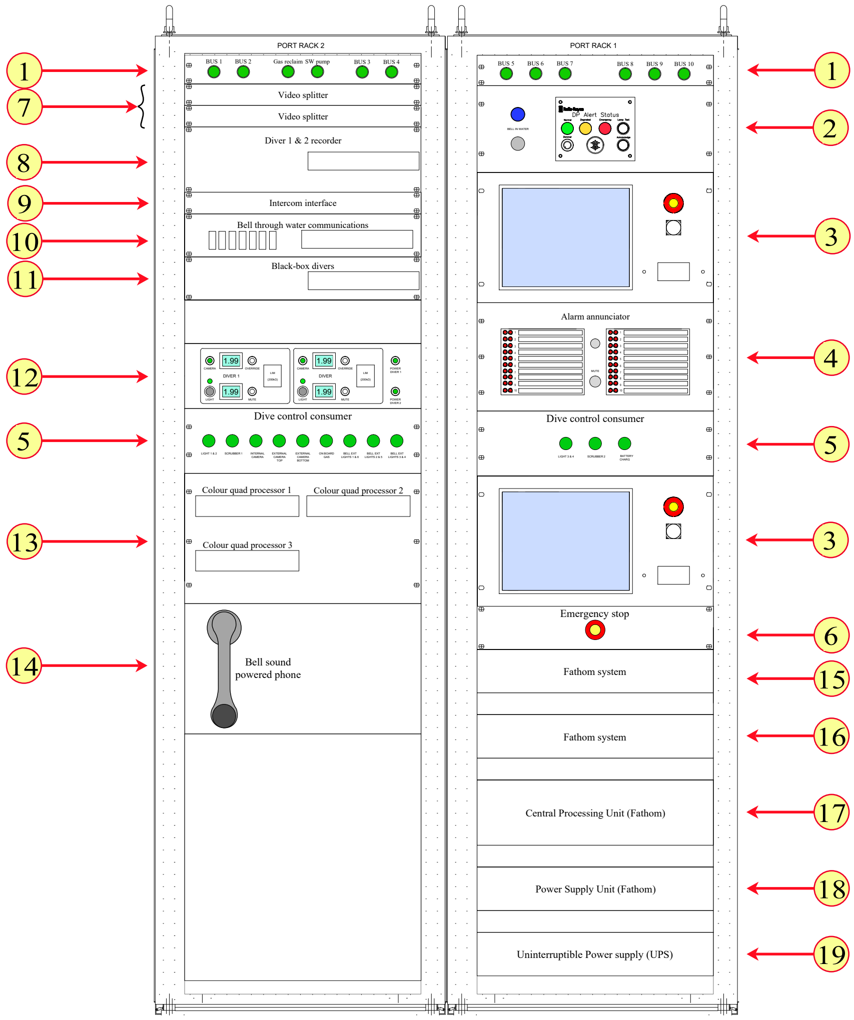
1.2 - Checklists

As indicated in Book #2, each saturation system has its specifications to which the checklist must be adapted. For this reason, this chapter indicates only the main principles to be in place when creating checklists.
Note that the old rule that says that a bell checklist is valid six hours should be in force

1.2.1 - Dive control panel checks

1.2.1.1 - Electrical supplies, recording , and communications

Electrical supplies of the dive control and the bell must be started. They are usually grouped in the electrical and data transfer cabinets where the electrical supplies and the various video and data signals are interfaced.



- The electrical supplies must be opened on the main electrical distribution panel, so the lights indicating that the “BUS” are energised are illuminated *(see #1 above)*.
- The “Uninterruptible Power Supply (UPS)” must be tested. That must be done with a minimum of elements activated. Computing systems or similar may be damaged by a sudden shut down and should not be activated during this test.
- Interfaces with hot water machines should be opened. They will be setup when preparing the hot water machine.
- The Alarm Annunciator Panel *(see # 4)* that displays the status of alarm signals using lights and sound features should be illuminated and active.
- The electrical supplies of the bell should be activated, except the external lights that will be tested during the external checks of the bell and will be opened only when the bell is in the water *(see #5)*.
- The video screens of the bell control panel should be switched on, and the video system and video splitters activated *(see #7)*. The clarity of the pictures should be checked and the cameras organised for the task. The colour quad processor (see #13) should be tested.
- The camera lights of the helmets *(see #12)* will be checked during the internal checklist of the bell.
- Intercom systems should be activated. They are usually installed on the diver monitoring panel with their interface in the electrical cabinet *(See #9)*.
- The diver monitoring screens should be switched on.
- The Power Supply Unit of the computers should be switched on. As a result, the Intelligent Acquisition Unit (see #15), Intelligent Network Logger (see #16), and Central Processing Unit (CPU), that are components of the diver monitoring system, should be activated.

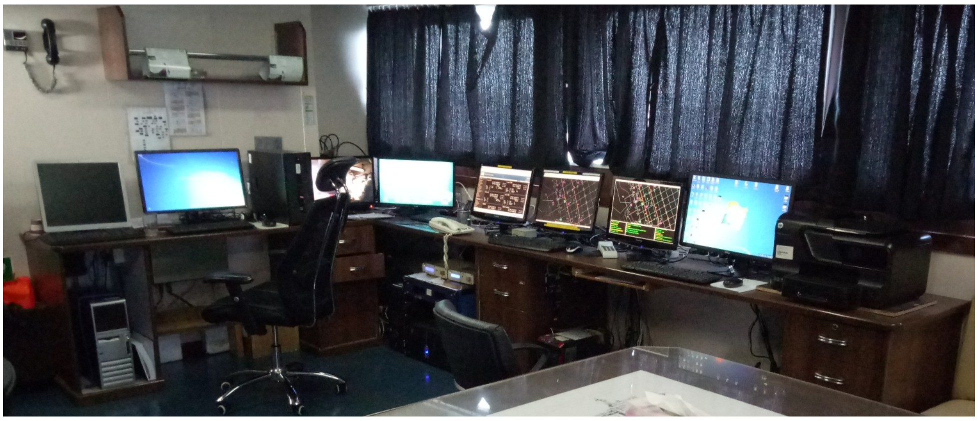
1.2.1.2 - Bell monitoring panels

- Diving monitoring system preparation *(for systems equipped with)*:
    - The diving supervisor logs on the system through the “Dive supervisor Login” button on the main screen display *(see #10 below)*.
    - When the diving supervisor is logged in, he resets the timers of the diver monitoring system, adjusts the duration of the shift, configures the bell run timer, and ensures that the names of the divers are correct.
- The appropriate gas mixes are online with their oxygen percentage indicated on the panel. The gas panel is to be setup with the reclaim system
- The analysers must be calibrated *(see in point 1.1.11.4)*.
- Diving monitoring panel.
    - Pressure gauges of the transfer lock and the trunk should be active *(see #1 & #2 below)*.
    - Internal depth gauge of the bell should indicate the pressure in the bell *(see #3 below)*.
    - External bell / diver 3 depth gauge should indicate zero *(see #4 below)*.
    - Depth gauges diver #1 & diver #2 should indicate the pressure in the bell *(see #5 & #6 below)*.
    - Cameras diver #1 and diver #2 should be switched on *(see #7 & #8 below)* and tested (the tests can be performed during the internal bell check).
    - Cameras of the bell trunk & the transfer lock must be switched on *(see #11 below)*.
    - External cameras of the bell must be switched on *(see #12 below)*.
    - ROV cameras should be displayed on the diving supervisor’s panel *(see #12 below)*.
    - The phone must be tested *(see #18)* - The test can be performed with the bridge.
    - The intercom must be tested *(see #17)* - The test can be performed with the bridge.
    - Marine radio must be checked *(see #15)* - The test can be performed with the bridge.
    - The VHF radio must be tested *(see #16)* - The test should be performed with the diving team.
    - The Dynamic Positioning lights must be tested - The test must be performed with the DP operator.
    - Main and backup bell and divers communication systems *(see #13 & #14 below)* must be tested (these tests are performed during the bell checks).

1.2.1.3 - Survey system

The function of the survey team is to establish a precise map of the worksite and position the vessel, and the divers in this map displayed on a monitoring screen in a direct view of the supervisor so he can easily assess the positions of the boat and the divers during the dive (see #9 in the photo on the previous page).
The combo screen of the supervisor may be provided with limited functions such as zooming a section. However, the

elements displayed and their distances are controlled by the surveyor, who is always in direct communication with the supervisor.
For clarity, the surveyor should minimize the elements displayed on the screen to those useful for the operations in progress. That means that elements that have been dismantled and do not represent harm to divers should not be displayed. Also, the display must be continuously refreshed so the supervisor is aware of the position of the divers and the boat.

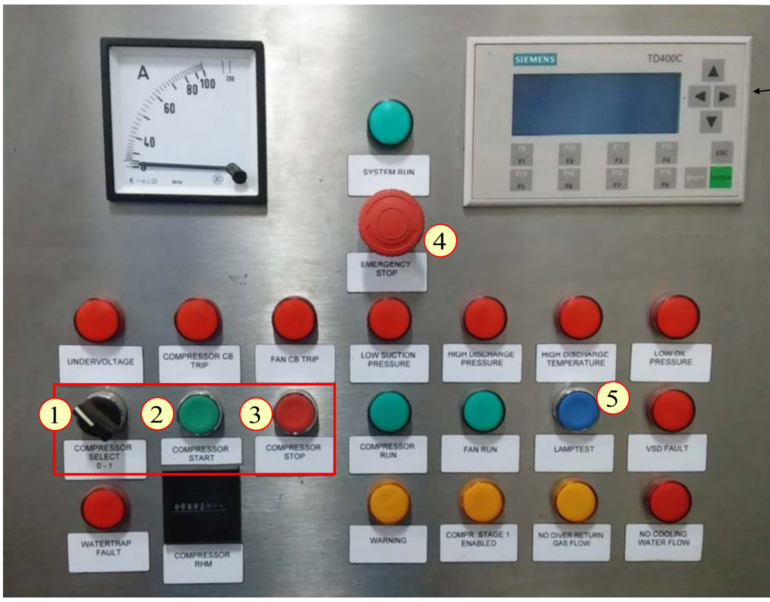


The reference systems used depend on the conditions of the project and are described in point 8.2.4.2 “Reference systems” of Book #1. For convenience, they should be installed in sufficient time in advance to allow for a reliable calibration and stability of the system.

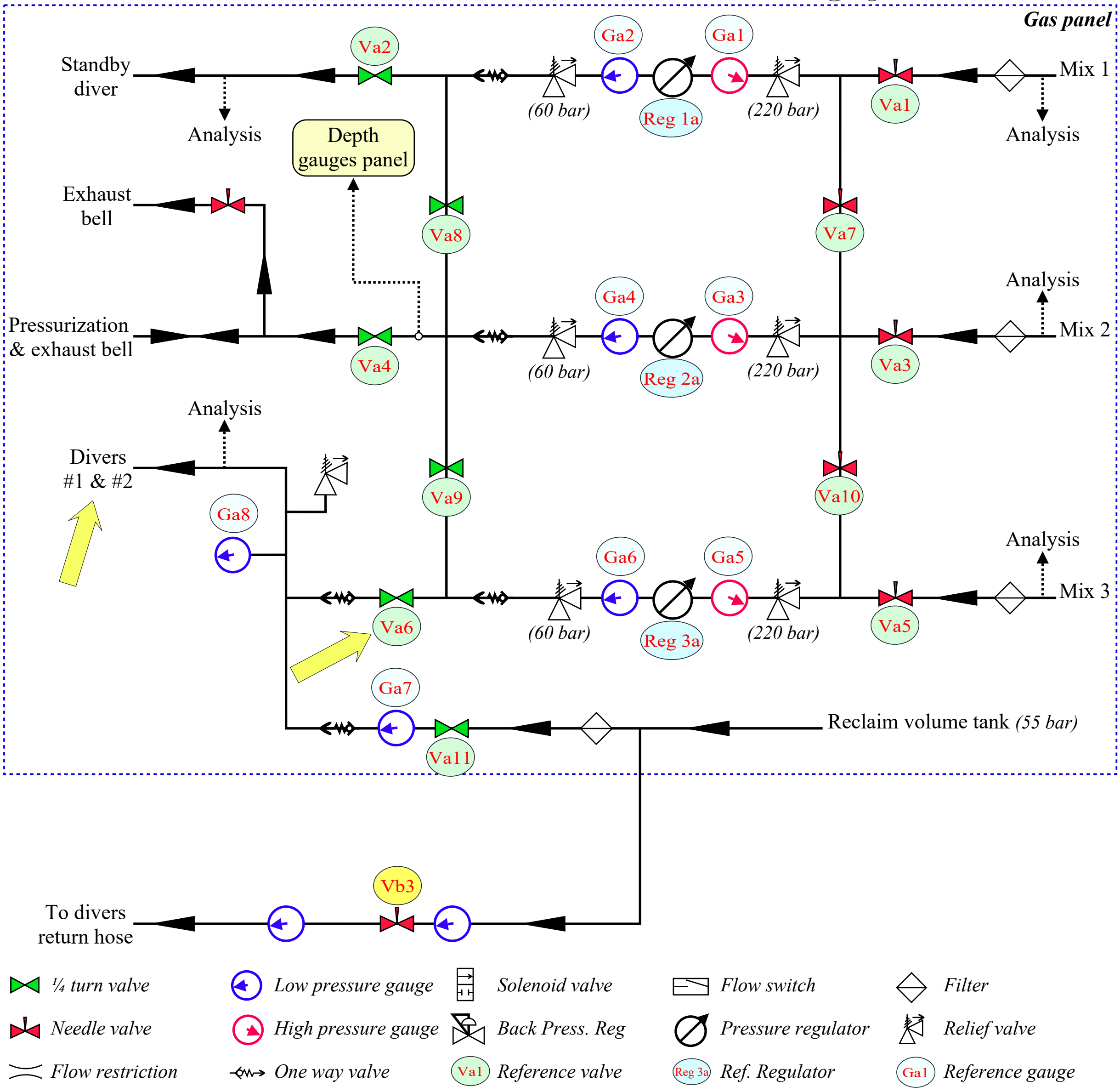
1.2.2 - Bell reclaim system setting up

The bell reclaim system is explained in point 1.1.11.5.

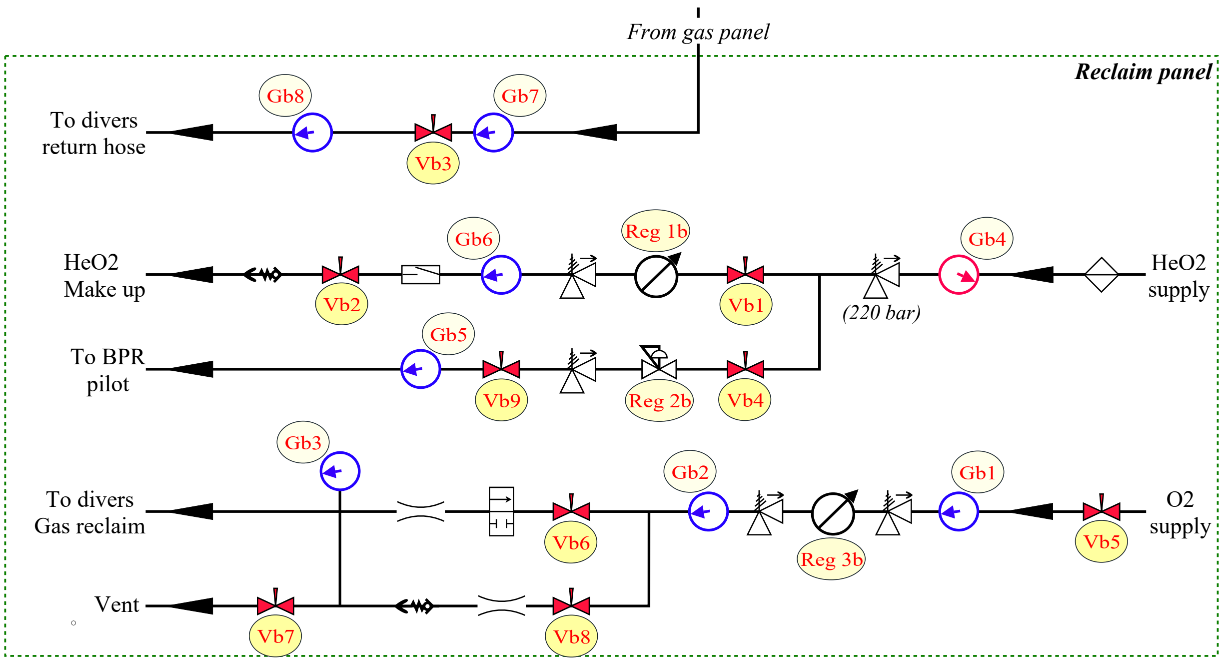
- Three suitable diving mixes for the depth planned are online and should be analysed using the analysis panel. One mix is selected to supply the gas reclaim system, and the two other mixes can be used as backup, for bell pressurization, and to supply the standby diver's umbilical.
- The selected make-up gas is supplied to the "reclaim panel".
- Pure Oxygen is ready for oxygen make-up.
- Pure helium should not be connected to the system under any circumstances.
- Ensure that all valves of the control panels are closed and that the hand-knobs of the regulators have been returned to zero (fully turn the hand-knob anticlockwise and then turn it back ¼ turn).
- Prepare the compressor:
    - Ensure that suitable electrical power is available for the compressor drive motors. It should be 440 Vac/ 60 Hz/ 40 KW for the model taken as an example.
    - Check the level of oil and that the cooling system of the compressor is ready for use.
    - Prepare the compressor for the depth of the dive, and switch off the 1st stage of the compressor if the dive is planned at 160 m or below.
    - When the electrical power is supplied, the compressor can be started.



- The scrubbers must have been prepared as indicated in point 1.1.11.5. Soda lime canisters must be ready for replacement during the operations.
- Start the compressor according to the procedure indicated in point 1.1.11.5. Note that the starting procedure changes depending on whether the pressure in the reclaim tank is below or above 45 bar:
    - If the pressure of the reclaim volume tank is below 45 bar, the outlet valve between the outlet of the scrubbers and the inlet of the storage tanks must be closed prior to starting the compressor. When the compressor is started, wait for the machine to reach its normal speed, then open again the closed valve.
    - If the volume tank is at a pressure above 45 Bar, the compressor cannot be started due to the high resistance of this pressure. If this is the case a message comes up on the HMI saying "Press. too hi for start" and the amber "warning" pilot light will be on.
      To start the compressor the valve between the inlet to the reclaim tanks and the outlet of the scrubbers must be closed. Then, the volume tank must be vented using the dedicated valve to the gas panel until the pressure gauge between the inlet to the reclaim tanks and the outlet of the scrubbers reads below 45 bar. Once the pressure is below 45 bar, start the compressor and wait for the machine to reach its normal speed, then the outlet valve V2 on the Topside Reprocessing Unit (TRU) can be opened again.
- When the compressor is started, the volume tank can be pressurized to the required value:
    - On the "gas panel" in the dive control *(see the first scheme on the next page)*:
        - Select the mix to be used as the source in the reclaim system among mixes 1 *(valve Va1)*, mix 2 *(valve Va2)*, or mix 3 *(valve Va5)*.
        - Then, open the corresponding valves of mix 1 *(valve Va1)*, mix 2 *(valve Va2)*, or mix 3 *(valve Va5)*, and sets the regulators "Reg 1a", "Reg 2a", "Reg 3a" to the correct pressures *(see on the next page)*.
        - When the regulators are adjusted to the desired pressures, use the cross-over valves Va7-Va10 or Va8-Va9 to supply the "makeup supply valve" Va6 with the mix selected and also have the "standby diver" and "bell pressurization" lines ready for use.
        - When the regulators are set up and the selected mix is supplied to the makeup supply valve "Va6", open this valve. As a result the selected gas flows to "divers 1 & 2".



- On the "reclaim panel" in the dive control:
    - Set the make-up regulator *(see "Reg 1b" in the drawing below)* to the desired "reclaim volume tank" pressure.
    - Then, open valves "Vb1" and "Vb2". These valves should be kept open throughout the diving mission. Note that the pressure can be read on the pressure gauge of the Topside Reprocessing Unit *(see in the drawing below)*.



- On the Topside Reprocessing Unit (TRU)
  - Ensure that the "Reclaim gas out valve" and "HEO2 makeup inlet valve" are open.
  - Enter the "reclaim volume tank" pressure as an alarm set point through the human Machine Interface (HMI). As a result, a warning light is visible if the actual pressure is 3 bar above the set point.

- Charge the return line and set up the Back Pressure Regulator pilot pressure on the "reclaim panel" in the dive control:
  - Open the supply valve Vb4 and the exhaust valve Vb9 *(see in the drawing on the previous page)*.
  - Slowly open the cross-over valve Vb3 until the entire umbilical reaches the bottom depth pressure. Note that the pressure can be read on the pressure gauge G6 on the TRU. When the pressure is reached the valve Vb3 must be closed.
  - When the valve Vb3 is closed, set the Back Pressure Regulator *(see "Reg 2b")* to the requested pressure indicated in the "reclaim table".

- Set the bypass BPR pressure on the Topside Reprocessing Unit (TRU) and using valve Vb3 on gas the reclaim panel:
  - To prevent the compressor from speeding up during the set-up, set the bypass pressure to 15.5 Bar on the Human Machine Interface (HMI) on the TRU.
  - Then, start the compressor and keep the compressor suction pressure to at least a pressure equal to the bypass pressure set point according to the "reclaim table" with the cross-over valve Vb3 on the gas reclaim panel.
  - When the pressure on the gauge on the Topside Reprocessing Unit (TRU) is at the required volume tank pressure, stop the compressor.
  - The inlet valve of the Topside Reprocessing Unit (TRU) is closed
  - Set the bypass pressure as a set point on the Human Interface Machine (HMI) on the Topside Reprocessing Unit (TRU) according to the "reclaim table".
  - Open the Back Pressure Regulator "Reg 1" one turn
  - Start the compressor, and with "Reg 1" regulate the compressor suction until this pressure has stabilised at the bypass pressure set point according to the "reclaim table".
  - Set the required bypass pressure according to the dive table as a set point on the Human Interface Machine.

- Set the oxygen to the required level:
  - Open the reclaim gas inlet valve on the Topside Reprocessing Unit (TRU).
  - Slowly open the cross-over valve "Vb3" on the "reclaim panel" in the dive control, and leave this valve in this position.
  - On the Topside Reprocessing Unit (TRU), when the compressor suction pressure has reached a value higher than the bypass pressure set point, start the compressor. As a result, the gas is circulating through the volume tank.
  - On the "reclaim panel" in the dive control, adjust the oxygen regulator *(see "Reg 3b)* to the desired pressure for the planned dive. Then, close the valve Vb3.

- Setting up in the bell

  Note: The numbers below are those of the drawing on the next page.

  1. Ensure that Diver has gas supply to helmet (regulator adjusted to the value indicated in the "reclaim table").
  2. Close the bell scrubber valve.
  3. Check that the SAECO/POS valve is fully open (The indicator is out).
  4. Close water trap drain valve.
  5. Close the diver exhaust manifold valve.
  6. Push in the water trap isolation valve.
  7. Open the diver exhaust hull valve slowly.
  8. Turn the BPR Loader needle valve anticlockwise until it stops rotating, then turn back half a turn.
  9. Adjust the BPR bleed (metering) valve to read 0.5 L/min on the BPR flowmeter (once set do not re-adjust).
  10. Adjust the BPR loader until the negative pressure gauge reads according to the "reclaim tables" *(If using a different brand of helmet than Divex, the manufacturer's recommendations)*. The Diving Supervisor must advise the divers of the desired negative pressure.
  11. Adjust the pneumo supply valve to read 0.3 l/min on the corresponding flowmeter (0.4 l/min maximum)
  12. Connect the exhaust hose to the helmet.
  13. Open the "shut off valve" of the helmet.
  14. Open the diver exhaust manifold valve.
  15. Put on helmet and breathe on recovery.

- Important note from the manufacturer of the equipment taken as example regarding shallow diving procedures:
  - Diving at depths less than 40 MSW (130 SFW), makes further demands on the system. At shallow depths, the compressors are exposed to the highest-pressure ratio and, as such, shallow diving makes the greatest demands on the compressors.
  - For this reason, the regulator settings advised should be rigidly adhered to. Low range gauges are also required for the BPR loader and umbilical suction. It might even be advisable to go for a shorter main umbilical, bypassing the umbilical winch, in order to reduce pressure losses.

- On the Topside Reprocessing Unit (TRU)
    - Ensure that the “Reclaim gas out valve” and “HEO2 makeup inlet valve” are open.
    - Enter the “reclaim volume tank” pressure as an alarm set point through the human Machine Interface (HMI). As a result, a warning light is visible if the actual pressure is 3 bar above the set point.

- Charge the return line and set up the Back Pressure Regulator pilot pressure on the “reclaim panel” in the dive control:
    - Open the supply valve Vb4 and the exhaust valve Vb9 *(see in the drawing on the previous page)*.
    - Slowly open the cross-over valve Vb3 until the entire umbilical reaches the bottom depth pressure. Note that the pressure can be read on the pressure gauge G6 on the TRU. When the pressure is reached the valve Vb3 must be closed.
    - When the valve Vb3 is closed, set the Back Pressure Regulator *(see “Reg 2b”)* to the requested pressure indicated in the “reclaim table”.

- Set the bypass BPR pressure on the Topside Reprocessing Unit (TRU) and using valve Vb3 on gas the reclaim panel:
    - To prevent the compressor from speeding up during the set-up, set the bypass pressure to 15.5 Bar on the Human Machine Interface (HMI) on the TRU.
    - Then, start the compressor and keep the compressor suction pressure to at least a pressure equal to the bypass pressure set point according to the “reclaim table” with the cross-over valve Vb3 on the gas reclaim panel.
    - When the pressure on the gauge on the Topside Reprocessing Unit (TRU) is at the required volume tank pressure, stop the compressor.
    - The inlet valve of the Topside Reprocessing Unit (TRU) is closed
    - Set the bypass pressure as a set point on the Human Interface Machine (HMI) on the Topside Reprocessing Unit (TRU) according to the “reclaim table”.
    - Open the Back Pressure Regulator “Reg 1” one turn
    - Start the compressor, and with “Reg 1” regulate the compressor suction until this pressure has stabilised at the bypass pressure set point according to the “reclaim table”.
    - Set the required bypass pressure according to the dive table as a set point on the Human Interface Machine.

- Set the oxygen to the required level:
    - Open the reclaim gas inlet valve on the Topside Reprocessing Unit (TRU).
    - Slowly open the cross-over valve “Vb3” on the “reclaim panel” in the dive control, and leave this valve in this position.
    - On the Topside Reprocessing Unit (TRU), when the compressor suction pressure has reached a value higher than the bypass pressure set point, start the compressor. As a result, the gas is circulating through the volume tank.
    - On the “reclaim panel” in the dive control, adjust the oxygen regulator *(see “Reg 3b)* to the desired pressure for the planned dive. Then, close the valve Vb3.

- Setting up in the bell

    Note: The numbers below are those of the drawing on the next page.

    1. Ensure that Diver has gas supply to helmet (regulator adjusted to the value indicated in the “reclaim table”).
    2. Close the bell scrubber valve.
    3. Check that the SAECO/POS valve is fully open (The indicator is out).
    4. Close water trap drain valve.
    5. Close the diver exhaust manifold valve.
    6. Push in the water trap isolation valve.
    7. Open the diver exhaust hull valve slowly.
    8. Turn the BPR Loader needle valve anticlockwise until it stops rotating, then turn back half a turn.
    9. Adjust the BPR bleed (metering) valve to read 0.5 L/min on the BPR flowmeter (once set do not re-adjust).
    10. Adjust the BPR loader until the negative pressure gauge reads according to the “reclaim tables” *(If using a different brand of helmet than Divex, the manufacturer’s recommendations)*. The Diving Supervisor must advise the divers of the desired negative pressure.
    11. Adjust the pneumo supply valve to read 0.3 l/min on the corresponding flowmeter (0.4 l/min maximum)
    12. Connect the exhaust hose to the helmet.
    13. Open the “shut off valve” of the helmet.
    14. Open the diver exhaust manifold valve.
    15. Put on helmet and breathe on recovery.

- Important note from the manufacturer of the equipment taken as example regarding shallow diving procedures:
    - Diving at depths less than 40 MSW (130 SFW), makes further demands on the system. At shallow depths, the compressors are exposed to the highest-pressure ratio and, as such, shallow diving makes the greatest demands on the compressors.
    - For this reason, the regulator settings advised should be rigidly adhered to. Low range gauges are also required for the BPR loader and umbilical suction. It might even be advisable to go for a shorter main umbilical, bypassing the umbilical winch, in order to reduce pressure losses.

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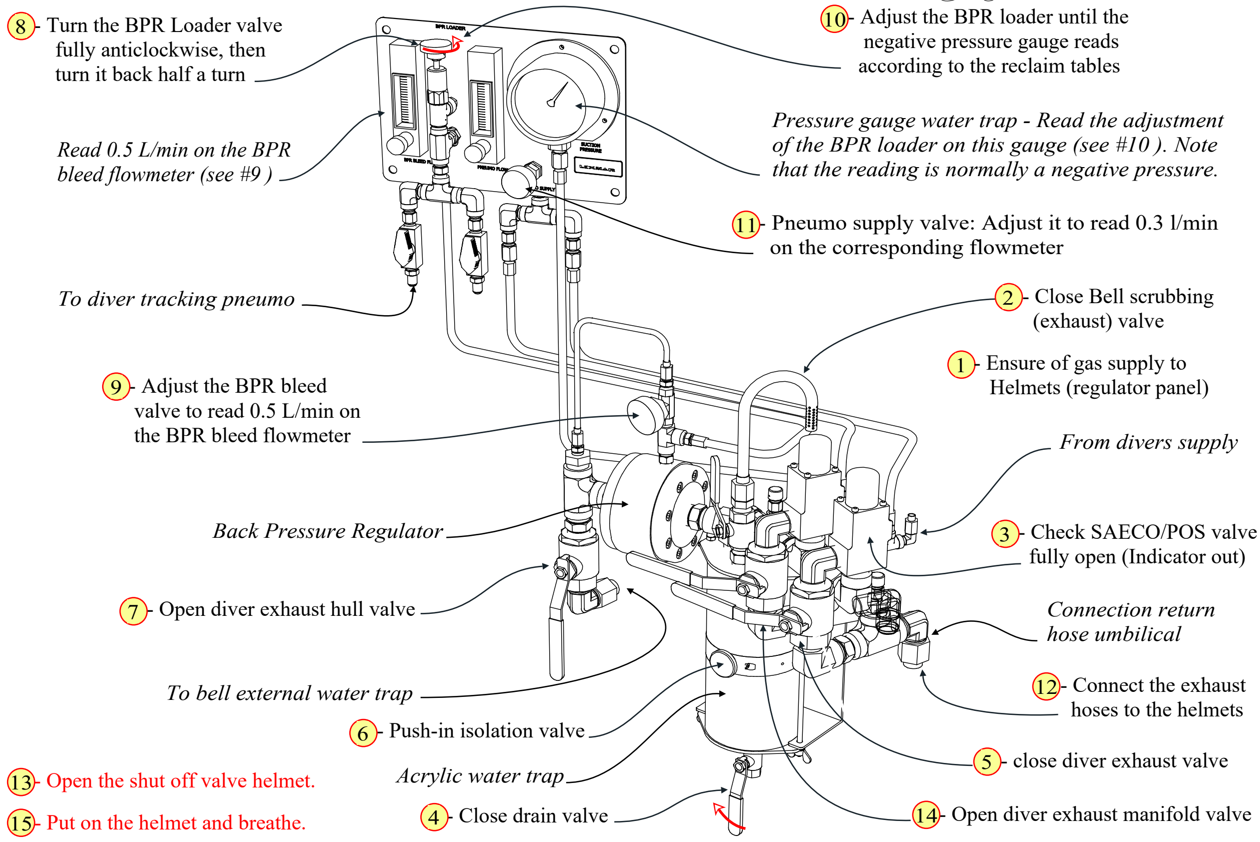


1.2.3 - Bell hot water machine setting up

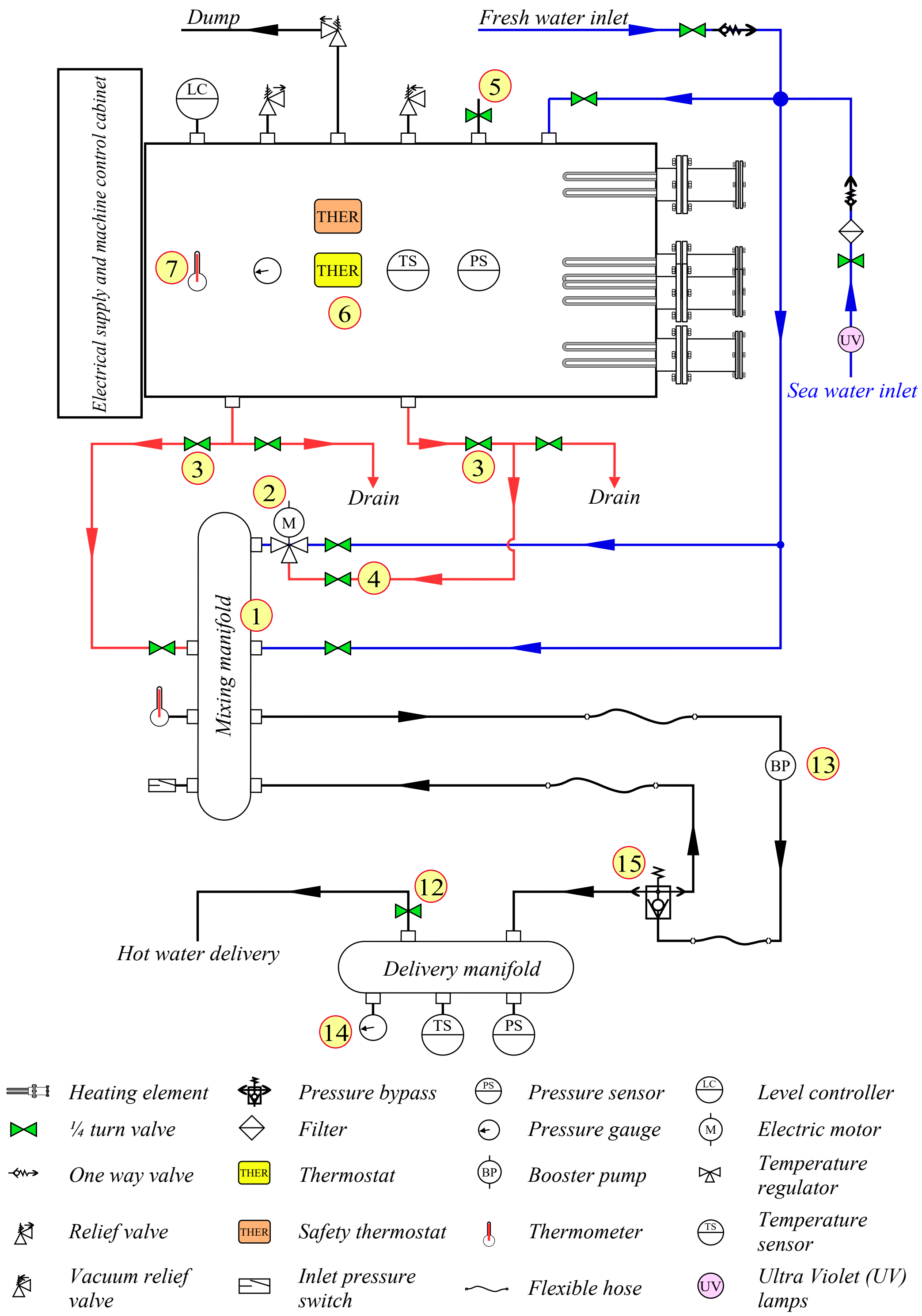
The hot water machine is explained in point 1.1.12.

1.2.3.1 - Machine starting

- Perform pipe leak tests
- Remove any filter clogging on water filters
- Switch on the command cabinet (Main switch on Control cabinet)
- Switch on the power cabinet (circuit breaker DN)
- Check that the electrical motor turn in the right direction (arrow sign on motors)
- Check that the pump by-pass (PBP) is set to the minimum (spring released)

1.2.3.2 - Regulation setting

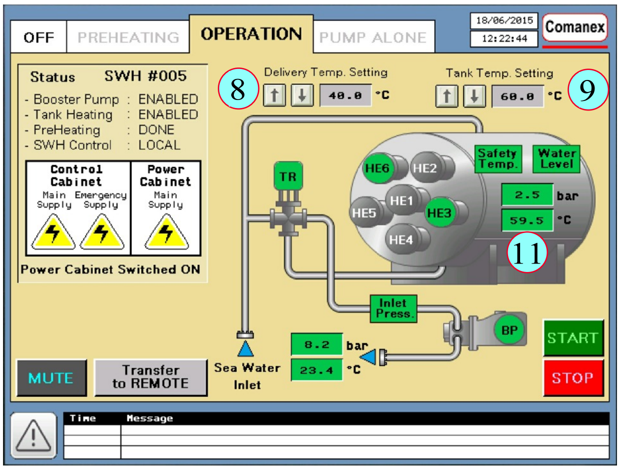
- Close the manual valves of the mixing manifold *(see #1 below).*
- Open the isolation valves of the regulation valve *(see #2 below).*
- Open the isolating hot water valves of the tank *(see #3 & #4 below).*

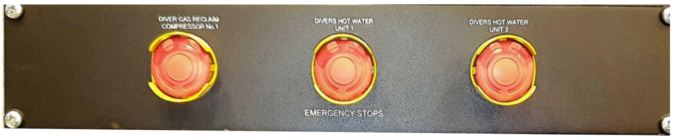


1.2.3.3 - Temperature setting

On the controller in the dive control:

- Press the arrows to set the desired temperature values (see #8 & #9 below) using a HMI system.
- Use the potentiometer to set the desired temperature using a classical system (see #10 below).





1.2.3.4 - Pre-heating

- Open vent valve *(see #5 in the drawing on the previous page).*
- Turn on the operation switch
- ensure that the safety thermostat is set to 80°C max *(See #6).*
- Switch the selected heating elements on the power cabinet
- When the heating elements are started, their corresponding light is on in the cabinet and on the remote control panel.
- Monitor the water temperature in the tank on the thermometer of the tank (See # 7) and the display of the remote control panel *(see #11 above)*

1.2.3.5 - High pressure feed

Once the tank has reached the desired heating temperature, a light switches-on on the cabinet's panel and the temperature is displayed on the Human Machine Interface. At this moment, the following operations can be undertaken.

- Open the water delivery valve *(see #12 in the drawing on the previous page).*
- Close vent valve *(see #5 in the drawing on the previous page).*
- Make sure that the downstream circuit and the diver distribution panel are ready to function
- Open water inlet valve of the bell and the water dump valve to establish the circuit.
- Start the booster pump *(see #13 in the drawing on the previous page)* using the dedicated button on the control cabinet.
- Check the delivery pressure on the pressure gauge of the delivery manifold *(see #14 in the drawing).*
- Set the pump by-pass 10 bars above the service pressure needed to supply the divers, up to a maximum of 70 bars *(see #15 in the drawing on the previous page).*
- Complete the temperature adjustment, using the setting buttons on the remote control panel *(see #8, #9, & #10 in the picture above)*, according to the readout temperature indicator *(See #11).* Note that it is also possible to check the delivery temperature on the temperature regulator on the delivery manifold and the control cabinet.

1.2.4 - Onboard gas

Onboard gas and oxygen add systems are described in points 1.1.2.6 and 1.1.2.7.

The onboard gas supply is designed to supply the diver if the surface supply fails. It is normally arranged to come on-line automatically if the surface supply pressure drops below a set level. It usually incorporates an audible and visual indication that the changeover has occurred, to warn the bellman to recall the diver and inform the diving supervisor.

IMCA says that there must be an emergency supply of breathing gas carried on board sufficient to support each working diver plus the bellman outside the bell for a minimum of 30 minutes at a breathing rate of 40 litres (1.5 ft^3) per minute at the maximum depth of the diving operation. This is to allow the diver(s) to return safely to the bell or allow the bellman to recover an injured diver, or allow a diver to clear debris if the bell is fouled. Note that the rates recommended by NORSOK (62.5 litres per minute) and the UK HSE study “The provision of breathing gas to divers in emergencies” (50 to 75 litres per minute) should be preferred; however, it may happen that the gas reserves have been calculated according to IMCA guidelines without more margins.

The onboard gas reserves should be checked prior to each bell run and should always be full.

The PPO_2 should be between 380 mb (0.375 ata) and 1400 mb (1.38 ata). The recommendation is to try to use higher PPO_2 limits. The table below indicates the lower and upper limits of various oxygen percentages.

% O_2 in mix	*Depth with 380 mb PPO_2*	*Depth with 1400 mb PPO_2*	*% O_2 in mix*	*Depth with 380 mb PPO2*	*Depth with 1400 mb PPO2*
21	8.1 m	56.7 m	***10***	28 m	130 m
20	9 m	60 m	***9***	32.2 m	145.6 m
19	10 m	63.7 m	***8***	37.5 m	165 m
18	11.1 m	67.8 m	***7***	44.3 m	190 m
17	12.4 m	72.4 m	***6***	53.3 m	223.3 m
16	13.8 m	77.5 m	***5***	66 m	270 m
15	15.3 m	83.3 m	***4***	85 m	340 m
14	17.1 m	90 m	***3***	116.7 m	456.7 m*
13	19.2 m	97.7 m	***2***	180 m	690 m*
12	21.7 m	106.7 m	***1.5***	243.3 m	923.3 m*
11	24.5 m	117.3 m	***1***	370 m	1390 m*

*Note: The maximum depths indicated with * are not reachable*

IMCA says that sufficient oxygen must be available for metabolic consumption by the maximum number of divers at 0.5 litres/minute per diver for at least 24 hours at the end of a bell run. This system is explained in point 1.1.2.7 of this book. Scrubber soda lime cartridges must be provided accordingly to collect the CO_2
It must be noted that 24 hours is a very minimum, and for this reason, many manufacturers propose bells with more onboard O_2 reserves than this minimum.

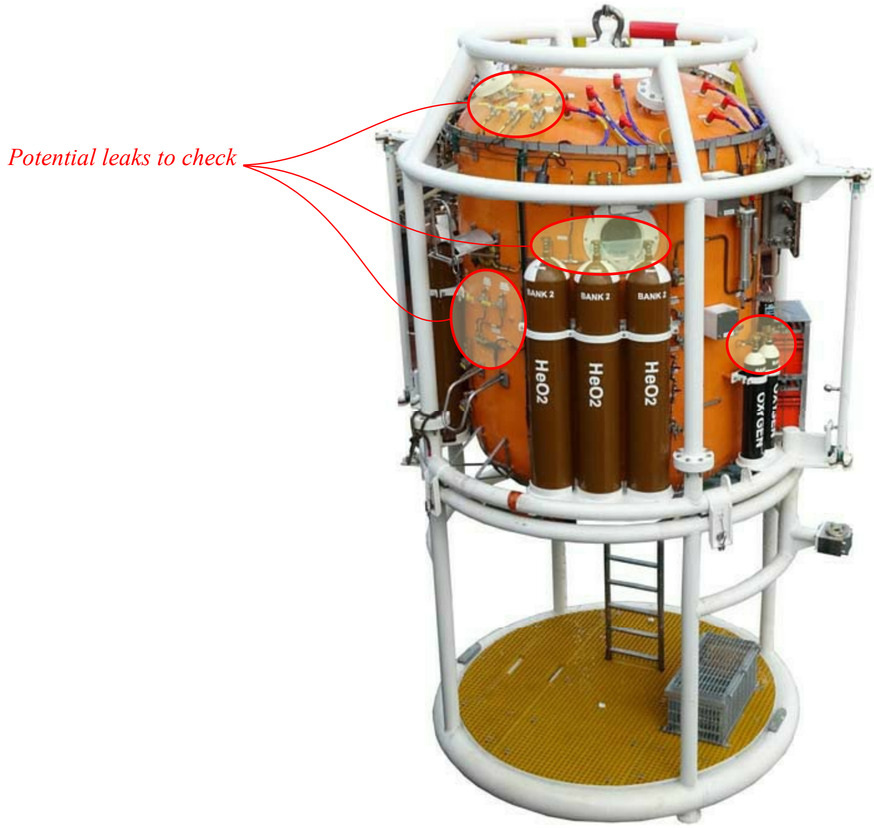
Water is often found inside the bell on-board gas cylinders charged by means of a manifold system, and in some cases in significant amounts.

- The presence of any moisture inside such cylinders can lead to the development of corrosion which could jeopardise the integrity of the cylinder.
- In an extreme case the ingress of water may be so large that a cylinder may no longer contain a sufficient quantity of gas to ensure the diver's safety. A circumstance which would not be detectable from a pressure check.

The following recommendations should be applied:

- The manifold's design should limit the atmospheric volume between the isolation valve and plug to a minimum and provide for venting it before removing the plug. Also, it should point downwards so that it will self-drain on the removal of the plug.
- Consideration should be given to using 'O' ring seal hand connectors on charging whips to ensure watertight integrity.
- Before connecting the charging whip, the manifold should be vented back. Of course, it is not possible when the manifold is fitted with a non-return valve; in this case, the portion between the non-return valve and the plug should point downwards, so it will self-drain. A screw lift isolation valve may also be installed.
- After fitting the plug, the isolation valve should be momentarily opened to back-charge from the charging point up to the plug, which must be suitable for the maximum working pressure of the manifold and provided with a venting capability. That should confirm the seal integrity of the plug and increase the gas pressure in this portion above the atmospheric pressure, so it will not be in depression when the bell is at depth.

- When bottles are pressure checked prior to refilling and a low pressure reading is obtained, consideration should be given to the fact that moisture may have entered.
- Charging panels and pillar valves should be checked for leaks during the bell checks. That can be done by spraying soapy water or specific leak detection products on the parts that can be sources of leaks.
- Leak checks must also be performed when the bell arrives at depth and prior to starting the working operations: Small bubbling indicates a leak that must be precisely located for repair. Also, its impact on the gas reserves must be evaluated. If the identified leak evaluation suggests that the gas reserves may be too impacted, the dive should be stopped and the bell repaired.



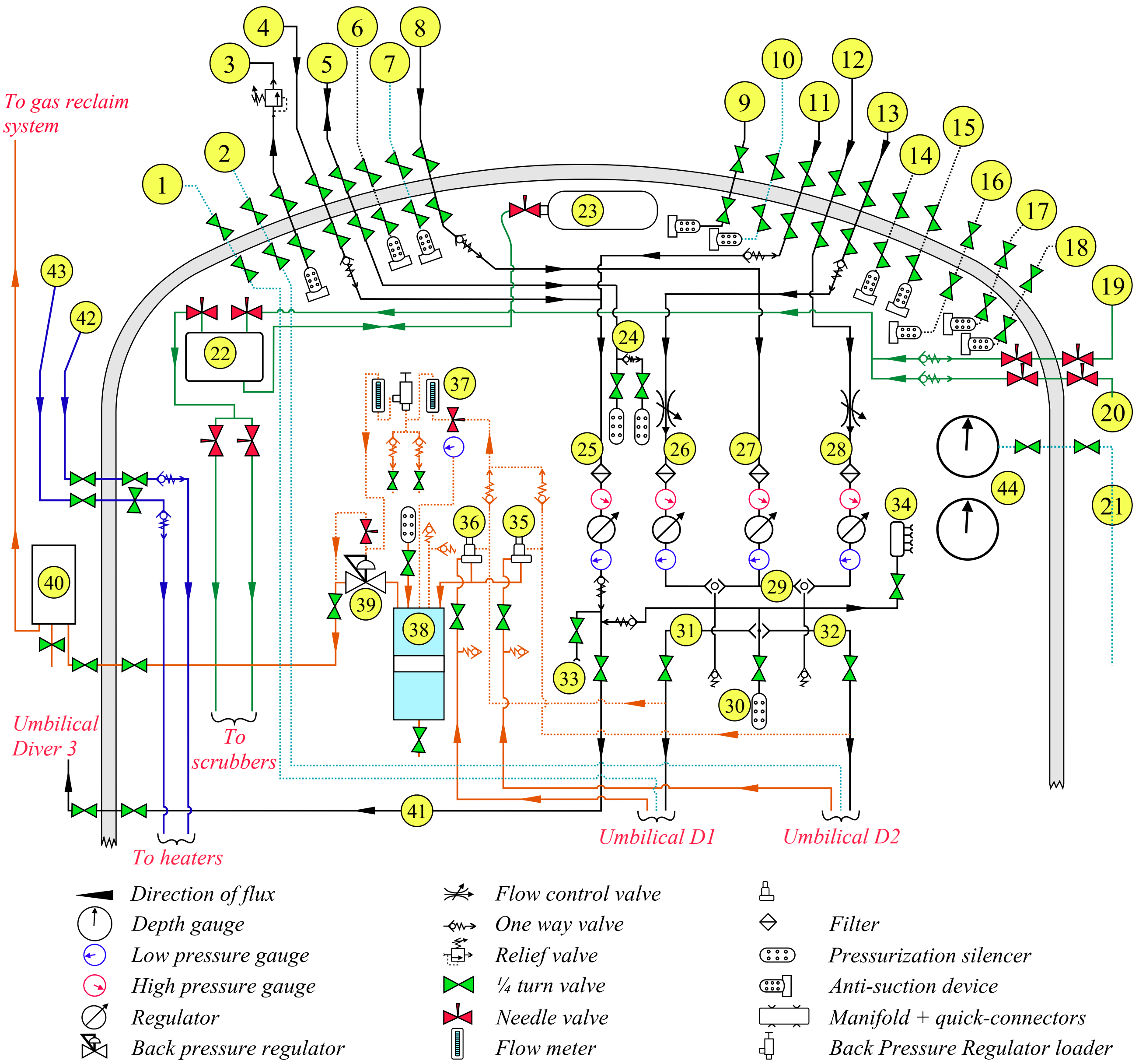
1.2.5 - Bell checks

Bell checks must be performed before each bell run.

1.3.5.1 - External checks

- Lifting devices, main umbilical, and protection frame:
  - The visible parts of main lifting wire and its socket must be in good condition and secured.
  - The main umbilical and its Chinese finger must be in good condition and appropriately secured.
  - The emergency recovery sling should be in good condition and secured.
  - Backup lifting hooks must be in good condition.
  - The fixations of the protection frame must be appropriately secured, and the frame should not have deformations that may affect its integrity.
- Emergency panel (to which the emergency umbilical is to be connected):
  - Emergency blow down must be closed and plugged *(see #9 in the drawing on the next page)*.
  - Hot water must be closed and plugged *(#43 in the drawing)*.
  - Depth monitoring connector must be plugged and the control valve closed *(#10 in the drawing).*
  - The power supply and comm's connector must be plugged.
- Bell locators and emergency communications:
  - Bell emergency location beacon must be secured in place and checked.
  - The through water communication transducer should be secured. It should be periodically tested underwater.
  - The strobe light must be secured at the top of the bell and working.
  - The external lights should be in good condition and function tested with normal and emergency supplies.
  - The tapping code should be in place.
- The viewports should not be corroded or scratched and be less than 10 years old. Their covers should be in place.
- The integrity of hollow and electrical penetrators should be checked.
- The oil filled connection boxes must be checked: There should not be water intrusion (small bubbles) and the box should be fully filled.
- The divers gas supply from the surface must be open *(see #8 in the drawing on the next page)*.
- The onboard gas cylinders must be open.
- The onboard banks tacking lines must be open *(see #14, #15, & #16 in the scheme)*.
- The hull valves of the emergency supplies from the onboard banks must be open *(see #12 & #13 in the drawing).*
- The supply to diver 3 from the dedicated onboard bank must be open *(see #11 in the drawing)*.
- The bell blow-down and exhaust valve must be open *(see #5 in the drawing)*.
- The tracking lines of the regulators of the oxygen banks should be open *(see # 17 & #18 in the drawing)*.
- The oxygen cylinders must be open.
- The isolation valves from the oxygen banks must be open *(see #19 &20 in the drawing)*.
- The external depth isolation valve must be open *(see #21)*.
- The hot water supply valve must be open *(see # 42)*.
- The hot-water dump valve must be open.
- The bilge drain must be open.
- The isolation of the safety pressure release valve must be open *(see #3 in the drawing on the next page)*.
- The hot-water supply to diver 3 must be open.
- The gas supply from the surface to diver 3 must be open *(see #4 in the drawing on the next page)*.
- The isolation valve of the return to the reclaim system must be open *(see #40 in the drawing)*.
- The external water trap of the reclaim must be open *(see #40 in the drawing)*.
- The external water trap drain valve must be closed *(see #40 in the drawing)*.
- The valve of the internal depth monitoring from the dive control must be open (#7 in the drawing).
- Diver #1 & #2 depths isolation valves must be open *(see #1 & #2)*.
- The analysis isolation valve to dive control must be open *(#6 in the drawing).*
- Medical Lock:
  - The equalization valve is opened to ensure that no gas or water is present, and then closed.
  - The vent valve is closed.
  - The door is closed and secured.
- The onboard oxygen charging panel should be closed and plugged.
- The onboard gas charging panel should be closed and plugged.
- The inlet and outlet hydraulic valves of the external bottom door must be open.
- Connections to the external backup hydraulic pump of the doors must be closed and plugged.

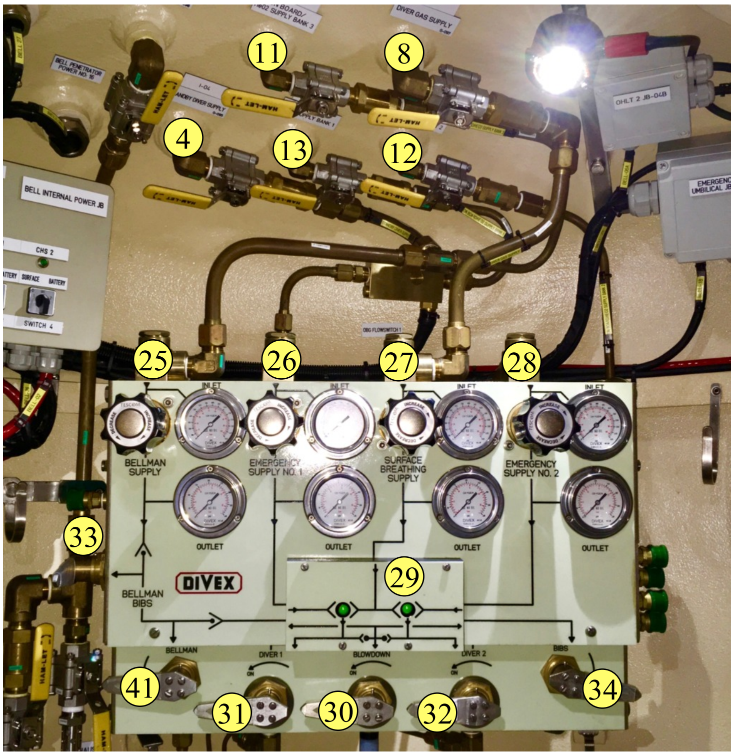
- The isolation valve of the external oil accumulator must be open.
- Bottom door:
  - Outside of the door: Equalization valve 1 is closed and equalization valve 2 is open.
  - Inside of the door: Equalization valve 1 is open and equalization valve 2 is closed.
- Stand by diver (Diver 3) umbilical:
  - It should be correctly secured so it cannot escape during the launching and the recovery of the bell.
  - Its communications must be checked and then plugged.
  - The hot water hose must be plugged
  - The gas hose must be plugged
  - When there are only two divers in the bell, the extremity of the umbilical must be stored such it can be recovered without launching the standby diver.
- Bailouts:
  - Bailouts may be stored in the clamp weight or in the storage box of the standoff frame.
  - They must be filled at their maximum working pressure with the appropriate mix for the planned depth, that must be indicated on the cylinder and be recorded by the diving supervisor.



1.2.5.2 - Internal checks

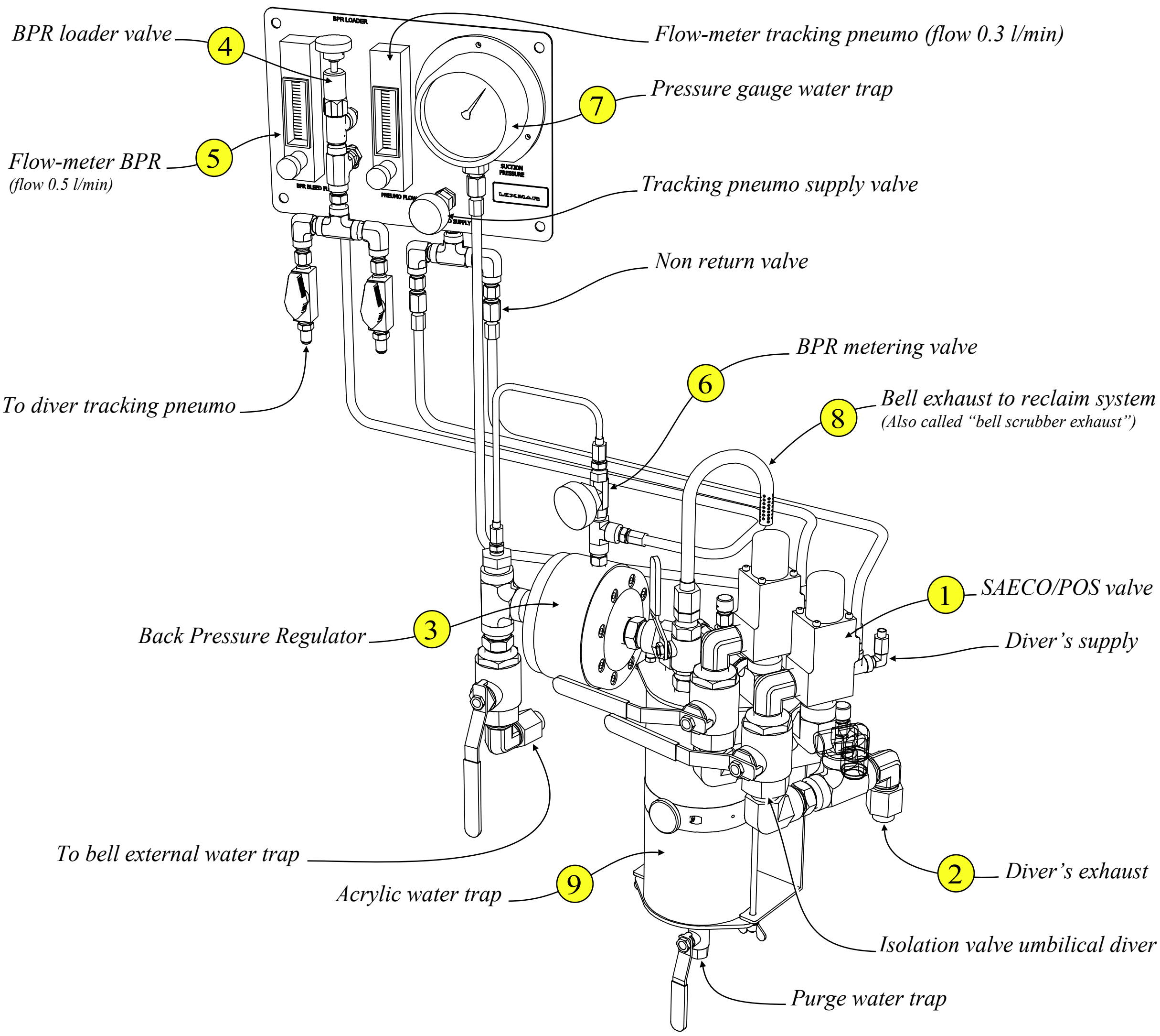
- Black box recorder and analysers:
  - Ensure that the black box is recording.
  - Record the gas status to the bell.
  - Ensure that the analysers are working and record the partial pressures of oxygen and CO_2.
  - Ensure that the hydrocarbons analyser (if the bell is provided with) is working and its status.
  - Confirm with the technician and the divers that fresh soda lime cartridges have been transferred to the bell.

- Lights and communications.
  - The intercom of the bell should work appropriately. Note that the check list is performed through it.
  - The electrical supplies should be checked and conform with the manufacturer recommendations.
  - The lights and the scrubbers must be tested with the normal and emergency supplies.
  - The sound powered phone must be checked.
  - The through water communications should be powered (it can be checked when the bell is in the water).
  - The communications, lights and camera of the helmets must be tested.
- The external condition of the helmets and the full face must be checked. Their communications, lights, and camera must be tested.
- Implement the gas supplies to the “Mara panel”:
  - The divers gas supply valve *(see # 8 & #27 in the scheme on the previous page and below)* should be opened, and the pressure reported *(usually approximately 14 bar)*.
  - The regulator *(see below #27)* must be adjusted to the recommended working pressure (approximately 12 bar). As a result of the established pressure the visual indicator of shuttle block *(see #29)*, which is designed to protect the divers from loss of gas supply, should be green.
  - The helmets should be tested by opening the valves #31 and #32 of the “Mara panel”. Then, the valves are closed and the helmets are vented.
  - The onboard gas supplies must be tested one by one. For this reason the supply valves of the onboard mix should be opened *(see lines #12 - #28 & #13 - #26 in the drawing and the photo below)* .
  - The regulators *(see below #26 & #28)* should be adjusted to the recommended working pressure (approximately 10 bar). As a result of the established pressure the visual indicator of shuttle block *(see #29)*, should be green.
  - The helmets must be tested with the onboard gas by opening the valves #31 & #32. The divers’ BIBS are also tested by opening the valve #34. If the tests are satisfactory, the valves are closed and the helmets and BIBS are vented.
  - The onboard supply of the standby diver (diver 3) must be tested: The hull valve *(see #11)* must be opened, the regulator adjusted appropriately *(see below #25)*, and the full face mask tested by opening the valve #41. The BIBS of diver 3 is also tested by opening the valve #33. When the tests are satisfactory the valves are closed and the full face mask and the BIBS are vented.



- The internal O2 analyser must be tested
- Implement the oxygen add system:
  - The hull valve of an onboard oxygen supply is opened *(see valves #19 & 20 in the drawing on the previous page)*.
  - The valve of the buffer tank is then opened to fill it *(see #23 in the drawing)*. It is closed when the buffer tank has been filled.
  - The inlet valves of the O_2 add manifold (see #22 in the scheme on the previous page) are opened. The oxygen injection valves are opened and the flow meter adjusted.
  - The valves are kept open until the PPO_2 f the bell is adjusted to the desired value. When this value is reached, the opened valves are all closed.

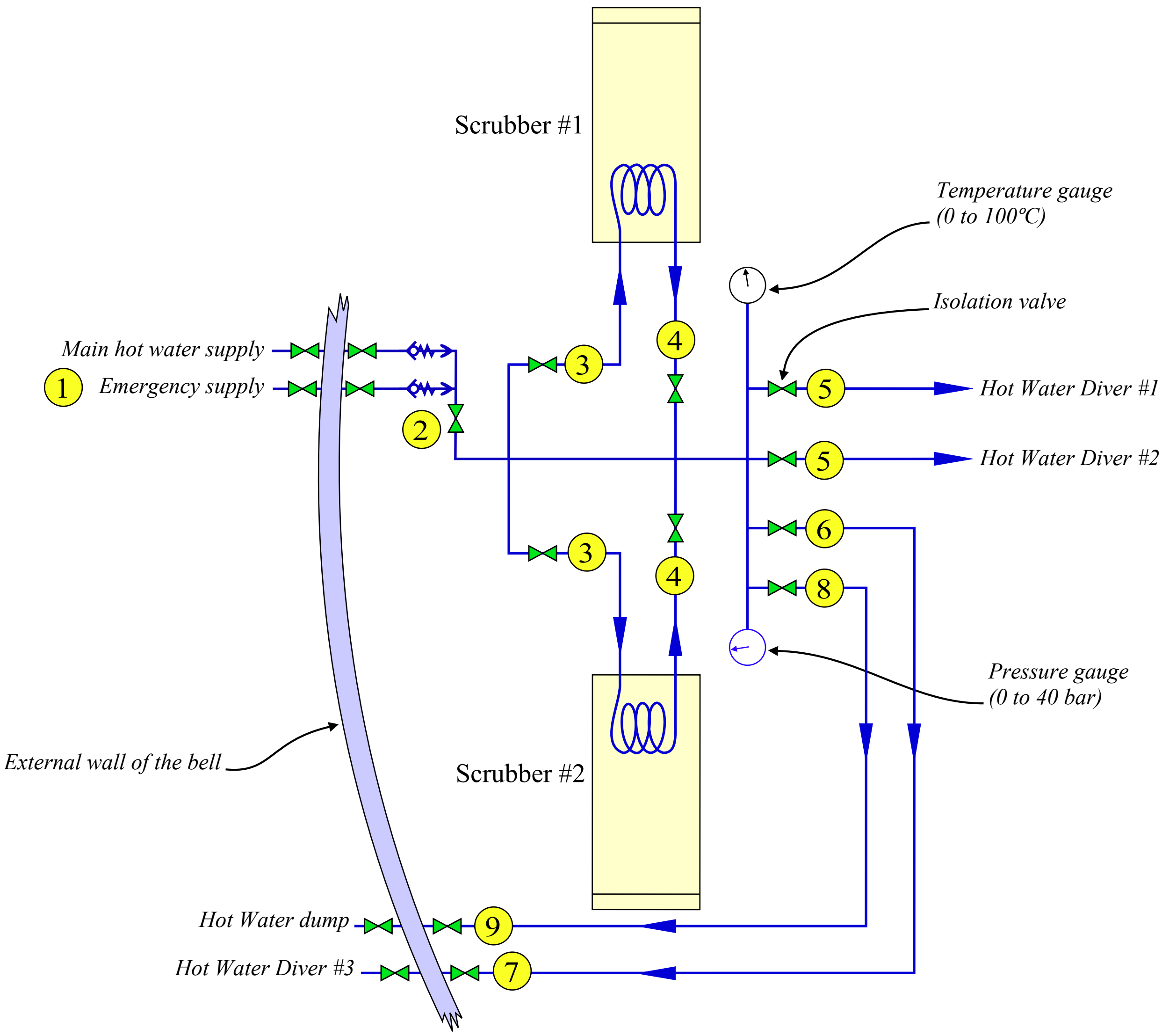
When the preparation of the Mara panel and the oxygen add system is completed, the check list can be undertaken:
- Depth gauges:
    - Internal depth gauge is open *(see #44 in the drawing in the previous page)*
    - External depth gauge is open *(see # 21 & #44 in the drawing in the previous page)*.
    - Bell internal depth monitoring from dive control is open *(#7 in the drawing in the previous page)*.
    - Diver 1 and diver 2 depth *(see #41 & #2 in the drawing in the previous page)*
- The bell blow-down and exhaust hull valve must be open *(see #5 in the drawing)*.
- The bell blow-down valve must be open *(see #24 in the drawing)*.
- The bell exhaust valve must be open *(see #24 in the drawing)*.
- The divers gas supply valves from the surface must be open *(see #8 & #27 in the drawing)*.
- The divers supply valves of the Mara panel are closed *(see #31 & #32 in the drawing)*.
- Standby diver supply from the surface must be open *(#4 in the drawing)*.
- Divers 1 & diver 2 onboard gas valves must be open *(see #12 & #13 in the drawing)*.
- Divers 1 & diver 2 onboard gas sensing lines must be open (see *#15, & #16 in the drawing)*.
- The hull valve of the dedicated onboard supply to diver 3 (standby diver) must be open *(see #11 in the drawing)*.
- Divers 3 onboard gas sensing line must be open *(see #14, in the drawing)*.
- Diver 3 supply (Mara panel) must be closed *(see #41 in the drawing)*.
- Emergency bell blow down Mara panel must be closed *(see #30 in the drawing)*.
- BIBS supply valve diver 1 & diver 2 must be closed *(see #34 in the drawing)*.
- BIBS supply valve diver 3 must be closed *(see #33 in the drawing*.
- The hull valve of the Pressure relief valve must be open *(see #3 in the drawing)*.
- Oxygen banks hull valves must be open *(see #19 & #20 in the drawing)*.
- Oxygen sensing lines must be open *(see #17 & #18 in the drawing)*.
- Oxygen valve buffer tank must be closed *(see #23 in the drawing)*.
- Oxygen valves manifold to and from buffer must be closed *(see #22 in the drawing)*.
- Oxygen valves to scrubbers must be closed
- Reclaim system *(note that this system is described in point 1.1.11)*:



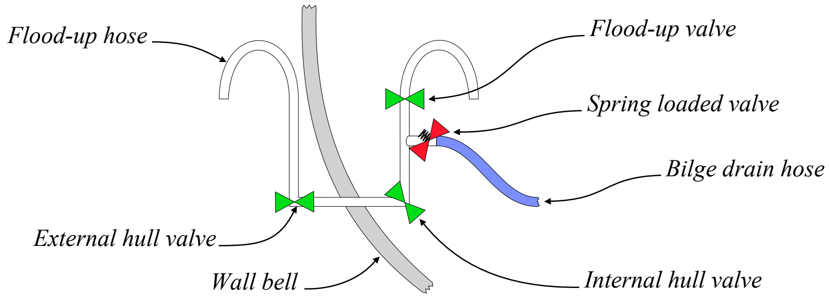
- The BPR (Back Pressure Regulator) loader valve *(see #4 above)* must be set up as per manufacturer recommendations.
- The BPR bleed flow meter *(see #5 above)* must be adjusted as per manufacturer set up procedure.
- The pneumo flow meter *(see near #5 above)* must be adjusted as per manufacturer set up procedure.
- The tracking pneumo supply valve *(see near flow meters)* should be set up as per manufacturer recommendations.
- The tracking pneumo ¼ turn valves *(see near flow meters)* diver 1 & 2 must be closed.
- The BPR metering valve *(see #6 in the drawing on the previous page)* must be closed.
- The bell exhaust to reclaim system *(see #8 in the drawing)* must be open.
- The water trap must be in good condition *(See #9)*.
- The water trap isolation plunger should be pulled out.
- The water trap water purge must be open.
- Divers' exhaust must be closed *(see #2)*.
- The valve of reclaim to surface (bell to external water trap) must be opened *(see below the Back pressure regulator in the drawing)*.
- The hull valve of the reclaim to surface (bell to external water trap) must be opened (not visible)

- Hot water system:

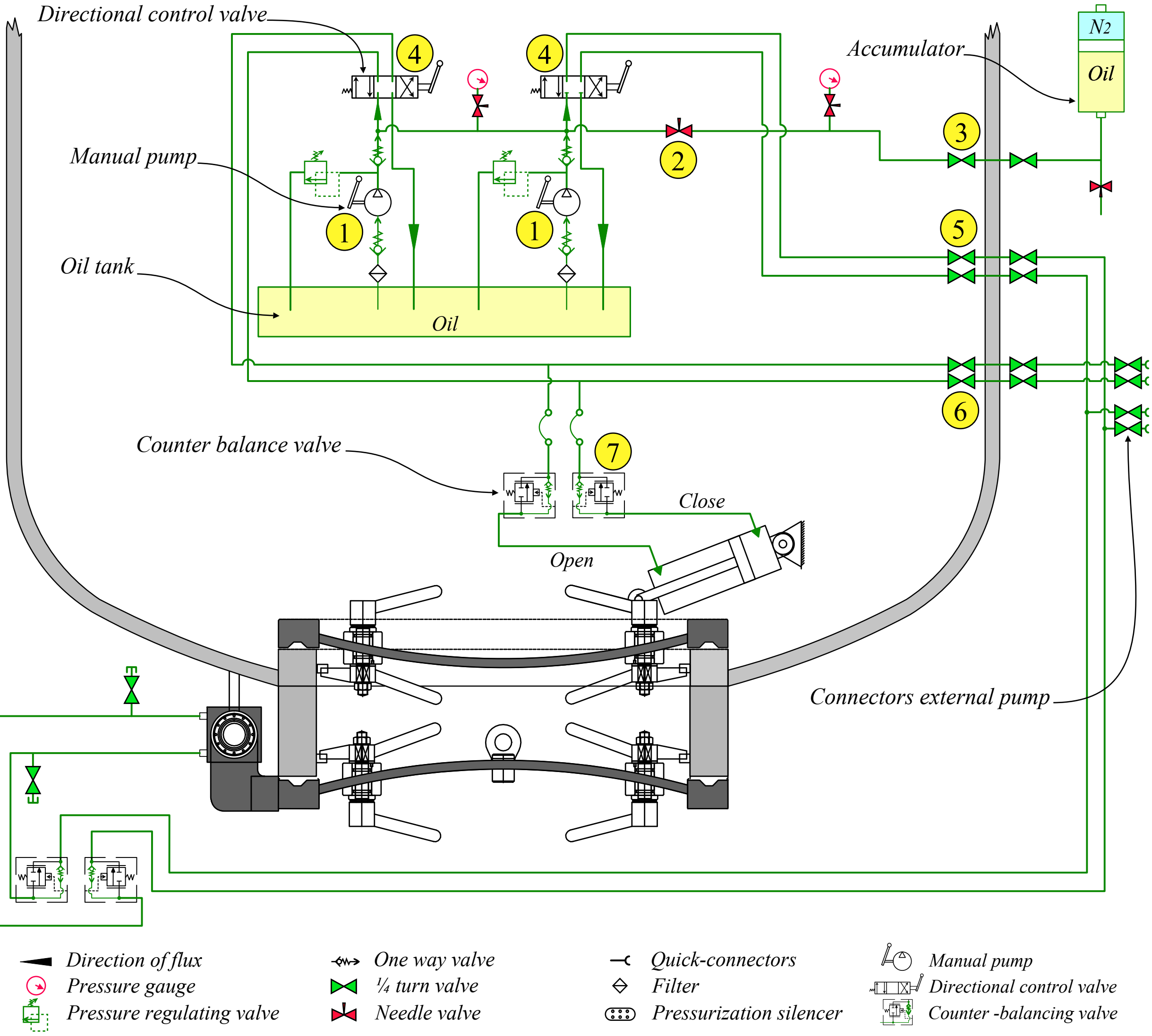
- The hot water inlet valve must be open *(see # 1 below)*.
- The emergency hot water supply is closed *(see #1 below)*.
- The hot water supply to manifold is open *(see #2 below)*.
- The inlets to scrubber #1 and scrubber #2 are open or closed as required *(see #3 below)*.
- The outlets from scrubber #1 and scrubber #2 are open or closed as required *(see #4 below)*.
- The manifold isolation valves to diver 1 and diver 2 are closed *(see #5 below)*.
- The manifold isolation and hull valves to diver 3 is closed *(see #6 below)*.
- The hull isolation valve to diver 3 is open *(see #6 #7 below)*.
- The manifold isolation and hull water dump valves are open *(see #8 & #9 below)*.



- Medical lock:
    - The equalization valve must be closed.
    - The door must be closed and secured
- The Hull valve of the analysis to dive control must be open *(see #6 in the drawing of the top of the bell).*
- The bilge drain and flood up hull valve must be closed *(see below).*
- The Spring loaded valve of the bilge drain is closed by the spring *(see below).*
- The flood-up valve must be closed *(see below).*



- Hydraulic system for the opening and closing of doors



- The manual hydraulic pumps are ready for use as required *(see #1 above).*
- The needle valve to/from the accumulator must be open *(see #2 above).*
- The hull valve to/from the accumulator must be open *(see #3 above).*
- The directional valves should be closed *(see #4 above).*
- The hull valves (inlet and outlet) to the external door are open *(see #5 above).*
- The hull valves (inlet and outlet) to/from the external pump are closed *(see #6 above).*

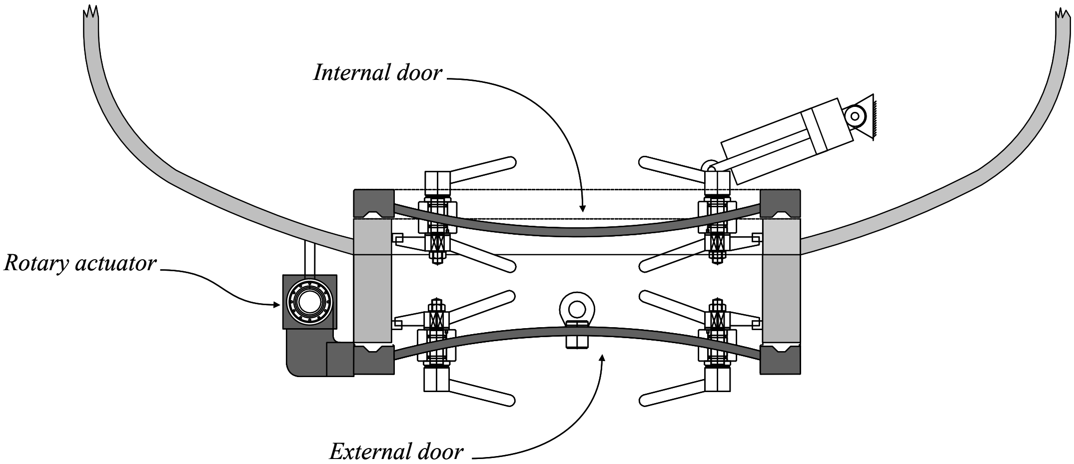
- Internal bottom door:
    - Outside of the door: Equalization valve 1 is closed and equalization valve 2 is open.
    - Inside of the door: Equalization valve 1 is open and equalization valve 2 is closed.

When the valves have been organized, the team must ensure that the elements that compose the internal equipment are present:
- The divers should wear hot water suits and harnesses when transferring to the bell. Also, they should have their hat liners, knives, scissors, and personal tools (adjustable spanner, pliers, etc.).
- If used, the buoyancy control devices must be checked prior to be installed on the bailouts.
- Divers' fins with spare straps and buckles must be in the bell. An additional pair of fins should be available.
- Working gloves should be provided. Burning gloves should be provided in case of such operations are planned.
- Weigh belts with adequate weights for the divers must be provided.
- Spare neck dams and hat-liners should be provided with two spare diving knives and an additional belt with spare weights.
- Emergency procedures, reclaim procedures, and the bell tapping code should be stored in the upper parts of the bell.
- Lung Power Scrubbers with in-date charges for at least 24 hours must be available (one per diver).
- Survival suits should be stored in the upper parts of the bell. There must be one unit per diver.
- The diver recovery hoist must be ready for deployment and in perfect condition.
- The diver medical kit that conforms to the guidance DMAC 15 must be in the bell.
- The Dragger Pump with in-date Tubes (for CO_2 and contaminated bell atmosphere) must be present.
- Two waterproof lights with spare batteries must be provided.
- One spare hat light, camera and pig-tail must be in place.
- One spare speaker and one spare microphone for the helmets must be provided.
- When open circuit bailouts are used, two spare first stage regulators and contents gauges must be provided.
- Spare "O"- rings for the bottom door, the medical lock and the bailouts must be provided with silicone grease.
- Spare batteries for the internal O2 analyser should be provided.
- Tape meters, paint sticks, light sticks, duct tape, electrical tape, a full set of tie-wraps (small, medium, large) should be provided.
- Disinfectant for the helmet and soap must be provided in the bell.
- Sufficient drinking water (150 ml/hour) and food must be in the bell.
- A set of spanners, pliers, and screwdrivers must be in the bell to allow performing small repairs.

Important note for testing helmets and masks:
To avoid the transmission of pathogens, the only person breathing in a helmet or a mask to test the regulator should be the diver diving with it. These tests should be performed before launching the bell.

1.2.6 - External bottom doors

Bells hatches are provided with two doors that are described in points 1.1.2.5 and 1.1.2.7: The internal door protects the divers from depression, so any accident that may arise from such a situation, and the external door protects the divers from overpressure if the bell is accidentally lowered below the planned level. As a result, the divers are secured at the storage depth during the deployment and the recovery of the bell. Of course, there is no protection against these potential accidents as soon as these doors are opened.
Having these two doors in place is required by most safety organizations and clients. As an example, in section 5 of IMCA D 024, it is written that "hatches should be capable of providing a pressure seal against both internal and external pressure".



External bottom doors are usually closed by hydraulic rotary actuators, and their closure is performed by acting on a manual pump described in point 1.1.2.7. However, the closure of this door is often slow. For this reason, it may happen that the dive team asks permission to remove it to gain time during the recovery of the bell and speed up the shift change. The opportunity of this operation must be discussed with the client representative as his company policy may prohibit such configuration. Also, the bottom door can be removed only when the divers work on the seabed, and so the planned storage depth of the bell is in its proximity. Thus, the team must be sure that the bell cannot be below a level close to its storage depth in case of an accidental descent. Some companies suggest ensuring that the potential flooding of the bell is limited to 15 - 20% of its volume.

1.2.7 - Maximum divers' umbilical length and selection of bailouts systems

Umbilicals are described in point 1.1.2 of this book.

Calculation of umbilical length when diving from a Dynamic Positioning vessel is explained in point 8.4.1 of Book #1 and not explained again in the text below.

Umbilical length calculation linked to bailout endurance is already explained in point 1.1.6.1 of this document.

1.2.7.1 - AODC 20 guidelines (IMCA D 022)

AODC 20 has been removed from IMCA publications and is kept in IMCA D 022. This guidance says:
A figure of 100 ft (30 m) has been established by custom and practice and has become the norm for North Sea operations. While this is a reasonably practical figure, it should not be construed that 25 m is always safe or that 35 m is unsafe as the selection of 30 m was entirely arbitrary, based on the average from a number of operations.
Factors which should be considered when deciding on the length of an umbilical are:

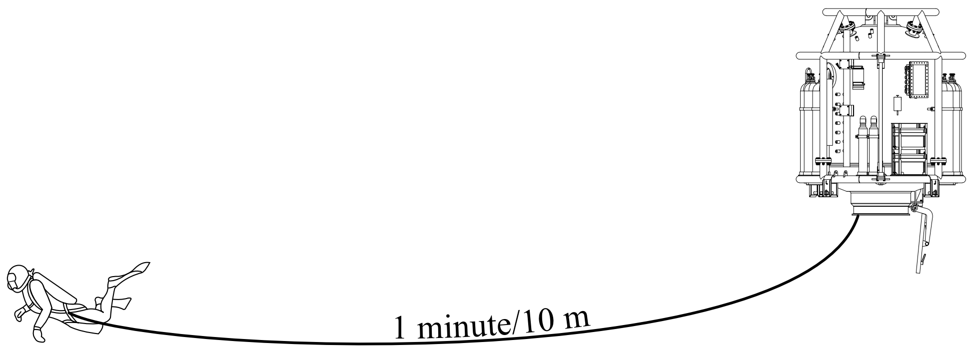
- The distance of the job from the proposed bell location.
- The duration of the divers bail out bottle at the depth. In the event of loss of gas supply, the diver must be able to return to the bell using his bail out bottle alone and this may dictate the distance he is away from the bell. The diameter of the bell manway must be considered when sizing the bail out bottle, as this will dictate the divers ease of entry into the bell.
- The size of the bell in relation to the storage of the diver's and bellman's umbilicals.
- The type of umbilical, its bulk and buoyancy. A long length of negatively buoyant umbilical will act to drag a diver down, while a bulky umbilical in current may have a similar effect.
- The condition of the worksite, including debris, rocks or other obstructions which could hinder the diver's return to the bell in an emergency.
- The unforeseen safety factor needed for particular situations such as DP incidents, loss of diver heating or trapped umbilicals.

Each operation should be considered on its merits and the length of diver's umbilical determined on the above and other factors relevant to the particular circumstances. In an emergency the bellman may need to pay out more umbilical than the pre-determined maximum length and for this purpose. "Spare" umbilical inside the bell, but lightly tied off to prevent routine use, is desirable.
In all operations the bellman's umbilical should be at least 2 metres longer than the divers'.

1.2.7.2 - Bailout

- IMCA says that every diver must carry a bailout bottle that contains enough gas that allows him to reach a place of safety if his main supply fails. For this reason, a calculation should be available showing that the capacity of the cylinder(s) at the depth of diving will allow breathing gas for 1 minute for every 10 metres of umbilical deployed from the diving bell. The calculation, which is based by IMCA on an emergency breathing rate of 40 litres (1.5 ft3) per minute, should be displayed in the dive control and consider the available pressure of the gas in the bailout bottle after deductions for depth and working pressure of the regulator.

- Divers consumption calculation:
  Gas consumption metric (Emergency) = Absolute pressure x litres/min in emergency
  Gas consumption Imperial (Emergency) = Absolute pressure x ft^3/min in emergency
- Free gas volume:
  Free gas volume = Floodable volume x pressure
- Available gas:
  1) Find the available pressure: Pressure bail out - pressure bottom - pressure regulator
  2) Find the available gas : Floodable volume x Available pressure
  3) Time available: Gas available / gas consumption = Time available



- Note that the emergency breathing rate of 40 litres (1.5 ft3) per minute given by IMCA to allow for the effects of cold shock and apprehension is insufficient and not based on scientific studies. For these reasons, other competent bodies recommend calculations with higher breathing rate values that should be applied in place of the IMCA 40 litres/minute. It is the case of the UK HSE document *"The provision of breathing gas to divers in emergencies"*, that is already taken as a reference in point 1.1.6.1 of this book, which says that these values should be between 50 to 75 litres per minute. Note that the NORSOK standard value of 62.5 litres minutes, which many companies commonly apply, is the medium value of those indicated above. In addition, helmet manufacturers such as Kirby Morgan and JFD provide tables indicating that the gas consumption values in an emergency can be higher than those indicated above. However, the breathing muscles are not designed to sustain such high respiratory rates for a long time.

- Also, note that other competent bodies propose methods of calculation and control that differ from the IMCA one and should be taken into account:
  - NORSOK standard U 100 limits the umbilical length to 45 m and says in point 7.8.3 that the bail-out system should provide the diver with gas for 10 min based on average consumption of 62,5 1/min surface.
  - NORMAM-15 limits the umbilical length to 33 metres and the bailout duration to at least 15 minutes during exceptional saturation.
- DMAC 04 says that the maximum PPO2 in a bail-out bottle should be 1.4 bar regardless of depth. The recommended limitation is more conservative than calculated limits based on the following Morrison and Reimers equation:
  T = 108 In 109 (pO 2 -[(DO2 + Di)/ DO2]0,21 [Y/2]3,33 - 122y1, which can be found in the document NORSOK U100, and where:
  T = maximal exposure time in minutes
  pO2= allowable partial pressure of 02 in kPa
  DO2 = partial density of 02 in gas mixture
  Di = partial density of inert gas in gas mixture
  Y= diver workload measured in oxygen-uptake (I/min STPD)

  It is good to indicate the oxygen percentage and the depth limits of the mix the bail-out is filled with on the calculation sheet and the cylinder. The LST in charge should confirm this percentage.
- As indicated in point 1.1.6.2 of this book, open circuit bailouts systems offer a limited operational range past a certain depth. As an example, a set 2 x 7 litres at 300 bar allows less than 6 minutes breathing time at 100 m, and a set 2 x 10 litres at 300 bar allows for 4 minutes at 200 m. For this reason, it is advisable to replace them with "Compact Bailout Rebreathing Apparatus," such as those proposed by JFD, which are described in point 1.1.6.3, which provide longer breathing times in addition to heating of the breathed gas. For example, such systems allow for 30 minutes of breathing at 100 m and 22 minutes at 200 metres.

1.2.8 - 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.

1.2.8.1 - Design requirements indicated in IMCA D 058

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

1.2.8.2 - Unsuitable options indicated by the guidance

- "Carabino" or "Carabineer" clips

- Cordage

- Cable ties (Ty wraps)

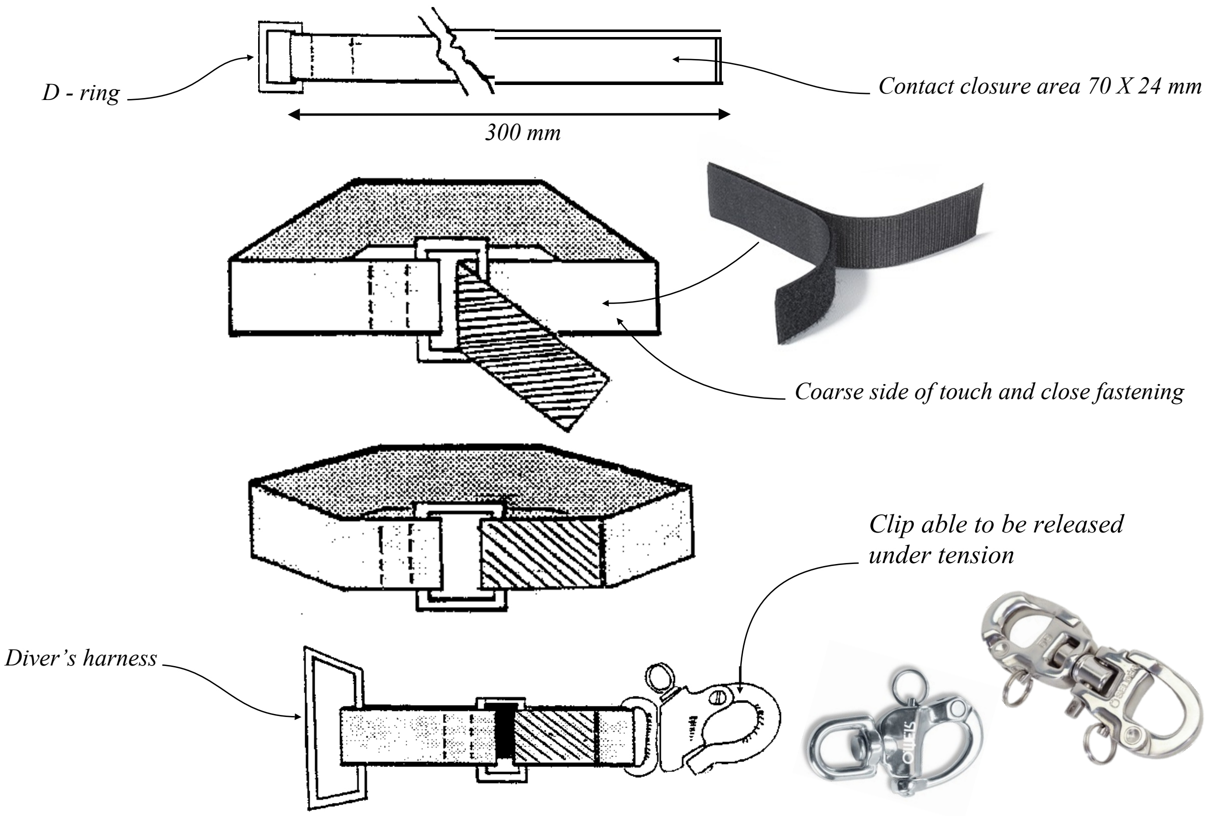
- Welding rods

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

- Safety hooks

1.2.8.3 - 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



1.2.8.4 - Rules to apply

It is not an obligation to fabricate exactly the system proposed by the guidance IMCA D 058 (previously AODC 058), but the four rules indicated in point 1.2.8.1 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 or be equipped with a system that conforms with the requirements indicated in point 1.2.8.1

1.3 - Check the working documents

1.3.1 - Task plan

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

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

The task plan is normally built in 7 parts :

1) - Presentation
2) - Description of the task
3) - Risk assessment
4) - Preparation of the task
5) - Dive plan
6) - Management of changes
7) - Post dive / next task

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

1) Presentation: The task plan is an official document where the following elements should be indicated:

- Name of the client.
- Names of the contractor and subcontractors (the team may operate as a subcontractor).
- Date of issue.
- Number of revision.
- 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 approved the task plan.
- The name and signature of the client representatives who have checked and agreed the task plan for the client.
- The date of approval of the task plan by the client.

2) Description of the task:

There must be a quick description of what to do, where to do it, and why. The team must have an idea of the project to which their task is linked. There must be:

- A description of the whole project (what to do?)
- The reason of the task inside the project (why?)
- A map of the oilfield indicating where the job is planned (where to do it?)
- A study of the weather conditions with prevailing winds, currents and the records of the tides
- A description of the job site with:
    - Precise drawings of the facility where the intervention is planned.
    - The potential hazards:
        - Pipe lines , risers (and what they carry).
        - Impressed current system, electrical.
        - Water intakes and discharge.
        - Scaffoldings
        - Every item which can trouble the access and the safety of the divers…
- The surface support selected and the reasons for this choice must be explained by documents such as:
    - A technical description of the surface support with precise drawings.
    - Studies of the positioning of the surface support on the job site.
    - Studies for the deployment of the divers and loads to transfer.
- Previous and simultaneous tasks: The task plan is part of an ensemble of works. For this reason, there must be a description of the previous tasks and the expected status of the job site after completion of these tasks, and a description of the simultaneous operations that may interfere with the planned operations.
- Step by step procedures: 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.
    - Important calculations for the divers such as pressure, apparent and real weight, etc.

- The simultaneous tasks linked to the task plan (for example, lifting…)
- The lifting plan if a crane has to be used.
- The step by step sequences of installation or inspection, using drawings and precise descriptions.
- Technical information about particular materials to be used.
- The technical references, client operating procedures, and international and local rules on which the sequences of installation and the safety procedures must be based.

3) Risk assessment:

- The process of a risk assessment is:
  - Identify the hazards.
  - Assess the risk .
  - Identify the suitable control measures.
  - Record the selected control measures.
  - Implement the control measures.
  - Ensure that the residual risks are as low as reasonably practical.

This document must be as compact as possible and focus only on 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, the risk assessment discussed with the divers and the supporting team during the toolbox talk can be under the format they are used to if that improves communication. The risk assessment must cover (but is not limited to) the following phases:

- The procedure to access to the diving station must indicate:
  - The dangerous areas.
  - The path to follow to safely reach the dive station and other working areas.
- Preparation of the task
  - Diving system function test.
  - Filling the bail outs and banks.
  - Preparation of the LARS and diving bells.
  - Preparation of the pieces to be sent to the bottom.
  - Procedures for working on deck.
  - Any additional task which may be necessary to prepare the dive.
- Launching the dives and divers' deployment
  - Transfer under pressure (divers).
  - Bell transfer.
  - Bell lowering and positioning on the job site.
  - Opening of the hatch and launching of the divers.
- Access to the job site
  - Distance of the bell from the job site.
  - Impact of underwater currents.
  - Impact of the underwater visibility.
  - Job site access.
  - Elements that may harm the divers to be under control, such as impressed current, electrical wires, pipes under pressure, pump intakes, etc.
  - Down line installation.
- Risks linked to diving
  - Technical break downs (regulators, helmet, gauges, hot water supply….).
  - Loss of communication.
  - Diving profiles during excursions.
  - Umbilical stuck or entangled.
  - Effects of misunderstanding.
  - Dangerous marine life.
  - Dynamic Positioning system alerts, failure of mooring, or risk of collision…
  - Fishing lines.
- Risk linked to the task
  - Simultaneous operation (lifting…).
  - Use of particular tools (Welding, burning, cutting, lever hoists ….).
  - Risks linked to several phases of the task (load transfers, use of lift bags..).
- Diver recovery
  - Umbilical recovery.

- Contingencies due to technical problems.
- Bell transfer to deck and clamping.
- Transfer under pressure.
- Post dive inspections.

- Leaving the dive station.
  - Description of how the shift change should be performed.
  - Safe transfer of deck personnel to the accommodation.

4) Preparation of the task:

- List of Tools needed. The tools are those identified in the “step by step procedure” such as, but not limited to:
  - Spanners, pliers, hammers, lump hammers , chisels…
  - Impact wrenches + sockets, tensioners, saw…
  - 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 some - it must strictly conform to the rigging and lifting plans
  - Wire slings (Certificate number indicated)
  - Soft sling (Certificate number indicated)
  - Shackles (ref number indicated)
  - Tirfors, chain blocks , lever hoist…
  - Lift bags (Certificate number indicated)
- Communications (Notice that these chains of communication will often change from one task to another)
  - Chain of communications with radio channels and/or interphone numbers.
  - Chain of communications in case of an emergency with radio 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 doing cold and hot work).
  - Dive permit: The form to be used (client or internal) must be specified.
- List of work site protection
  - Barriers, segregations …
  - Conflicting activities to be stopped during the dive.
  - Maritime signalization.
  - External boat management procedures.
- List Extra deck personnel (names and function)

5) Dive plan: It is built on the “step by step procedure”, but the steps must be detailed more precisely.

  - The depth indicated must be to those indicated in the description.
  - The range of the tides should be specified.
  - 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 “tic” when the action is completed.
  - Particular actions performed from the surface to support the diving activities must be indicated.
  - The hazards must be integrated in the dive plan and highlighted.
  - Ensure that the duration and depth planned conform to those possible from the storage depth.
  - Check the excursion profiles.

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. Generally it conforms to the following plan:
  - 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 dive: It must indicate the following:

- Situation on the job site at completion, and next task planned.
- Safety procedures for the divers.
    - Behaviour in chamber after the dive.
    - Minimum interval before the next dive.

1.3.2 - 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.

1.3.2.1 - 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.
- Revision number.
- If there were one or several previous revisions, what have been modified.
- The name of the issuer.
- The name and the signature of the company representatives who have approved the emergency response plan.
- The name and signature of the client representatives who have checked and approved 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 2 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.

1.3.2.2 - Check some elements of the document

- The diving medical specialists approved 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.
- In case a helicopter is to be used to evacuate a diver immediately following a decompression, the procedure must indicate that it must fly below 300 m and as low as possible.

1.3.3 - Check the permits to work and the isolation certificates

The purpose of this point is not to explain how to fill the permit to work, because each client has his permit to work system:

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

Normally the application of the permit is done by the representative of the company. It may be the diving supervisor or the diving superintendent. Most clients request the applicants to pass their module "permit to work" before being authorised to do so.
In most systems, the application of permit to work must be submitted at least 24 hrs before starting the project. The duration of validity are from a few hours to several weeks, depending of the client's systems.
When the permit to work returns to the dive station, it is signed by the authorizing authority (generally the Offshore Installation Manager or similar position) and the chain of command identified in the permit to work system (the area authority and the performing authority). Normally, the permit to work conforms with what is planned, but several experiences have shown that mistakes can happen. For this reason, the diving supervisor must check it in detail:

- At the 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 is corresponding to the permit to work selected.
  - The hazard identification is corresponding to what is indicated in the risk assessment.
  - The control measures are corresponding 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 chain of command identified in the client's work permit system, and the dates of validity are indicated in the dedicated slots.
- The isolation certification is part of the client's permit to work system. As for the main form, the diving supervisor/ superintendent must ensure that:
  - The supporting documents attached to the permit to work conform to what is indicated.
  - The isolation certificates are fully completed, signed, dated, and the duration of the isolation conforms to what is indicated in the permit to work.
  - The reference numbers of the supporting documents and isolation certificates also conform to those of the list indicated in the task plan.

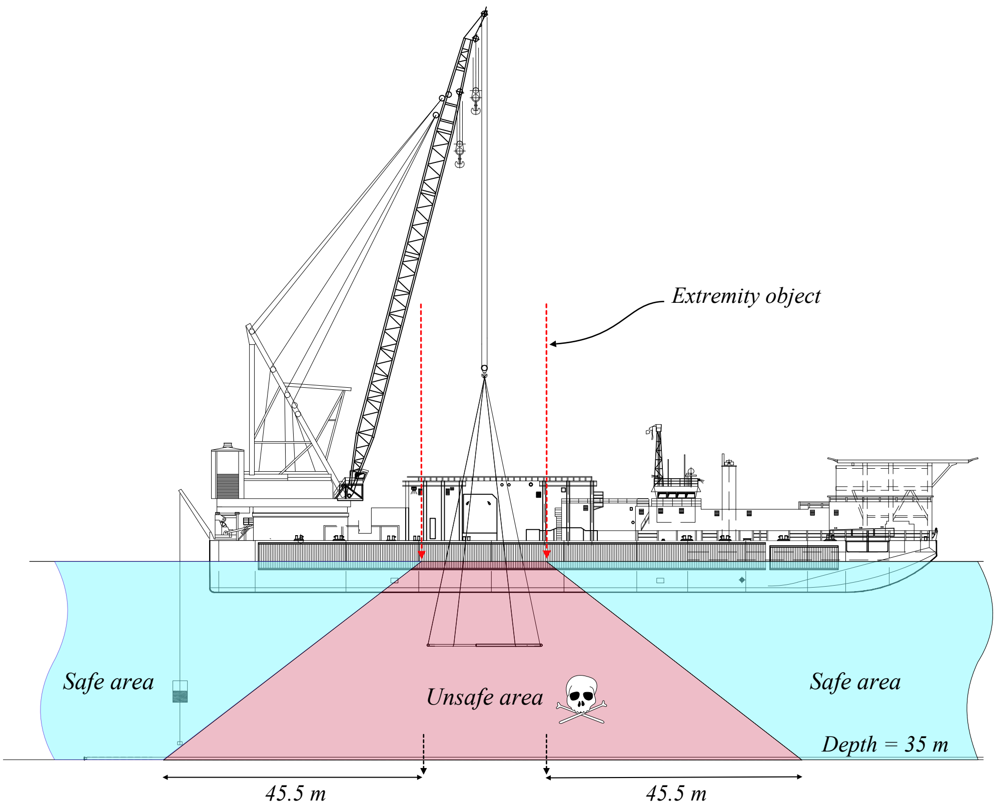
If something does not conform, the permit to work must not be signed, and the operation cannot start until the problem detected is resolved.

1.3.4 - Falling object prevention

Many teams and companies think that the bell is sufficiently robust to protect the divers from falling objects and that they are in a safe place if they are recalled under it, either on the clump weight or in the standoff frame, during load transfers. Opposite to this belief, a bell is extremely fragile, and a falling object may easily damage it and make the recovery of the divers impossible, if the diving system is provided with only one bell.

It must be remembered that the bell is equipped with numerous items that are essential for the divers' survival and are very vulnerable to shocks. They are protected from damage by the protection frame during the launching and the recovery of the bell. However, this protection system is not designed to protect the bell from weighty falling objects. For example, a pipeline section of which half its overall length was found vertically sunk in the mud during a seabed cleaning operation in Indonesia. If this object had hit a bell with this angle, this bell's integrity could have been seriously compromised.
For this reason, the bell and the divers should never be under a load and within an area where it may fall. Thus, the object to transfer should be lowered to the bottom before the bell, or the deployment area must be sufficiently far away, so the bell and the divers will not be affected in case the load is dropped.
Several calculation methods to keep the bell and the divers away from falling objects have been published, which some of them are based on probabilistic databases. Among these procedures, two guidelines are commonly used by teams to calculate safe distances: The IMCA guideline D 007 *"Overboard scaffolding operations and their effect on diving safety"*, and the recommended practice DNV-GL-RP-F107 *"Risk assessment of pipeline protection"*.

IMCA D 007 says that diving operations must not be conducted directly underneath activities such as scaffolding or overboard movement of tubes or any other construction work. This guideline also says that between scaffolding activities and diving operations, a minimum horizontal distance should be applied of 1.3 times the depth at which the diver is working. Note that this calculation is based on an approximate evaluation resulting from working experiences instead of specific calculations. However, this procedure has proved its efficiency since 1996, and IMCA still recommends it. Note that it has often been used to calculate distances from voluminous objects than in the absence of other evaluation means.

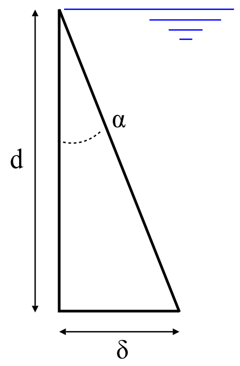


DNV-GL-RP-F107 is a document based on scientific studies regarding sinking objects' trajectories that provides a methodology for assessing the risks and required protection from dropped crane loads and ship impact to risers and pipeline systems within the safety zone of installations.
This guideline, which says that an object excursion in water is extremely dependent on its shape and weight and that the fall pattern of a pipe is dependent on the entry angle into the sea, concludes that an object falling area can be calculated using the following equation:

$$p(x) = \frac{1}{\sqrt{2\pi}\delta} e^{-\frac{1}{2}\left(\frac{x}{\delta}\right)^2}$$

where:

- P(x) = probability of a sinking object hitting the sea bottom at a distance x from the vertical line the drop point.
- x = horizontal distance at the sea bottom (in metres)
- δ = lateral deviation (in metres). Note that " δ " means "delta" in the Greek alphabet.



d = Depth

δ (delta) = Distance of deviation, which is the tangent of the angle

α (alpha) = Angle in degrees

DNV-GL provides seven categories of angular deviations based on the weight and the shape of the objects commonly transferred, and are indicated in the table below, which can be used to predict an object's falling area.

Cat.	*Description*	*Weight in air (tonnes)*	*Angular deviation (Degrees)*	*Typical objects*
1	Flat/long shaped	< 2	15	Drill collar/casing, scaffolding
2		2 - 8	9	Drill collar/casing
3		> 8	5	Drill riser, crane boom
4	Box/round shaped	< 2	10	Container (food, spare parts) , basket, crane block
5		2 - 8	5	Container (spare parts , basket), crane test block
6		> 8	3	Container (equipment) , basket
7	Box/round shaped	> > 8	2	Massive objects as BOP, pipe reel, etc.

The object's falling area can be calculated through a specific software based on the formula provided on the previous page or by calculating the tangents of the angular deviations indicated above that are displayed in the table below. Thus, the δ (delta) of the angular deviations DNV-GL can be found by multiplying the relevant tangent value by the depth.

Angle (Degrees)	*Tangent (Deviation for 1 m depth)*		*Angle (Degrees)*	*Tangent (Deviation for 1 m depth)*		*Angle (Degrees)*	*Tangent (Deviation for 1 m depth)*		*Angle (Degrees)*	*Tangent (Deviation for 1 m depth)*
1º	0.0174		5º	0.0875		9º	0.1584		13º	0.2309
2º	0.0349		6º	0.1051		10º	0.1763		14º	0.2493
3º	0.0524		7º	0.1228		11º	0.1944		15º	0.2679
4º	0.0699		8º	0.1405		12º	0.2125		16º	0.2867

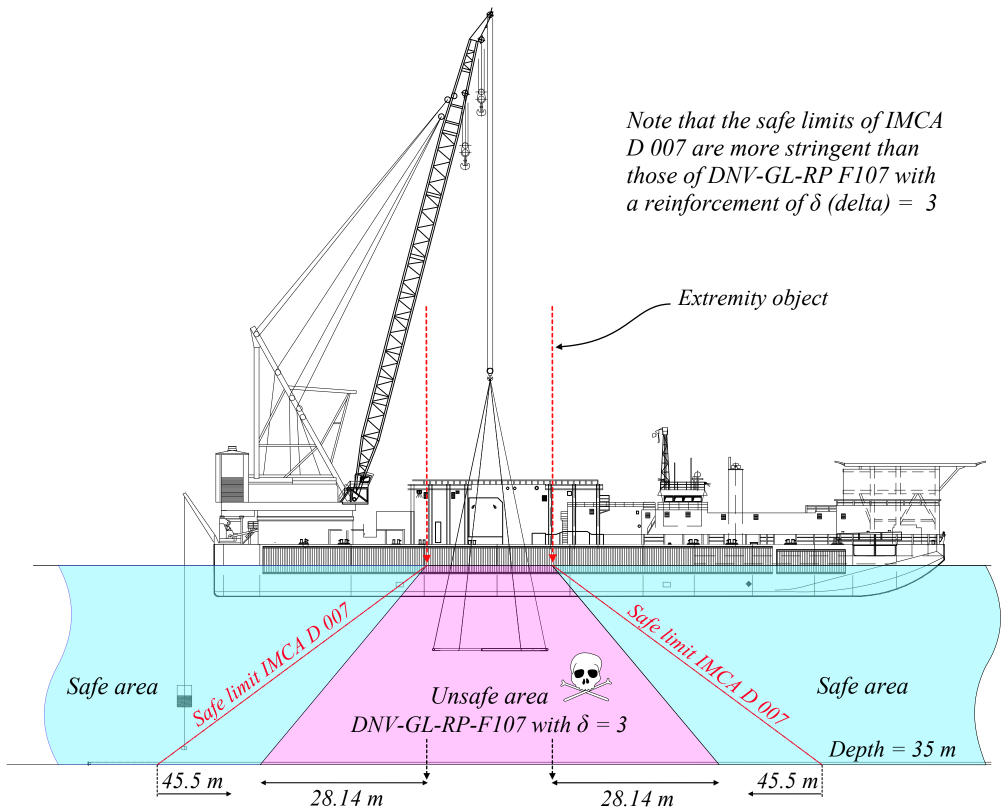
Note that IMCA D 060 “Guidelines for lifting operations”, says that these angular deviations are based on a standard deviation of 1, which gives 68% impact probability, and that an accepted practice is to apply 3 standard deviations to ensure that 99.7% of objects fall within the drop cone diameter to obtain a conservative approach.
This procedure consists of multiplying the δ (delta) of the angular deviations DNV-GL (standard deviation of 1) by 1.96 or 2.58 to obtain 95% and 99% probabilities of impact.
IMCA D 060 provides an example of such a reinforcement for a depth of 90 m, which gives the following results:

Cat.	*Description*	*Weight in air (tonnes)*	*Angular deviation*	*Distance δ = 1 (68% probabilities)*	*Distance δ = 1.96 (95% probabilities)*	*Distance δ = 2.58 (99% probabilities)*
1	Flat/long shaped	< 2	15	24	47	62.2
2		2 - 8	9	14	28	36.7
3		> 8	5	8	15	20.2
4	Box/round shaped	< 2	10	16	31	40.9
5		2 - 8	5	8	15	20.2
6		> 8	3	5	9	12.1
7	Box/round shaped	> > 8	2	3	6	8.1

As already said, the safe distances δ (delta) = 1 can be obtained by multiplying the relevant tangent by the depth; for example, an angular deviation of 15 degrees = 0.2679 x 90 m = 24.11 m, and an angular deviation of 9 degrees = 0.1584 x 90 m = 14.26 m, etc.

Because the purpose of the calculation is protecting divers, it can be considered suitable to calculate a probability of impact using the less favourable angular deviation category, so category #1 of the DNV-GL classification, and to take into account the recommendations from IMCA D 060, to reinforce the deviations provided by the original δ (delta) by multiplying it by 3 to obtain a conservative calculation that can be used in many situations. The reason for using a δ (delta) reinforcement that is more stringent than the 2.58 recommended in IMCA D 060 is that IMCA says that a δ (delta) reinforcement of 2.58 provides a 99% probability that the load falls within the predicted falling area. Thus, a δ (delta) of 2.58 does not guarantee at 100% that a falling load will be within the safety limit required for divers.
Note that most safety organizations say that the safe distance should be calculated considering the maximum possible dispersion angle for each type of object that may fall through the water. For this reason, it not ridiculous and safer to apply a safety factor of 3 instead of 2.58 to ensure that no falling object hits the divers and the bell. The table below is an example of such calculations.

Depth	***Deviation δ = 1***	***Deviation δ = 3***	***Depth***	***Deviation δ = 1***	***Deviation δ = 3***	***Depth***	***Deviation δ = 1***	***Deviation δ = 3***
10	2.68	8.04	130	34.83	104.49	250	66.99	200.97
20	5.36	16.08	140	37.51	112.53	260	69.67	209.01
30	8.04	24.12	150	40.19	120.57	270	72.35	217.05
40	10.72	32.16	160	42.87	128.61	280	75.03	225.09
50	13.4	40.20	170	45.55	136.65	290	77.71	233.13
60	16.08	48.24	180	48.23	144.69	300	80.38	241.14
70	18.76	56.28	190	50.91	152.73	310	83.06	249.18
80	21.44	64.32	200	53.59	160.77	320	85.74	257.22
90	24.12	72.36	210	56.27	168.81	330	88.42	265.26
100	26.79	80.37	220	58.95	176.85	340	91.1	273.30
110	29.47	88.41	230	61.63	184.89	350	93.78	281.34
120	32.15	96.45	240	64.31	192.93	360	96.46	289.38



Regarding the application of the model in deep waters, DNV-GL says the spreading of long/flat objects will increase down to approximately 180 metres depth, and does not significantly increase further down.
Note also that in deep waters, the spreading of objects on the seabed does not necessarily follow the normal distribution (Katteiand and Oygarden, 1995).

DNV-GL-RP-F107 also says the following regarding currents:
The effect of currents becomes more pronounced in deep water. The time for an object to reach the seabed will increase as the depth increases. This means that any current can increase the excursion. At 1000 metres depth, the excursion has been found to increase 10-25 metres for an average

current velocity of 0.25 m/s and up to 200 metres for a current of 1.0 m/s (Katteiand and Oygarden, 1995).
The effect of currents may be included if one dominant current direction can be identified. This can be applicable for rig operations over shorter periods, such as during drilling, completion and intervention on subsea wells. However, for a dropped object assessment on a fixed platform, seasonal changes in current directions can be difficult to incorporate. Note also that the current may change direction through the column for large water depths. If applicable, this should be accounted for.
The effects of current should be considered when establishing a "safe distance" away from lifting activities.

The table below compares values of DNV-GL-RP-F107 with safe distances δ (delta) x 3 with those of IMCA D 007.

Depth	***DNV-GL $\delta = 3$***	***IMCA D 007***	***Depth***	***DNV-GL $\delta = 3$***	***IMCA D 007***	***Depth***	***DNV-GL $\delta = 3$***	***IMCA D 007***
10	8.04	13.0	130	104.49	169.0	250	200.97	325.0
20	16.08	26.0	140	112.53	182.0	260	209.01	338.0
30	24.12	39.0	150	120.57	195.0	270	217.05	351.0
40	32.16	52.0	160	128.61	208.0	280	225.09	364.0
50	40.2	65.0	170	136.65	221.0	290	233.13	377.0
60	48.24	78.0	180	144.69	234.0	300	241.14	390.0
70	56.28	91.0	190	152.73	247.0	310	249.18	403.0
80	64.32	104.0	200	160.77	260.0	320	257.22	416.0
90	72.36	117.0	210	168.81	273.0	330	265.26	429.0
100	80.37	130.0	220	176.85	286.0	340	273.3	442.0
110	88.41	143.0	230	184.89	299.0	350	281.34	455.0
120	96.45	156.0	240	192.93	312.0	360	289.38	468.0

Important notes:
In case several load transfers have to be performed that cannot be at a distance that is guaranteed 100% safe for the divers, the bell (and the clump weigh) must be recovered to a safe depth and then lowered again to the worksite when the load is close to the bottom. Such procedure obliges several deployments and recoveries of the divers and the bell. However, it guarantees that the divers are always safe. Also, note that today's technology allows not exposing the divers, as ROVs can be used to monitor the descent of the load and pre-position it near the final installation place. Thus, a relevant organization of the operations can avoid unnecessarily exposing divers to potential dangers.
Another important point is to ensure that no unplanned operation will be carried on during the dives. That is usually prevented by implementing a permit to work system and announcements when launching the dive.

1.3.5 - Ensure the dive system checks and of suitable weather conditions

The method to establish reliable check lists is indicated in point 1.3.

Check lists include the housekeeping and the organisation of the dive station. Some parts of the system, such as the living chambers, the machinery, or gas storage are performed by the technicians who are in charge.
The diving supervisor is responsible for the checklists under his responsibility. For this reason, he must ensure that:

- The people who are performing checklists are competent and understand how important it is to do it properly. Note IMCA D 022 chapter 12/ point 3,5 indicates: "*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*".
- All parts of the diving system should have been properly checked.
- Each checklist is signed with the date and time indicated.
- Corrective action to close-up the defects which could have been reported should have been successfully implemented.
- Any defect indicated in the checklist should be reported to the management of the company with the corrective actions implemented to solve them. Note that the dive may be delayed or aborted if the defects seen could not be quickly solved.
- The Offshore Construction Manager (OCM) and the client representative are informed of every defect, which could delay the operation or abort it.
- Updated weather forecasts must be available in the dive control and suitable for diving.
- Sky observation conforms to what is indicated in the weather forecast, and that no sign of imminent degradation is visible.
- The underwater current is to be checked as far as possible. It should conform to the previsions and be acceptable for diving.
- The diving operations can be started only if the diving system and the weather conditions allow it to be done safely.

1.3.6 - Toolbox talk

For obvious operational reasons, when the divers have been transferred in the chambers, there should be separate toolbox talks for the personnel on deck and the divers in the saturation complex.
It has been proved that the toolbox talk is a convenient and effective method of communicating for reinforcing the safety message throughout the workforce that significantly enhances the development of a safe working culture.
The toolbox talk is a means of discussion between the supervisor and the diving team that allows monitoring the health and the mood of the diving team. Several topics and not only the task to perform during the shift must be discussed during this meeting.

1.3.6.1 - 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 not only for the diver himself but also the other divers. Diseases and injuries can become very critical during saturation. That is why the divers must indicate any problem or stress they are suffering to the diving supervisor. On his side, the diving supervisor must implement all the necessary precautions to ensure that the divers are in a condition to be in saturation and dive safely.

- Any disease, ear infection or inability to equilibrate the ears must be indicated to the diving medical specialist.
- Any medical treatment must be agreed by the diving medical specialist before committing the diver in saturation.
- 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 diving doctor. Support and recovery to surface may have to be implemented.
- Note that the symptoms of diseases linked to diving are listed and explained in the document “Diving accident”.
- Particular problems may be posed by personnel under alcohol or drugs. Note that the document CCO Ltd *“Implement a drug and alcohol abuse policy”* , that is available free of charge, provides guidelines based on scientific facts to ensure that such a problem never happens on the worksite.

1.3.6.2 - Task & dive plan

To have an efficient and positive discussion, the written task plan should be transmitted to the divers at least 1 day before the toolbox talks to understand what is planned and prepare their questions and suggestions. 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 team must review the risk assessment, and additional precautions can be implemented: This is the last step of the risk assessment. Because the divers will be exposed to the identified risks and are responsible for their safety, 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.

1.3.6.3 - 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.

1.3.6.4 - Safety and onboard life

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

- The safety observation cards emitted by the team members and the onboard personnel are discussed with the measures to be in place to follow up each case.
- 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.

1.4 - Last pre-dive checks

The permit to dive is an official document indicating that the dive can be performed safely.
When the client does not have a permit to dive system in place, the document to issue should be the form of the diving company.
Before signing this document, the diving supervisor must ensure that all precautions for safe operations are in place.

1.4.1 - Work site inspection and element to install

1.4.1.1 - Above the surface

In most permit to work systems, the area authority must ensure that the work-site conforms to the safety requirement before signing the permit to work. However, when the diving supervisor has access to the facility where conflicting activities are performed, it advisable to control by himself that the things are secured as requested. Normally, this inspection has to be performed with the client representative.

1.4.1.2 - Underwater

An inspection should be undertaken immediately on arrival on the job site.
Prior to sending the inspection dive, the possible falling objects above the job site should be removed or secured, and conflicting activities must be stopped. Then, the ROV (or air divers for the shallow parts) should be sent to carry out a full visual inspection of the work site.
The diving supervisor should be present during the survey. He has the authority to require the ROV pilot to prolong investigations he may judge necessary. As a result of this inspection, the diving procedures may have to be organized in another manner.
A precise task plan is to be established, indicating where the ROV starts, the areas and elements to check, and where the inspection finishes. The travelling of the machine is to be organized, so the risk of catching the umbilical is minimized, and to allow the people involved to easily follow the operation.
Obstructions, debris, gas bubbles, and other dangers which may harm the divers should be recorded precisely. Then corrective actions should be implemented to ensure that the hazards recorded will be under control:

- The position of the bell should be modified in case of obstructions
- If pipe lines, risers, or manifolds, not recorded previously are found, they should be identified and depressurized according to the guide lines given in IMCA D 06 and IMCA D 044
- If electrical systems are found and not previously indicated, they should be identified and secured according to IMCA D 044 & D 045.

1.4.1.3 - Pieces to install

The pieces to install must be checked by the dive team and the field engineer in charge.

- The specifications of the piece must be those indicated in the dive plan.
- The tools and spares planned for the installation must be present and secured.
- The rigging must conform to what is indicated in the dive plan, and the certification of the slings must be up to date.

1.4.2 - Communications to deck and to clients

Note that communications to the bridge and boats, and the Dynamic Positioning alarm systems have normally been tested during the check list of the dive control.

1.4.2.1 - Communications to surface team

- Communication with the supervisor in charge of the rescue team.
- Communications (direct line) to the person in charge of the launching and recovery of the bell must be checked.
- Communication (direct line) with the person in charge of the opening /closing of the clamp must be checked
- Communications to the diving technician must be checked.
- Communications to the dive station (2 way loudspeaker and headsets) must be tested.
- Audio and video communications with the chamber control room must be checked.
- If the supervisor has no direct vision of the dive station, the video installed must be working.

1.4.2.2 - Communications to the client representatives

- The radios should be tested.
- The phone to the client's office must also be tested.

1.4.2.3 - Communications with ROV

- The main communications (hands free) with the ROV pilot are checked.
- The backup communications with the ROV are checked.
- The main ROV screen is displayed in the dive control and active.
- The screen indicating the map of the worksite and the position of the ROV and the divers should have been tested during the dive control checklist. It should be active.

1.4.2.4 - Dive planned with crane operations

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

1.4.2.5 - Dive planned with specific machines *(for example, grouting…)*

- The communications to the operators must be tested.

1.4.3 - Surface support and rescue boat pre-dive checks

The vessel check list is the responsibility of the master and must be done prior to starting the dive.

1.4.3.1 - Anchored vessels

- The vessel must be moored as explained in the chapter *"Diving from anchored vessels"* in Book #1
- The mooring must be checked, particularly in 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 must 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 the lights Red -White-Red must be in place and visible.
- The surrounding vessels must be warned to keep outside the 500 m perimeter around the job site.
- The weather forecast is confirmed suitable for diving by the master.
- Main and backup communications have been tested
- The Offshore Installation Manager 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 turns on 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).

1.4.3.2 - Dynamic positioning vessels

- The vessel must be as explained in the chapter *"Diving from DP vessels"* in Book #1. Before moving on location and starting the "location set up check list" the DP pre-dive check list must have been completed.
- The drift test (if requested) must have been completed and conforms 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 audio alarms must have been tested (at the end of the test, the lights are kept on, 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. Remember:
    - Three references should be online 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 the lights Red -White -Red must be in place and visible.

- The surrounding vessels must be warned to keep outside the 500 m perimeter of 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 turns on 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 verbally informs the diving supervisor that the dive can start. The document from the bridge is sent to the supervisor at this time.

1.4.3.3 - Static surface supports (facilities)

The precautions must be as indicated in Book #1 of this manual.

- The signalization of the diving work is in place:
    - By day: 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 perimeter around the job site.
- The weather forecast is confirmed suitable for diving by the facility control.
- 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 the facility that the diving operation is going to start has been performed.
- The supervisor turns on 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).

1.4.3.4 - Rescue boat pre-dive checks

IOGP 411, Diving recommended practices, appendix 8 requires a "towing/reception vessel to support hyperbaric evacuation".

This vessel must be contacted at regular intervals during the day and the night. It is also a good practice to inform it when the bell is launched and recovered. This contact should be performed by the bridge, but the diving supervisor / superintendent should ensure that the contact with this boat is established.

1.4.4 - Bell pre-launch checks

1.4.4.1 - Check the clamp and check the trunk for leaks

Before allowing the divers to transfer from the transfer lock to the bell, the clamp should be visually inspected by a competent person and the trunk should be checked for leaks. (This should be part of the check list)

1.4.4.2 - Check the tenders

Before opening the guards and deploying the bell, the diving supervisor must ensure that the people working near the edge of the boat or the moon pool have a safety harness secured to dedicated rings and an adequate work vest to avoid potential falls and drowning.

1.4.4.3 - Ensure that the checks of the rescue team have been completed

The check list of the diving system and of the stand by diver at the surface should have been performed. These checks must be recorded: IMCA D 022 point 3.9 / 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"*

1.4.4.4 - Ensure that the divers know what they have to do and how the work site is organised

Some time may have elapsed between the time the bell is going to be launched and the tool box talk. The work site may have been changed, and the diver(s) may have forgotten some important elements. Before transferring the divers to the bell, it is important to ensure that the diver(s) know(s):

- Where the work site is (depth, level if on a jacket…).
- How to reach the work site.
- What are the potential dangers to avoid, such as: water intakes, electrical systems, pipe lines, risers… and where these dangers are situated.
- If working from a Dynamic Positioning vessel and using taut wire, where the taut wire is deployed.
- Where the down line is installed (There may be several down lines…), and if used the surface reference tugger.
- Where the tools are (Basket tool or dedicated places).
- What has been done on the bottom.
- What will be their task.
- What are the difficulties they may have to face, and what are the risks and the precautions to implement.

1.4.4.5 - Ensure that all personnel are ready

The transfer under pressure of the divers and the launching of the bell are critical phases requiring organization and discipline.
Before starting the transfer under pressure, the supervisor should make sure that the team is ready. Normally, it is done with the communication checks, nevertheless, it happens that some team members are busy with other tasks during these checks and are not at their assigned position for the launching/recovering of the bell.

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2) Diving operations

2.1 - Summary of the compression procedures to the 1st storage depth discussed in Book #2

Steps	Elements to consider	Values or procedure	Explanations
Pressurization to 1st storage depth	***PP O_2***	*0.4 to 0.57 bar (400 to 570 mbar)* *570 mbar is acceptable only at the arrival at the storage level*	*Book #2/point 3.2: "Pressurisation to the 1st storage depth and elements to control during the saturation"*
	PP CO_2	< 0.005 ATA (< 5 mb)	
	Establish 1st partial Press oxygen	*The procedure consists of establishing an initial seal, then pressurize the chamber to 10 m (33 ft), and stop the descent at this depth for a minimum of 20 minutes. During this time, checks must be performed.* *Two options can be used to pressurise the system:* *1 - A single gas to storage depth sometimes called an "ideal gas".* *2 - A rich mix to an initial depth then a lean mix (also called "poor mix") to storage.* *The divers should be on BIBS at least during the first 10 metres.*	
	Compression rates	***- Depth range: 0 to 100 m*** *- Maximum compression speed: 1 metre / minute* *- Stabilization stops:* • *Two hours at 100 m or proportional time to the depth between the surface and 100 m, calculated by the expression: Stabilization time (min) = 2 x 60 x depth (m)/100*	
		- Depth range: 101 to 180 m *- Maximum compression speed: 1 metre / minute* *- Stabilization stops:* • *1st stabilization stop for 2 hours at 100 m* • *2nd stabilization stop at the arrival at depth, calculated by the expression: Stabilization time (min) = 2 x 60 x (depth - 100)/100*	
		- Depth range: 181 to 240 m *- Maximum compression speed:* • *Surface to 100 m: 2 minutes/msw (0.5 msw/minute)* • *From 100 to 200 m: 4 minutes/msw (0.25 msw/minute)* • *From 200 to 240 m: 6 minutes/msw (0.166 msw/minute)* *- Stabilization stops:* • *1st stabilization stop for 2 hours at 100 msw* • *2nd stabilization for two hours at 200 msw* • *3rd stabilization of at least 6 hours at the saturation depth*	
		- Depth range: 241 to 300 m *- Maximum compression speed:* • *Surface to 100 m: 2 minutes/msw (0.5 msw/minute)* • *From 100 to 200 m: 4 minutes/msw (0.25 msw/minute)* • *From 200 to 300 m: 6 minutes/msw (0.166 msw/minute)* *- Stabilization stops:* • *1st stabilization stop for 2 hours at 100 msw* • *2nd stabilization for two hours at 200 msw* • *3rd stabilization of least 12 hours at the saturation depth*	
		- Depth range: 301 to 350 m *- Maximum compression speed:* • *Surface to 100 m: 2 minutes/msw (0.5 msw/minute)* • *From 100 to 200 m: 4 minutes/msw (0.25 msw/minute)* • *From 200 to 300 m: 6 minutes/msw (0.166 msw/minute)* • *From 300 to 350 m: 8 minutes/metre (0.125 msw/minute)* *- Stabilization stops:* • *1st stabilization stop for 2 hours at 100 msw* • *2nd stabilization stop for 2 hours at 200 msw* • *3rd stabilization stop for 2 hours at 300 msw* • *4th stabilization stop of least 12 hours at the saturation depth*	
Aborted pressurization procedure	***Depth + bottom time***	*- Calculate the He partial pressure and the bottom time and apply a corresponding bounce heliox table if available (Comex MT92 closed bell recommended).* *- If no bounce table is available, perform normal saturation decompression.*	*Book #2 / 3.2.2.5 "Aborting the pressurization"*

Steps	Elements to consider	Values or procedure	Explanations
Initial storage depth after stabilization	***PPO_2***	*0.38 to 0.45 bar (380 to 450 mb)* *Divers can be at 800 mb during excursions*	*Book #2 / point 3.4.2 "Stabilization periods before excursions"*
	PP CO_2	*< 0.005 ATA (< 5 mb)*	
	Downward & upward excursions at arrival.	*Prior to undertaking excursions, the pre-dive stabilization periods must be completed.* *After this initial stabilization period, upward and downward excursions are possible regardless of the depth in which the saturation is.*	

2.2 - Launch the ROV

Diving with Remotely Operated Vehicles (ROV) is discussed in point 10 of Book #1. During diving operations, they are commonly used for:

- Acoustic transponder installation.
- As-found and as-built surveys.
- Bell descent monitoring and checks when arrived on the bottom.
- Divers observation.

Acoustic transponder installation must be performed in sufficient time in advance to ensure the correct calibration of the system that must be stabilized before performing the final checklists.

As found survey should have been performed before preparing the checklists as indicated in point 1.5.1.2 in chapter "Last pre dive checks".

The ROV should be sent first to be ready to inspect the bell at its arrival at depth. It is today a common ROV task that should be organized according to the standard procedures indicated in point 10.5.3.3 of Book #1.

When the inspection of the bell is completed, the ROV is usually used to give a panoramic view of the worksite, which provides the supervisor a better appreciation of the situation of the divers if the visibility underwater permits it. The ROV can also be employed to visualize some elements that are far from the divers or some critical parts of a system the divers are working on. The precautions indicated in point 10.5.3.4 "Divers observation" of Book #1 must be implemented.

2.3 - Transfer the divers under pressure and locking off the bell

The divers will have to transfer into or from the bell during the project. This phase is one of the most critical as an error could have fatal consequences (see “Byford Dolphin” accident in Book #4). For this reason, the transfer under pressure (TUP) requires precautions, organization, and discipline.
Transfers under pressure in the saturation complex and from the Life Support Supervisor's point of view are explained in point 3.3 of Book #2.

- Before transferring, the diving supervisor checks the atmosphere in the bell and ensures it is breathable. He makes sure the bell is at the storage depth.
- The Diving supervisor and LSS/LST ensures there are no leaks and it is safe for the bellman to enter the trunk.
- As already indicated in Book #2, the bellman transfers into the transfer lock (TL) and closes the chamber doors behind him.
  Note #1: In this example, the Bellman enters the Transfer Lock (TL) first; nevertheless, it is considered acceptable that the other team member(s) enter the TL simultaneously. This is depending on the decisions of the diving supervisor and the LSS. One rule to always remember is that transfer doors should be closed at all times.
- The LSS/LST tells the bellman that it is clear to open the internal TL door to the bell trunk.
- The bellman enters the bell (alone), close the internal door and checks that the scrubber is running.
- Meanwhile, the other divers check their personal gear, get dressed, and stand by in the chamber in case any equipment, tools, drawings etc., have to be sent in. (*Refer to “Note #1” regarding this point)*
- At completion of the bell check, the diving supervisor tells the LSS/LST he is ready for the divers to come into the bell.
- The divers enters the TL on direction from LSS/LST with their equipment and close the doors behind them.
  (Note that the divers may be already in the TL as indicated in note #1)
- The divers notify the LSS/LST that the doors are closed and they are opening the door to the bell trunk.
- The LSS/LST then notify the diving supervisor that the divers are ready to open the door of the trunk and come through to the bell.
- On the diving supervisor’s "go ahead", the LSS/LST sends the diver(s) into the bell. The isolation door of the trunk is closed when the last diver enters into the bell.
- The last diver, into the bell, ensures the internal bell door's equalization valves are closed and then closes the door.
- The bellman reports to the dive supervisor that they are ready to seal the trunk.
- The diving supervisor contacts the dive control and tells the LSS/LST that he is ready to take a seal on the bell trunk.
- On confirmation from the LSS/LST that it is "good to go," he vents off the trunk 1 to 3 m.
  Note #2: The divers in the bell push on the door for a good seal. The LSS/LST might require the assistance of a diver to seal the trunk door in the TL. Note that with some systems, the trunk is controlled by the LSS/LST.
- Upon confirmation from the bellman and the LSS/LST that they have got a seal and it is holding, the diving supervisor tells the LSS/LST that he will vent the trunk to surface.
- When the diving supervisor gets confirmation from the clamp operator and the LSS/LST that the trunk is at "0 by gauge" and the interlock is disengaged, he tells the clamp operator to open the clamp.
  Note #3: Because this phase is very critical to the divers safety, the clamp operator wears a headset to be in direct communication with the diving supervisor all the time.
  Note #4: Lesson learnt from the “Byford Dolphin” accident in 1983 (see report in book #4 “Diving accidents” / “Decompression accident”): It is of outmost importance that there is communication silence and no talking going on except for the orders and confirmations needed during the transfer phase.
- The clamp operator must "never" operate the clamp unless:
  - He receives a clear order from the diving supervisor (the order must be confirmed).
  - The gauge on the trunk indicates "zero".
  - The bleed valve is fully open and no gas is coming through.
  - The interlock is confirmed disengaged.
- When the clamp operator has confirmed the clamp is fully open with "0 - by gauge" and the interlock is disengaged, the diving supervisor tells the clamp operator to "open the clamp".
- The bell is now ready to be taken away from the chamber system.
- The diving supervisor gives instruction to the clamp operator/winch operator to take the bell away from the system.
- All vent valves should be closed. The O-ring should be checked, lubricated, and changed if necessary. The trunk should be left ready for “bell recovery”.
- A top mated bell trunk should have a light weigh protection cover put on to protect it from damages.

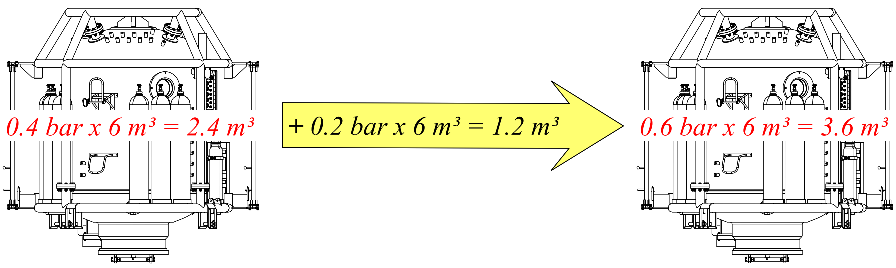
2.4 - Oxygen partial pressure adjustment

In point 2.1, it is indicated that after the stabilization period, the divers performing excursions can breathe mixes between 380 to 800 millibars (0.38 to 0.8 bar) instead of 380 to 450 millibars in chambers.
The selection of the mixes to be used during the bell run and how the partial pressure of oxygen is increased is the diving supervisor's responsibility.
Depending on the dive profile, the activity planned, and the storage depth of the bell, he may decide to increase only the partial pressure of oxygen of the breathing mix of the divers and keep the oxygen partial pressure of the bell equal to the partial pressure of the chambers or also increase the partial pressure of oxygen in the bell. The formula to calculate the volume of oxygen to add in the bell is as follows:

Volume of oxygen added = (Final partial pressure - Initial partial pressure) x Floodable volume of the bell

Note that this calculation is to be done using bar and cubic metres (metric system), or atmosphere and cubic feet (Imperial system)

As an example, if the initial PPO2 in the bell is 0.4 bar (400 mb), and the desired partial pressure is 0.6 bar (600 mb), 0.2 bar (200 mb) of oxygen is to be added (0.6 bar - 0.4 bar = 0.2 bar)
If the volume of the bell is 6 m^3, the volume of oxygen added is 0.2 bar x 6 m^3= 1.2 m^3



Initial status *Final status*

If the partial pressure of the bell has been raised above the PPO2 of the chambers, it will mix with the gas present in the entry lock if the bell has not been ventilated with fresh gas of the same PPO2 of the chamber. However, note that the connection between the two units is made by the trunk of 90 - 80 cm diameter and that they are at the same pressure. So, full mixing will take some time. The formula to calculate the final partial pressure after mixing is:

$$\text{New PPO2} = \frac{\text{(PPO2 chamber x floodable volume Chamber) + (PPO2 bell x floodable volume bell)}}{\text{(volume bell + volume chamber)}}$$

As an example, in the theoretical case that the bell above is not closed for a sufficient long period (which is not recommended) after the dive, and the volume of the transfer lock is 24 m^3, the final partial pressure should be:

- Oxygen volume in the bell: 0.6 bar x 6 m^3 = 3.6 m^3
- Oxygen volume in the transfer lock: 0.4 bar x 24 m^3 = 9.6 m^3
- Total volume oxygen: 3.6 + 9.6 = 13.2
- Volume transfer lock + bell: 24 + 6 = 30
- Partial pressure bell + transfer lock after mixing: 13.2 / 30 = 0.44 bar (440 mb)

2.5 - Launch and recover the bell

It must be remembered that due to the movements of the surface support, huge forces will be applied to the lifting system during the transfer from air to water. For this reason, great care must be taken, and the duration of this phase should be as reduced as possible. The bell movements must be monitored all the time during this phase, particularly with a portable system designed to launch overboard that have fewer means of control than a built-in system designed for launching through a moonpool, such as the LARS described in point 1.1.10.5 of this document.
Despite its weight of several tonnes, the waves can be sufficiently powerful to toss the bell to the hull when it is in the splash zone, resulting in damages and puts the divers in an uncomfortable or critical situation. For this reason, the bell should not be kept in the air and at the surface for a longer time than necessary, particularly when waves are established. If the weather conditions become unsuitable, the launching of the bell should be aborted.

2.5.1 - Transfer to the work site

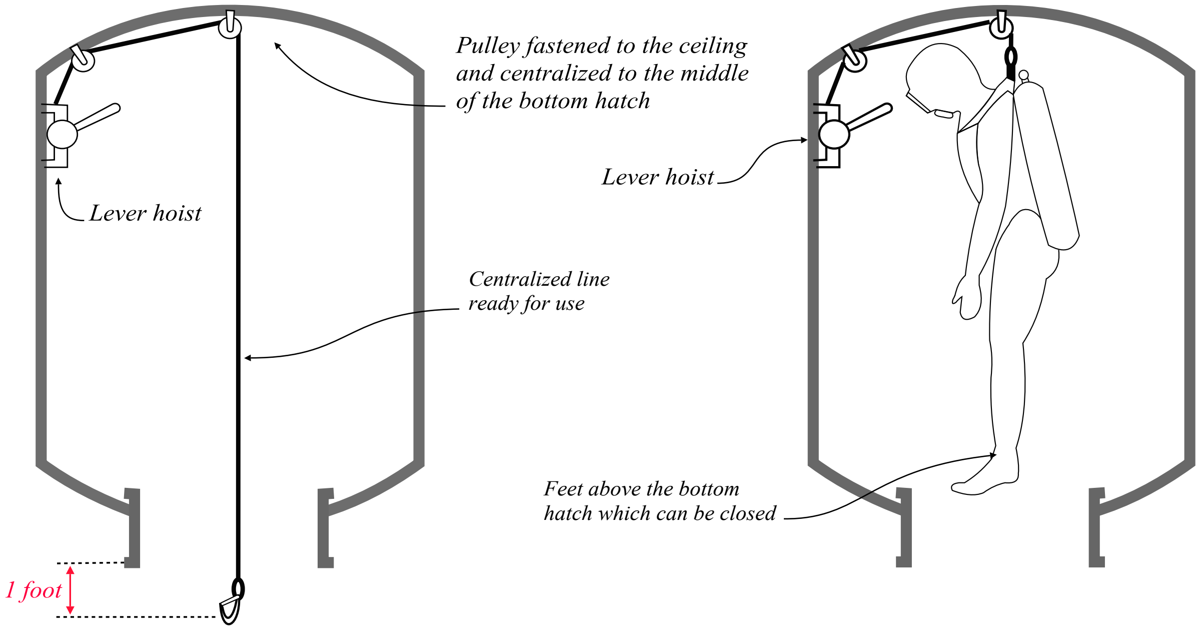
Situation: The divers have been transferred in the bell, and the bell has been unclamped.

- If the transfer under pressure was performed using the lateral door, the external lateral door must be closed and dogged. Note that the external bottom door must be closed.
- Before starting the transfer to the water, the person in charge on deck confirms the status of the external door(s), and the integrity of the bell to the supervisor.
- During the transfer, the divers inside the bell must sit on their seats and be secured by the safety belts.
- On instruction from the supervisor, the Launch And Recovery System (LARS) operator adjusts the bell above the moon pool or overboard it. Prior to to the descent, the guide wires are connected and secured on each side of the bell. Note that these operations are detailed in point 1.1.10 “Bell launch and recovery and connecting systems”.
- The deck leader should inform the diving supervisor when the bell is ready to be lowered. The descent should start only when instructed to proceed by the diving supervisor.
- The diving supervisor must be informed when the bell is in the water and has left the surface.
- The bell umbilical must be monitored to ensure it is not too tight or slack, both when lowering and raising (if its deployment system is manually controlled). On old generation systems, whips may have to be installed to secure the umbilical to the main wire. In this case, the bell will have to be periodically stopped during the descent.
- The depth of the bell should be monitored during the descent, and the bellman may be asked to report it to the supervisor (from his external pressure gauge). If possible, the divers should keep a close lookout via the ports for obstruction, anchor wires/chains, the seabed or sub-sea structure, and the position of the umbilical. (Too slack may induce fouling - too tight may rip it off the bell.). Note that the ROV can also monitor the descent of the bell.
- Once the bell is on the worksite, it is adjusted with the help of the ROV.
- The bell must be positioned as close as possible to the divers work station to reduce repetitive ascents.
- The bell depth should remain within the “standard excursion limits” *(see excursion tables)*.
- When working close to the bottom, the clump weight should be at least 5 m above the bottom or the obstructions seen during the pre-dive inspection. Precaution should be implemented to ensure that the bell is not above gas bubbling from the bottom (H_2S and other gasses). The bell should not be exactly above the job site, but slightly away.
- The ROV performs a general visual inspection of the bell, looking for leaks and possible damages. The ROV also makes sure that there is no gas emission from the bottom under the bell (see point .
- On instruction from the diving supervisor, the bellman opens the external bottom door, and adjusts the pressure of the bell to open the internal bottom door.
- When the door is opened, if the bell is equipped with a standoff frame, the ladder or the stair in place can be used to exit the bell. If the clump weight is used as a stair to enter and leave the bell, it must be adjusted according to the needs of the divers. If the clump weight cannot be used for this purpose, the water level is adjusted in the trunking to let the diver leaving and returning into the bell comfortably.
- When the bottom door is opened, the divers can be dressed. The following elements should be considered:
    - Communications are clear.
    - The bail out is checked and in good condition (it should have been tested during the pre-dive checks).
    - The bail out content (pressure x volume) is corresponding to the excursion planned.
    - The helmet is in good condition.
    - The neck dam is in good condition (it should have been tested during the pre-dive checks).
    - The light is working (it should have been tested during the pre-dive checks).
    - The camera is working (it should have been tested during the pre-dive checks).
    - The no return valve has been tested and is reported to be working fine.
    - The bail-out bottle has been connected and tested. It is open and the side valve of the helmet is closed.
    - If a rebreather such as COBRA or MK 4 is to be used, it must be satisfactorily tested. The gas supply hose must be connected to the side block of the helmet, and the hot water flowing from the surface to the diver’s suit should be diverted to the hot water housing of the backpack through the splitter block.

- The reclaim system is open and working satisfactory.
- The helmet is supplied (main supply) and is working satisfactorily.
- The depth gauge of the diver ('pneumo') has been tested.
- The neck dam is properly adjusted.
- The diver wears the helmet that should be secured so as not to be lost.
- The diver has a proper hot water suit connected to the supply system through a quick connector that is checked not to disconnect during the dive.
- The hot water temperature and flow conforms to the recommendations for the depth and the surrounding temperature.
- The diver has a harness in good condition.
- 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 available).
- The diver has his personal tools. (Most of the tools should be transferred into the tool basket)
- The diver has a weak link that conforms to IMCA D 058.
- The diver has gloves.
- The diver is fit to dive and is happy to go.

- The bellman umbilical may be stored at the outside of the bell. In this case, the 1st diver must be launched to pick up its end. However, if there are only two divers in the bell, its extremity must be installed at the direct proximity of the door, such it is not necessary to dive to collect it. The reason for this rule is that there must be a standby diver ready to intervene for every diver in the water. Prior to sending the diver(s) to the worksite, the bellman's mask should be installed and his checks completed. Thus, the diver(s) should stay inside the bell during the bellman checks.

Note: The bellman must always be dressed in a state of readiness whilst the diver(s) is/are out of the bell, and the "man-lift" device should always be deployed or on hand in an operational (and lifting) mode.



- The diver moves to the job site only when instructed to leave the bell by the diving supervisor. When the/a diver leaves the bell, the bellman:
  - Indicates to the supervisor that the diver is leaving the bell.
  - Report the umbilical length deployed, and make sure that the length is within the bail out range.
  - Monitors the breathing and bell gas supplies, oxygen and CO_2 levels.
  - Monitors the reclaim
  - Monitors the divers hot water temperature and flow rate
  - Ensures that the CO_2 scrubber is running.
  - Tends the divers umbilical.
- The bellman should visually check the diver's equipment as soon as the diver(s) leaves the bottom door to ensure whether there are no leaks from the bailout set and connecting hoses. He should try to keep an eye on the diver(s) during the work/task (if the diver(s) is/are in view of the bell).
- Whilst the diver(s) is/are working, the bellman should not call the supervisor unnecessarily, unless to clarify an instruction, request permission to operate some valve or equipment, or informing the supervisor of a particular action he is about to take.

2.5.2 - Recover the divers to the saturation complex

- The bellman reports to the diving supervisor once a diver is back in the bell and whether the diver feels well or not.
- Before undressing the divers, the bellman umbilical must be returned to its initial position and adequately secured.
- Then, the bellman undress the diver(s), stow the equipment and prepares to leave the worksite (unless changing roles). *Note: Dirty suits and equipments should be cleaned prior to coming back into the bell. Additional precautions such as over suits left outside the bell should be implemented if hydrocarbons are suspected.*
- The external and internal bottom doors are closed and the bellman pressurises the bell 1 - 3 m above the surrounding pressure to make a seal. The door is then checked for leaks, and the internal pressure monitored to make sure that the seal is holding.
- Once the door is confirmed sealed, the bell can be recovered. However, the bellman must monitor the pressure gauges to ensure the seal is maintained on the way up.
- Prior to coming up, the diver should be secured to their seats.
- The procedure and precaution to recover the bell to the deck are the same as for the launching (of course the steps are in reverse order).
- The Diving Supervisor notifies the LSS/LST that the bell is coming up.
- The LSS/LST ensures that nobody is in the Transfer Lock, except for the person who may be needed for assistance.
- The LSS/LST also ensures that all the doors are closed.
- The bell is manoeuvred smoothly into contact with the flange *(see in point 1.1.10)*.
- Once the bell is mated, the Diving Supervisor tells the clamp operator, to close the clamp. Note that with modern systems, the clamp is closed from the control console by the winch operator.
- The clamp operator confirms the instruction from the supervisor by repeating it and closes the clamp. He informs the Diving Supervisor when the clamp is closed and secured with the interlock in place. In the case of a modern system, the interlock is controlled from the control console. However, a person should be assigned to check that it is really in place and that the clamp is secured.

- The Diving Supervisor informs the LSS/LST and the divers in the bell that the clamp is closed, secured, and that the trunk is ready to be pressurized 1 - 3 m on chamber mix.
- Depending on the system, the Diving Supervisor tells the clamp operator, or the LST in charge to pressurize 1 to 3 m and to check for leaks.
- The clamp operator or the person in charge in the case of a clamp that is controlled from the console confirms that there is no leak and the interlock is fully engaged.
- When the Diving Supervisor & LSS/LST confirm on their gauges that the pressure is holding, the trunk can be taken down to 3 m shallower than the storage depth.
- After the leak tests, the Diving Supervisor orders to adjust the depth to the storage depth, and tells the divers to open their door equalization valve. Note: NORSOK standard U-100 recommend 10 m/min (33 feet/min).
- Once the internal bell door is open to the trunk, the divers can transfer to the Transfer Lock when they are authorized to proceed by the diving supervisor who informs the LSS/LST that they are coming through.

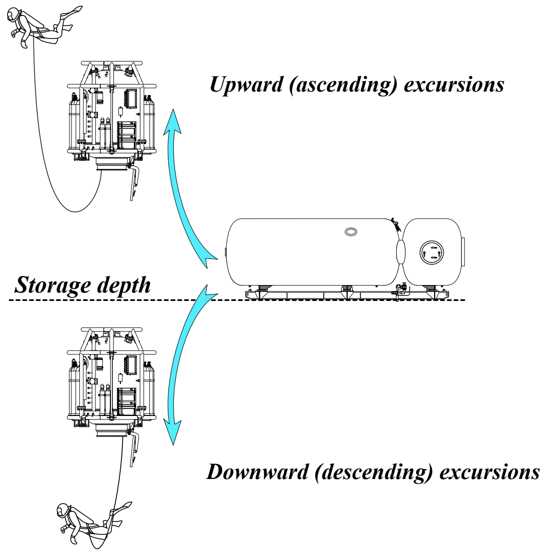
- The Bellman stays in the bell to clean-up, get read of old soda lime and trash. He ensures the bell is ready for the next team (cleans and disinfects helmets) and do minor maintenance as needed. He will report technical problems to the Diving Supervisor.
- Once the Bellman has completed the cleaning and post dive checks, he closes the internal bell door equalization valves (if needed) and he transfers to the TL. He closes the door of the bell when he is in the trunk.
- When the Bellman is in the Transfer Lock, he closes the door and the equalization valves of the trunk and informs the LSS/LST that he can take the bell trunk away (if needed).
- From the transfer lock, the team transfers into the living chamber for rest. Before, they transfer the suits and diving gear they have used out of the complex for cleaning using the transfer tool lock.
- The LSS/LST ensures they close the doors to the Transfer Lock, and that they are secured in their chamber.

2.6 - Excursions during the bell runs

2.6.1 - Types of excursions

2.6.1.1 - Ascending and descending excursions

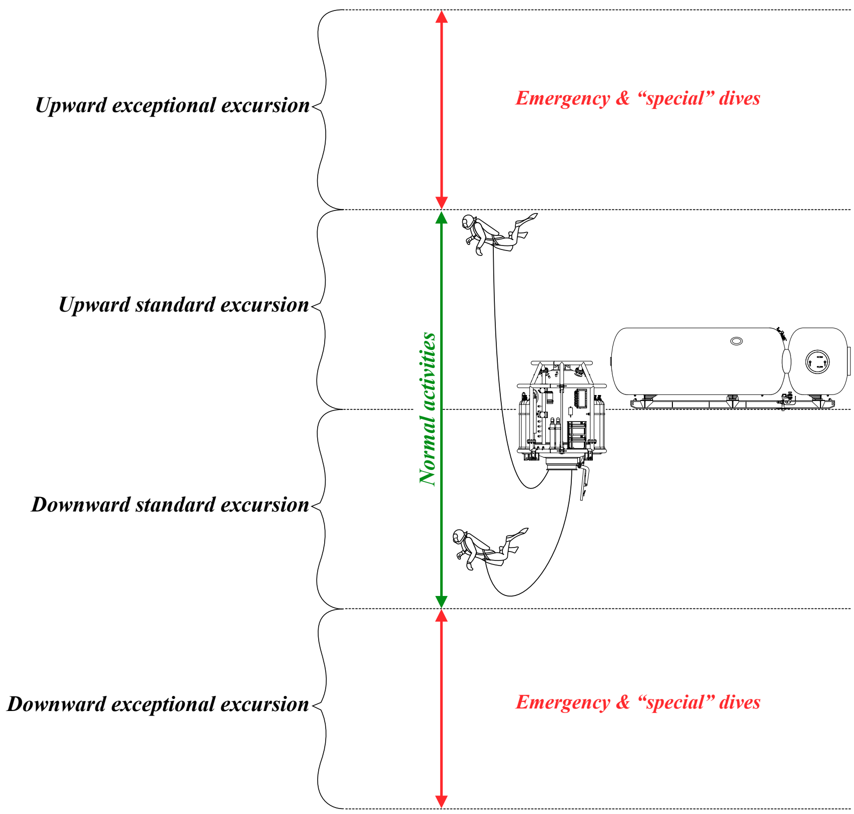
- Ascending excursions, also called upward excursions, are dives performed at depths shallower than the "storage depth", also called "life level".
- Descending excursions, also called downward excursions, are dives performed at depths deeper than the storage depth.



2.6.1.2 - Excursion depths range

Excursions are characterised by the pressure difference existing between the storage depth and the working depth which is called the excursion depth range or the excursion depth amplitude. There are two types of excursion depth ranges:

- Standard excursions allow moderate amplitudes. These excursions are those to be used for normal diving operations undertaken during underwater construction or inspection projects. Depending on the storage depth, they allow from 2 to 15 m amplitude.
- The exception excursions allow greater distances than standard excursions. However, these excursions should not be scheduled as routine and should be employed only in special or emergency situations.



2.6.1.3 - Explanation of the excursions ranges Normam-15

NORMAM-15 excursions are the evolution of those published in the COMEX saturation procedures MT-92 still in force in France. These excursions are limited to roughly 1/3 of those described in the US Navy diving manual.
US Navy saturation excursions are still massively used in the diving industry. However, even though some scientists say that no one has been able to document that excursion distances are involved in the risk of decompression accidents, it is recognized that the U.S. Navy's procedures have led to decompression accidents in many cases, especially vestibular symptoms. Thus, it is reasonable to consider a relationship with the amplitude of the excursions. Regarding this point, the UK HSE study *"Excursion tables in saturation diving decompression implications of current UK practice"* shows the relationship between the magnitude of the excursion, the pressure from which the excursion starts, and the volume of gas which is predicted to form into bubbles.
Considering these facts, many diving companies have reduced their excursion limits to between 70% and 50% of the original excursions USN to secure them. However, this rule is empirical, and for this reason, some safety organizations have implemented studies to obtain excursion limits based on more scientific facts. NORSOK standards U-100 excursion limits result from these studies in Norway.
It must be noted that the distances of excursion proposed by NORSOK are very similar to the "standard" excursions of NORMAM-15 and COMEX MT-92 tables, which proves that these amplitudes are relevant. Nevertheless, NORSOK procedures do not propose exceptional excursions such as NORMAM-15 and MT-92, which can be a problem in an emergency or other exceptional conditions. For this reason, although the study CCO Ltd "Reinforce the US Navy saturation procedures", recommends adopting NORSOK excursions to strengthen this procedure, the study also suggests keeping the original excursions USN as exceptional excursion limits that can be used in an emergency.
Other elements of NORMAM-15 and MT-92 not proposed by NORSOK are the tables to manage the combined excursions and the stabilization periods between two excursions. Note that the fact that a sufficient decompression time is necessary between two excursions is also highlighted in the UK HSE study *"Excursion tables in saturation diving decompression implications of current UK practice"*, which says that that excursions and decompression must be considered together. The same study also says that decompression problems may result from the combination of excursions followed by the final decompression before bubbles have totally disolved. For this reason the study recommends a stabilization period after excursions, prior to start the final decompression.

The tables below show a comparison between NORMAM 15 and NORSOK U100 excursions.

Comparison downward excursions distances NORMAM-15 - NORSOK U-100 revision 5

Storage level	***NORMAM 15***	***NORSOK***	***Difference***	***Storage level***	***NORMAM 15***	***NORSOK***	***Difference***
12	3	3	0	***97***	10	10	0
15	3	4	-1	***101***	11	11	0
18	4	5	-1	***104***	11	11	0
21	4	5	-1	***107***	11	11	0
24	5	5	0	***110***	11	11	0
27	5	7	-2	***113***	11	11	0
30	6	7	-1	***116***	11	11	0
33	7	7	0	***119***	11	11	0
37	7	8	-1	***122***	12	12	0
40	8	8	0	***125***	12	12	0
43	8	8	0	***128***	12	12	0
46	8	8	0	***131***	12	12	0
49	8	8	0	***134***	12	12	0
52	8	8	0	***137***	12	13	-1
55	8	8	0	***140***	13	13	0
58	8	9	-1	***143***	13	13	0
61	9	9	0	***146***	13	13	0
64	9	9	0	***149***	13	13	0
67	9	9	0	***152***	13	13	0
70	9	9	0	***155***	13	13	0
73	9	9	0	***158***	13	13	0
76	9	9	0	***161***	13	13	0
79	9	10	-1	***165***	13	13	0
82	10	10	0	***168***	13	13	0
85	10	10	0	***171***	13	13	0
88	10	10	0	***174***	13	13	0
91	10	10	0	***177***	13	13	0
94	10	10	0	***180***	15	13	2

Negative differences indicate that NORMAM-15 is the most stringent

Comparison upward excursions distances NORMAM-15 - NORSOK U-100 revision 5

Storage level	NORMAM 15	NORSOK	Difference	Storage level	NORMAM 15	NORSOK	Difference
12	2	0	2	***97***	10	10	0
15	2	1	1	***101***	11	11	0
18	4	4	0	***104***	11	11	0
21	4	4	0	***107***	11	11	0
24	5	5	0	***110***	11	11	0
27	5	5	0	***113***	11	11	0
30	6	6	0	***116***	11	11	0
33	7	7	0	***119***	11	11	0
37	7	7	0	***122***	12	12	0
40	8	8	0	***125***	12	12	0
43	8	8	0	***128***	12	12	0
46	8	8	0	***131***	12	12	0
49	8	8	0	***134***	12	12	0
52	8	8	0	***137***	12	13	-1
55	8	8	0	***140***	13	13	0
58	8	8	0	***143***	13	13	0
61	9	9	0	***146***	13	13	0
64	9	9	0	***149***	13	13	0
67	9	9	0	***152***	13	13	0
70	9	9	0	***155***	13	13	0
73	9	9	0	***158***	13	13	0
76	9	9	0	***161***	13	13	0
79	9	9	0	***165***	13	13	0
82	10	10	0	***168***	13	13	0
85	10	10	0	***171***	13	13	0
88	10	10	0	***174***	13	13	0
91	10	10	0	***177***	13	13	0
94	10	10	0	***180***	15	13	2

Negative differences indicate that NORMAM-15 is the most stringent

Note that the differences do not exceed 2 metres, and that most distances are identical. That proves what is said previously regarding the convergence of results. Also, when several teams not working together obtain similar answers, we can consider that they are not far from reality.

2.6.2 - Stabilization periods before excursions

2.6.2.1 - Excursions upon arrival at the storage depth

Excursions upon arrival at the storage depth are not possible.
Prior to undertaking excursions, the pre-dive stabilization periods explained in point 3.2.2 of Book #2, must be completed.
After this initial stabilization period, upward and downward excursions are possible regardless of the depth in which the saturation is.

2.6.2.2 - Excursion after a previous excursion

Normam-15 says that after an excursion the diver should observe a stabilization period before going on another excursion according to the table below:

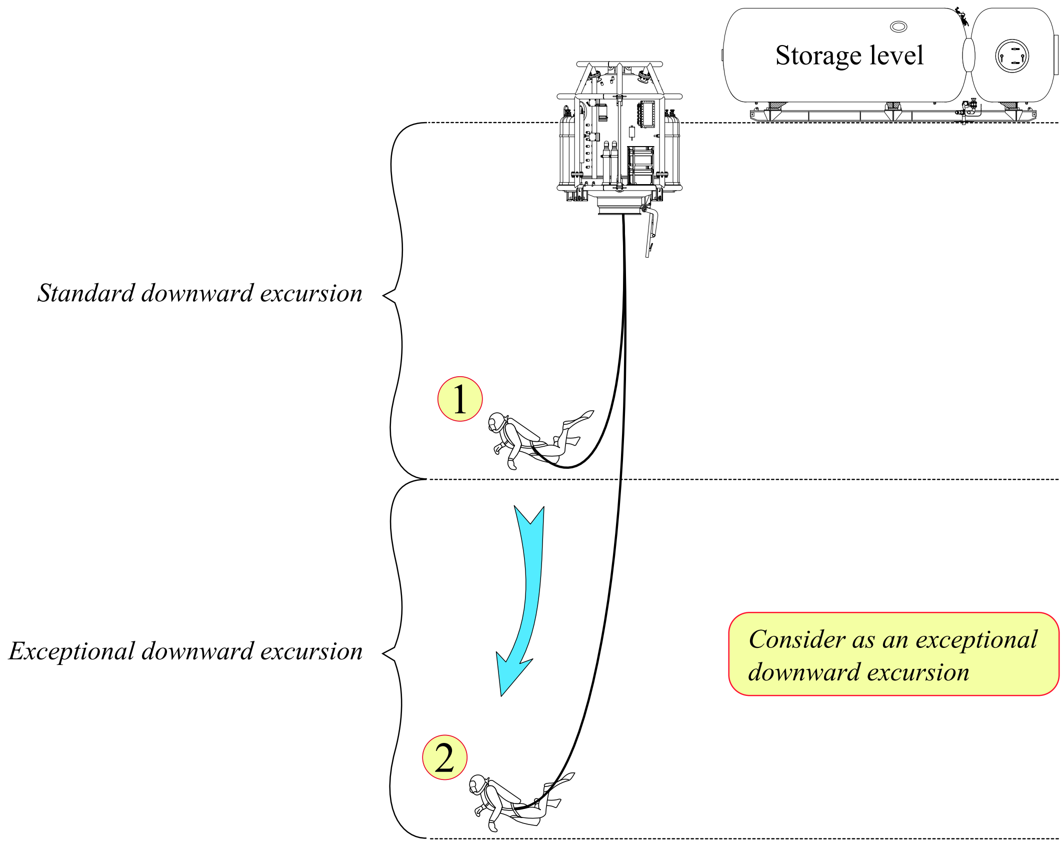
Stabilization period	*After a standard downward excursion*	*After a standard upward excursion*	*After an exceptional downward excursion*	*After an exceptional upward excursion*
Before a standard downward excursion	None	None	None	12 hours
Before a standard upward excursion	None	None	12 hours	12 hours
Before an exceptional downward excursion	None	None	48 hours	48 hours
Before an exceptional upward excursion	12 hours	None	48 hours	48 hours

Fundamental rule:
A saturated diver can perform only two exceptional excursions per saturation.
As a reminder, the maximum duration of a saturation dive is 28 days.

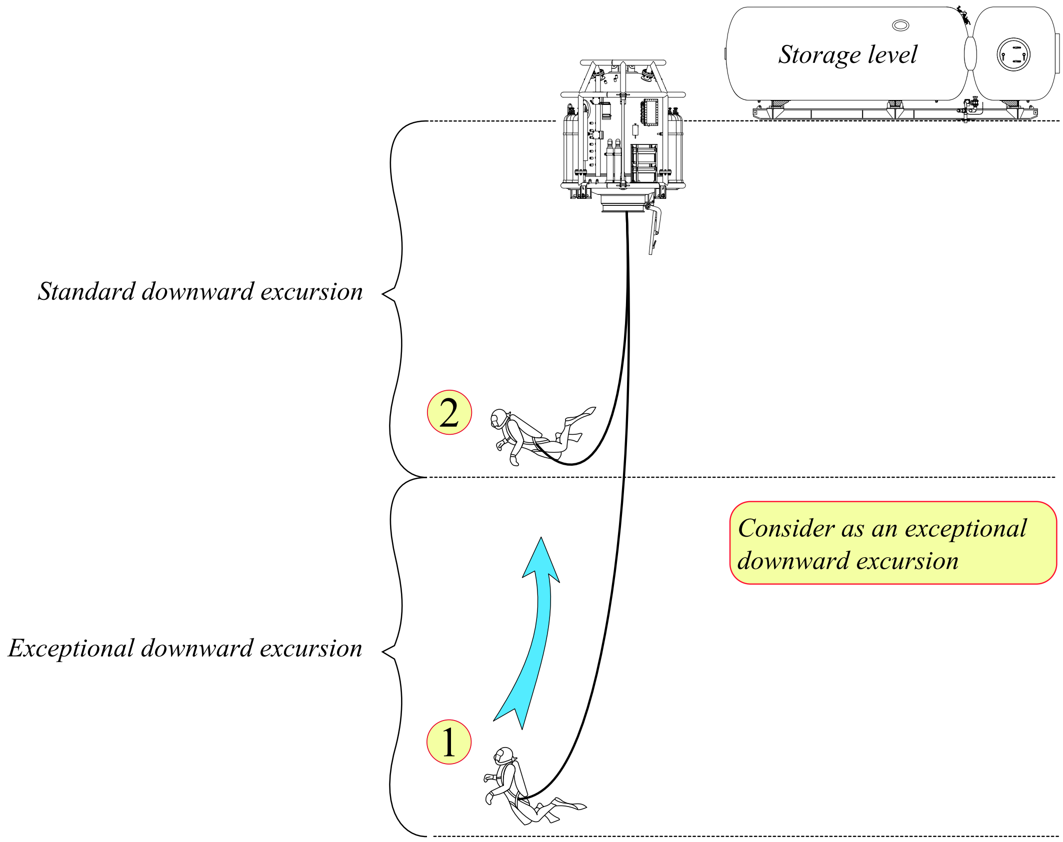
2.6.3 - Combinations allowed for excursions with no break

Combinations of standard and exceptional downward and upward excursions may have to be performed. The possible combinations are recorded below and should be done according to the criteria established in the previous point.

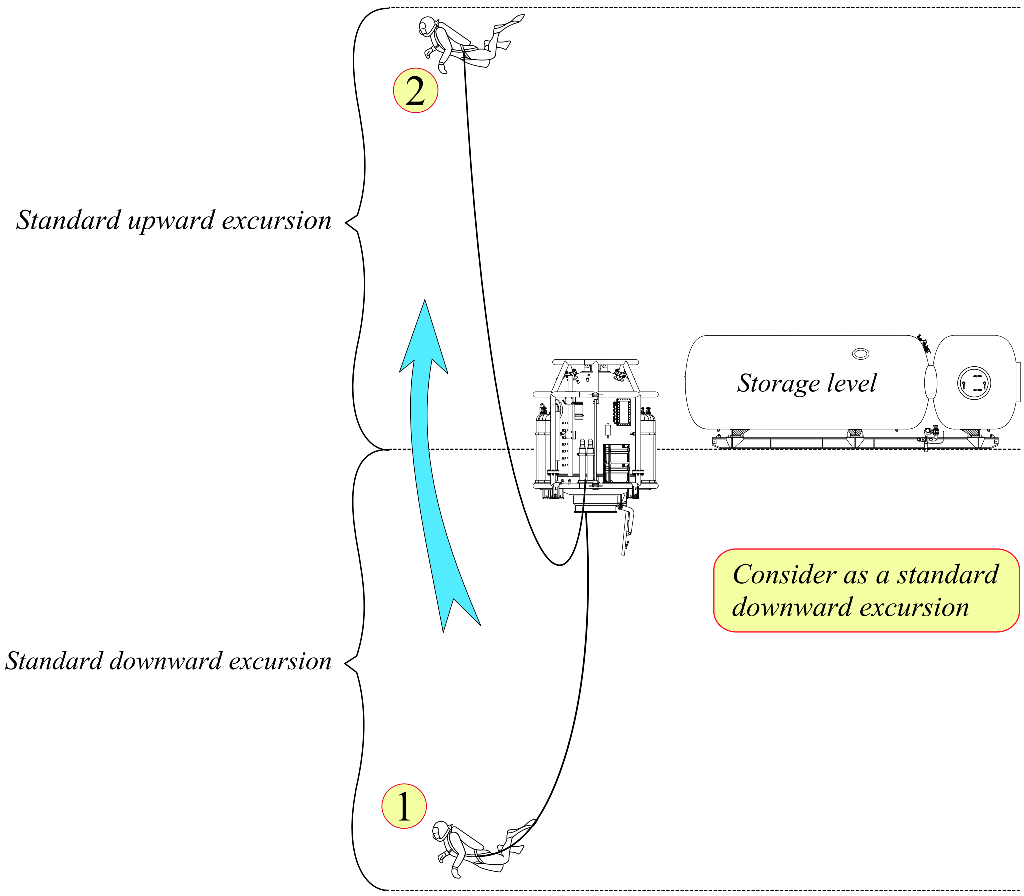
2.6.3.1 - Standard downward excursion followed by exceptional downward excursion



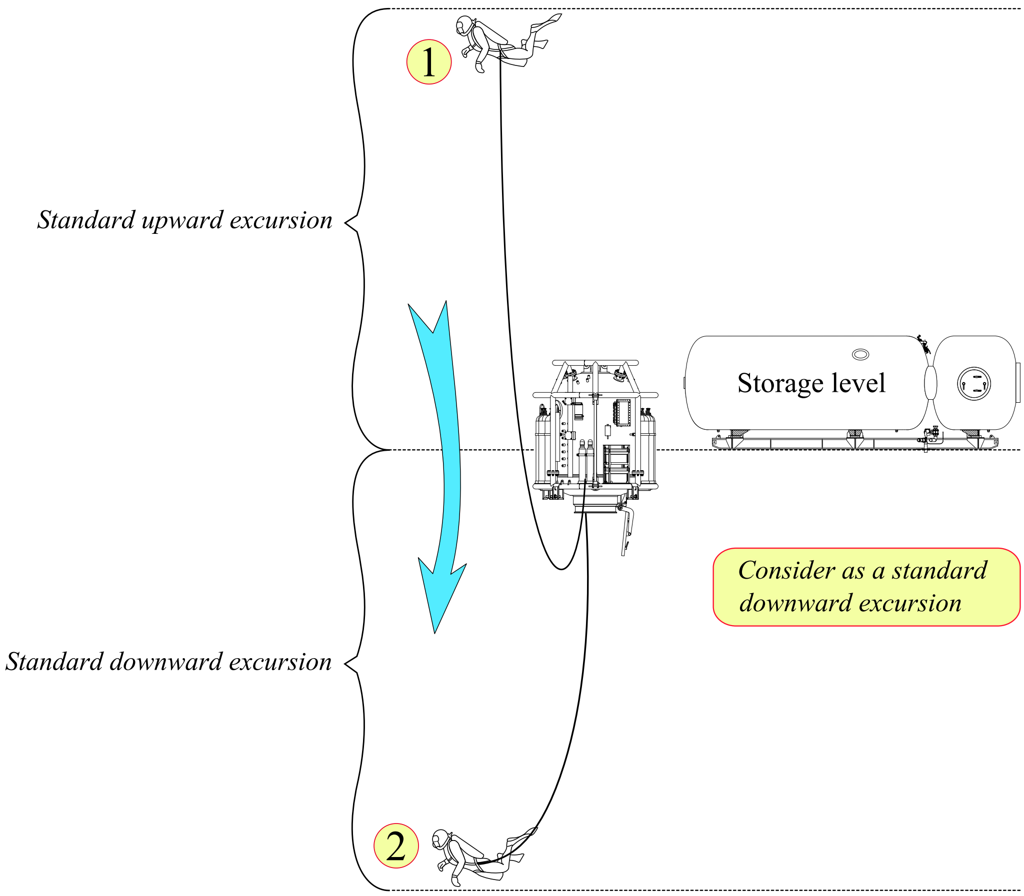
2.6.3.2 - Exceptional downward excursion followed by a standard downward excursion



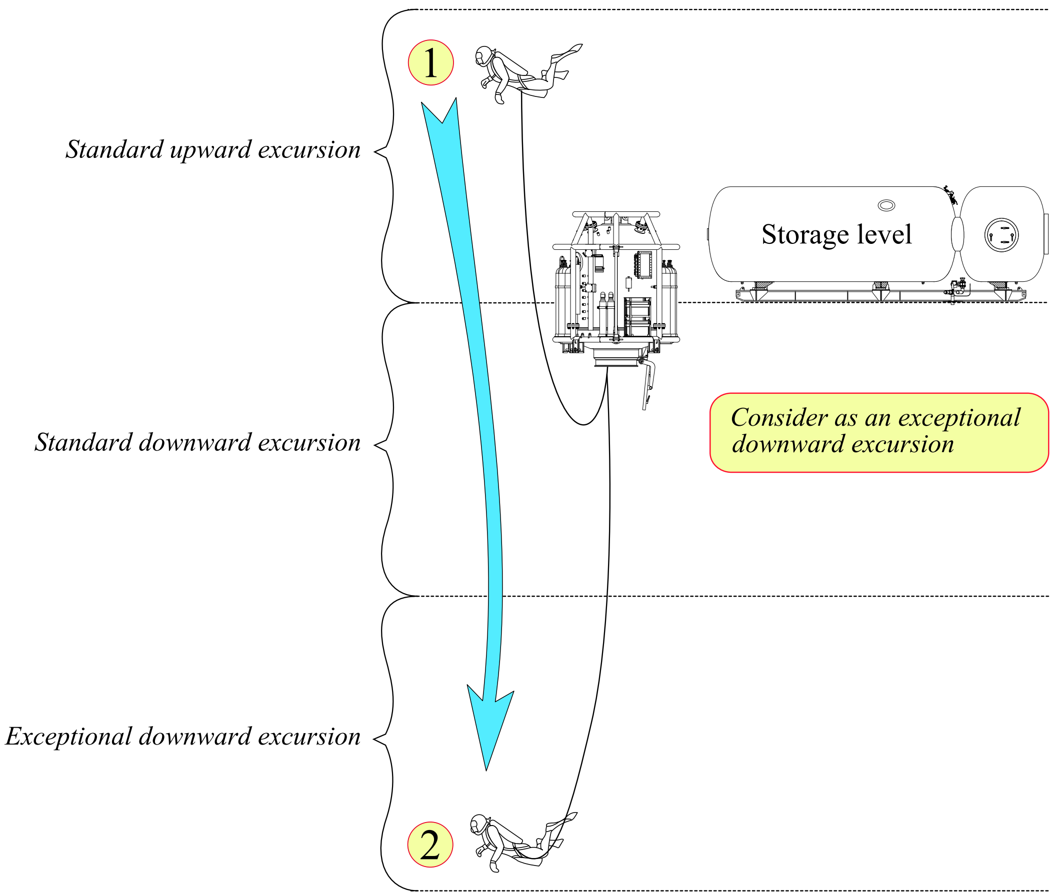
2.6.3.3 - Standard downward excursion followed by standard upward excursion



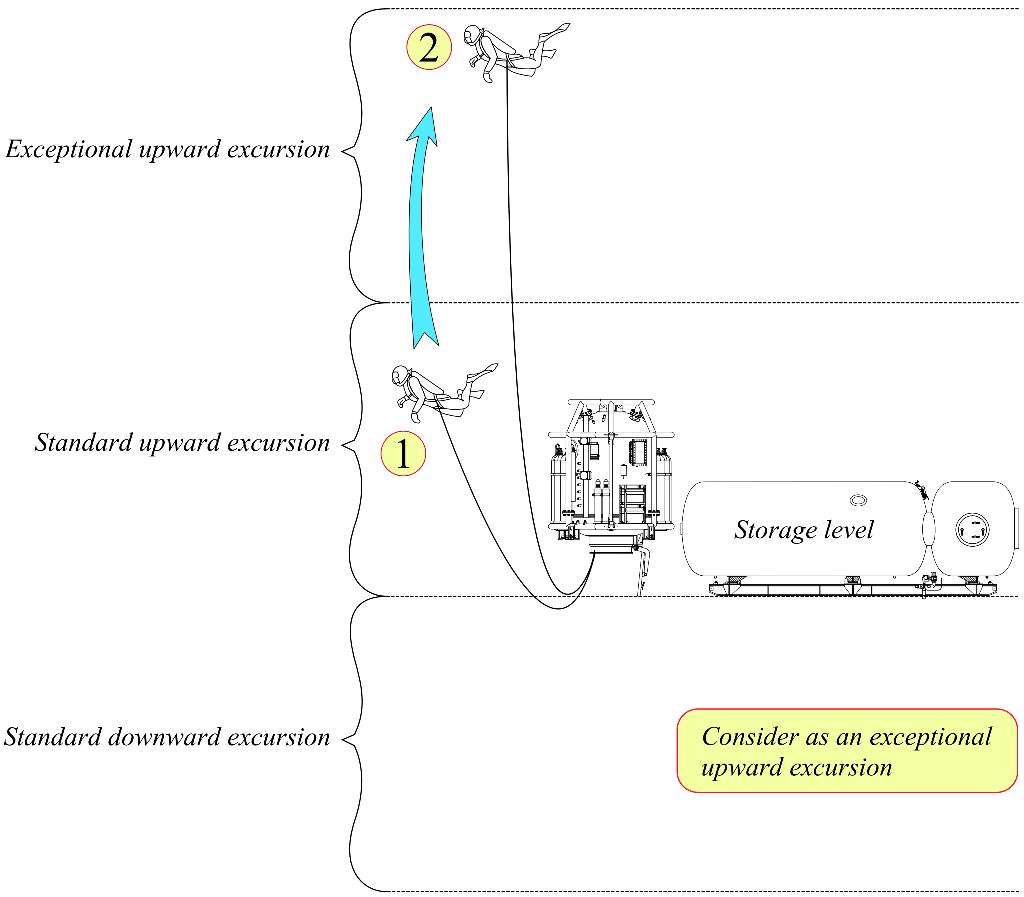
2.6.3.4 - Standard upward excursion followed by standard downward excursion



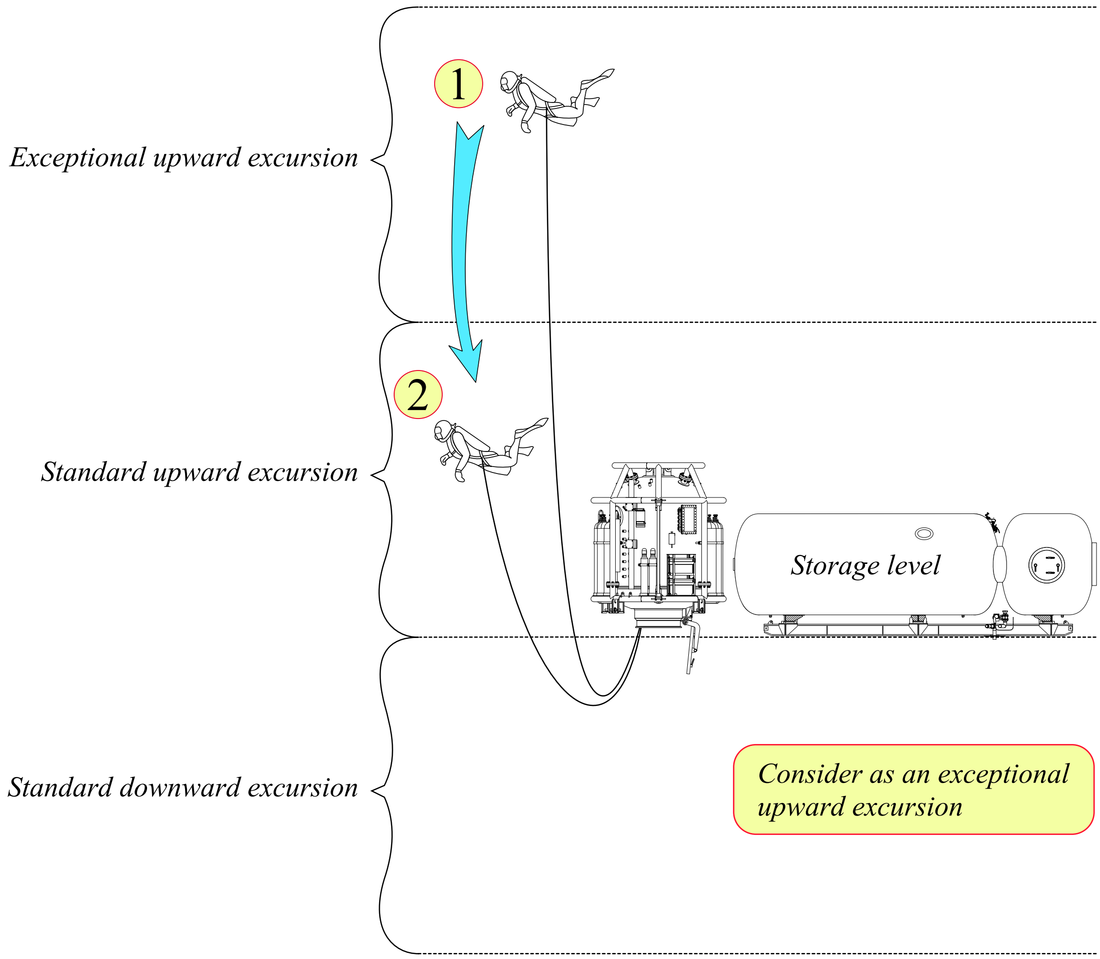
2.6.3.5 - Standard upward excursion followed by exceptional downward excursion



2.6.3.6 - Standard upward excursion followed by exceptional upward excursion



2.6.3.7 - Exceptional upward excursion followed by a standard upward excursion



2.6.4 - Recommendations for organizing bell runs and excursions *(NORSOK & French decree 15th of May 92)*

The working times should be organized in a way that the divers have regular rotations, so the working time and recovery times happen at the same hours every day. This point is very important to allow the divers a full recovery of their efforts.

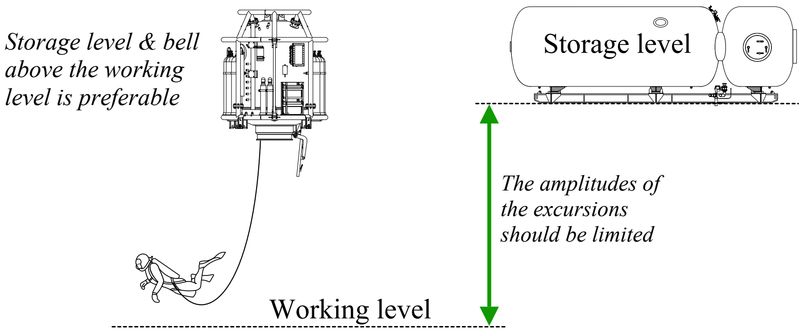
For a given bell run, the preferred choice should be:

- Descending excursions rather than ascending ones. It is preferable to have the storage level (chamber) and the bell above the working level.
- Standard excursions rather than exceptional ones.
- The work planning to be arranged so as to avoid repeated ascents for the divers.
- The living depth that is as close to the working depth as possible.

When adjusting the bell:

- The depth of the bell must be kept within the limits of "standard excursion" dives.
- A bell depth equal to or deeper than the storage level is preferable.

The storage level should be as close to the working depth as possible to limit the amplitudes of the excursions.



2.6.5 - Duration of bell runs

The bell run durations are given “seal to seal” *(from bell locked off the system to bell locked on the system)*.
Note that these durations are the maximum allowed by NORMAM-15 for 24 hours and that there must be at least 12 hours of full rest between 2 bell runs. The bell runs can be shortened according to the real time spent in the water.

The bell runs and times in the water should be organised as follows:

Depth	***0 - 210 m***	***211 - 260 m***	***261 - 300 m***	***301 - 350 m***
Maximum duration bell run	8 hours/24 hours	8 hours/24 hours	8 hours/24 hours	6 hours/24 hours
Maximum time in the water	6 hours/24 hours	5 hours/24 hours	4 hours/24 hours	3 hours/24 hours
Resting time 30 min or diver change *	At mid-dive	At mid-dive	At mid-dive	Not specified *(At mid dive)*

Resting time 30 min or diver change * :
The diver who goes into the water can at his own discretion and with the authorization of his supervisor, be replaced by the emergency diver.
If he is not replaced, he should have a resting period inside the diving bell where he can remove his diving helmet, eat, and re-hydrate. It is recommended that this resting period is to be up to thirty minutes.
Diver change or the rest period should be organized at the halftime of the time to be spent in the water.

Note that NORSOK U-100 says the following:

- The total in water time shall not exceed 5:30 hours and the break in the bell must be logged. During a two-man bell-run, total time in water during a 12 h period shall not exceed 4 h for each diver.
- Each diver shall be given a dry day as bell-man every third day
- The diving supervisor shall have a rest period from the direct communication control after a period of 4 h. The rest period shall be at least 30 min. The total time for this function shall be limited to 8 h in the course of a 12 h period. The workload should determine the length of the rest periods. Inside a 24 h period supervisory personnel should normally have a 12 h period of continuous rest.

2.6.6 - Excursion tables

The excursion tables displayed below and on the next pages indicate the maximum excursion depths and distances metre by metre from 10 msw to 350 msw.

To read the table, select the depth in the column on the left side and follow the horizontal line to read the corresponding maximum distances and depths of the downward or upward standard or exceptional excursions.

In the case of a storage depth between two levels:

- For an upward excursion, select the depth immediately deeper. As an example, for a depth between 20 & 21 msw, select 21 m. It is also possible to calculate the excursion using the "upward distance".
- For a downward excursion, select the depth immediately shallower. As an example, for a depth between 20 & 21 msw, select 20 m. It is also possible to calculate the excursion using the "downward distance".

Life depth (metres)	*Standard excursions*				*Exceptional excursions*			
	Downward distances	*Downward depths*	*Upward distances*	*Upward depths*	*Downward distances*	*Downward depths*	*Upward distances*	*Upward depths*
10	3	13	2	8	Forbidden	–	Forbidden	–
11	3	14	2	9	Forbidden	–	Forbidden	–
12	3	15	2	10	Forbidden	–	Forbidden	–
13	3	16	2	11	Forbidden	–	Forbidden	–
14	3	17	2	12	Forbidden	–	Forbidden	–
15	3	18	2	13	Forbidden	–	Forbidden	–
16	3	19	2	14	Forbidden	–	Forbidden	–
17	3	20	2	15	Forbidden	–	Forbidden	–
18	4	22	4	14	Forbidden	–	Forbidden	–
19	4	23	4	15	Forbidden	–	Forbidden	–
20	4	24	4	16	Forbidden	–	Forbidden	–
21	4	25	4	17	Forbidden	–	Forbidden	–
22	4	26	4	18	Forbidden	–	Forbidden	–
23	5	28	5	18	10	33	Forbidden	–
24	5	29	5	19	10	34	Forbidden	–
25	5	30	5	20	10	35	Forbidden	–
26	5	31	5	21	10	36	Forbidden	–
27	5	32	5	22	10	37	Forbidden	–
28	5	33	5	23	10	38	Forbidden	–
29	5	34	5	24	10	39	Forbidden	–
30	6	36	6	24	12	42	Forbidden	–
31	7	38	7	24	14	45	14	17
32	7	39	7	25	14	46	14	18
33	7	40	7	26	14	47	14	19
34	7	41	7	27	14	48	14	20
35	7	42	7	28	14	49	14	21
36	7	43	7	29	14	50	14	22
37	7	44	7	30	14	51	14	23
38	7	45	7	31	14	52	14	24
39	7	46	7	32	14	53	14	25
40	8	48	8	32	16	56	16	24
41	8	49	8	33	16	57	16	25
42	8	50	8	34	16	58	16	26
43	8	51	8	35	16	59	16	27
44	8	52	8	36	16	60	16	28

Life depth (metres)	Standard excursions				Exceptional excursions			
	Downward distances	Downward depths	Upward distances	Upward depths	Downward distances	Downward depths	Upward distances	Upward depths
45	8	53	8	37	16	61	16	29
46	8	54	8	38	16	62	16	30
47	8	55	8	39	16	63	16	31
48	8	56	8	40	16	64	16	32
49	8	57	8	41	16	65	16	33
50	8	58	8	42	16	66	16	34
51	8	59	8	43	16	67	16	35
52	8	60	8	44	16	68	16	36
53	8	61	8	45	16	69	16	37
54	8	62	8	46	16	70	16	38
55	8	63	8	47	16	71	16	39
56	8	64	8	48	16	72	16	40
57	8	65	8	49	16	73	16	41
58	8	66	8	50	16	74	16	42
59	8	67	8	51	16	75	16	43
60	9	69	9	51	18	78	18	42
61	9	70	9	52	18	79	18	43
62	9	71	9	53	18	80	18	44
63	9	72	9	54	18	81	18	45
64	9	73	9	55	18	82	18	46
65	9	74	9	56	18	83	18	47
66	9	75	9	57	18	84	18	48
67	9	76	9	58	18	85	18	49
68	9	77	9	59	18	86	18	50
69	9	78	9	60	18	87	18	51
70	9	79	9	61	18	88	18	52
71	9	80	9	62	18	89	18	53
72	9	81	9	63	18	90	18	54
73	9	82	9	64	18	91	18	55
74	9	83	9	65	18	92	18	56
75	9	84	9	66	18	93	18	57
76	9	85	9	67	18	94	18	58
77	9	86	9	68	18	95	18	59
78	9	87	9	69	18	96	18	60
79	9	88	9	70	18	97	18	61
80	10	90	10	70	20	100	20	60
81	10	91	10	71	20	101	20	61
82	10	92	10	72	20	102	20	62
83	10	93	10	73	20	103	20	63
84	10	94	10	74	20	104	20	64
85	10	95	10	75	20	105	20	65
86	10	96	10	76	20	106	20	66
87	10	97	10	77	20	107	20	67
88	10	98	10	78	20	108	20	68

Life depth (metres)	Standard excursions				Exceptional excursions			
	Downward distances	Downward depths	Upward distances	Upward depths	Downward distances	Downward depths	Upward distances	Upward depths
89	10	99	10	79	20	109	20	69
90	10	100	10	80	20	110	20	70
91	10	101	10	81	20	111	20	71
92	10	102	10	82	20	112	20	72
93	10	103	10	83	20	113	20	73
94	10	104	10	84	20	114	20	74
95	10	105	10	85	20	115	20	75
96	10	106	10	86	20	116	20	76
97	10	107	10	87	20	117	20	77
98	10	108	10	88	20	118	20	78
99	10	109	10	89	20	119	20	79
100	11	111	11	89	22	122	22	78
101	11	112	11	90	22	123	22	79
102	11	113	11	91	22	124	22	80
103	11	114	11	92	22	125	22	81
104	11	115	11	93	22	126	22	82
105	11	116	11	94	22	127	22	83
106	11	117	11	95	22	128	22	84
107	11	118	11	96	22	129	22	85
108	11	119	11	97	22	130	22	86
109	11	120	11	98	22	131	22	87
110	11	121	11	99	22	132	22	88
111	11	122	11	100	22	133	22	89
112	11	123	11	101	22	134	22	90
113	11	124	11	102	22	135	22	91
114	11	125	11	103	22	136	22	92
115	11	126	11	104	22	137	22	93
116	11	127	11	105	22	138	22	94
117	11	128	11	106	22	139	22	95
118	11	129	11	107	22	140	22	96
119	11	130	11	108	22	141	22	97
120	12	132	12	108	24	144	24	96
121	12	133	12	109	24	145	24	97
122	12	134	12	110	24	146	24	98
123	12	135	12	111	24	147	24	99
124	12	136	12	112	24	148	24	100
125	12	137	12	113	24	149	24	101
126	12	138	12	114	24	150	24	102
127	12	139	12	115	24	151	24	103
128	12	140	12	116	24	152	24	104
129	12	141	12	117	24	153	24	105
130	12	142	12	118	24	154	24	106
131	12	143	12	119	24	155	24	107
132	12	144	12	120	24	156	24	108

Life depth (metres)	Standard excursions				Exceptional excursions			
	Downward distances	Downward depths	Upward distances	Upward depths	Downward distances	Downward depths	Upward distances	Upward depths
133	12	145	12	121	24	157	24	109
134	12	146	12	122	24	158	24	110
135	12	147	12	123	24	159	24	111
136	12	148	12	124	24	160	24	112
137	12	149	12	125	24	161	24	113
138	12	150	12	126	24	162	24	114
139	12	151	12	127	24	163	24	115
140	13	153	13	127	26	166	26	114
141	13	154	13	128	26	167	26	115
142	13	155	13	129	26	168	26	116
143	13	156	13	130	26	169	26	117
144	13	157	13	131	26	170	26	118
145	13	158	13	132	26	171	26	119
146	13	159	13	133	26	172	26	120
147	13	160	13	134	26	173	26	121
148	13	161	13	135	26	174	26	122
149	13	162	13	136	26	175	26	123
150	13	163	13	137	26	176	26	124
151	13	164	13	138	26	177	26	125
152	13	165	13	139	26	178	26	126
153	13	166	13	140	26	179	26	127
154	13	167	13	141	26	180	26	128
155	13	168	13	142	26	181	26	129
156	13	169	13	143	26	182	26	130
157	13	170	13	144	26	183	26	131
158	13	171	13	145	26	184	26	132
159	13	172	13	146	26	185	26	133
160	13	173	13	147	26	186	26	134
161	13	174	13	148	26	187	26	135
162	13	175	13	149	26	188	26	136
163	13	176	13	150	26	189	26	137
164	13	177	13	151	26	190	26	138
165	13	178	13	152	26	191	26	139
166	13	179	13	153	26	192	26	140
167	13	180	13	154	26	193	26	141
168	13	181	13	155	26	194	26	142
169	13	182	13	156	26	195	26	143
170	13	183	13	157	26	196	26	144
171	13	184	13	158	26	197	26	145
172	13	185	13	159	26	198	26	146
173	13	186	13	160	26	199	26	147
174	13	187	13	161	26	200	26	148
175	13	188	13	162	26	201	26	149
176	13	189	13	163	26	202	26	150

Life depth (metres)	*Standard excursions*				*Exceptional excursions*			
	Downward distances	*Downward depths*	*Upward distances*	*Upward depths*	*Downward distances*	*Downward depths*	*Upward distances*	*Upward depths*
177	13	190	13	164	26	203	26	151
178	13	191	13	165	26	204	26	152
179	13	192	13	166	26	205	26	153
180	15	195	15	165	30	210	30	150
181	15	196	15	166	30	211	30	151
182	15	197	15	167	30	212	30	152
183	15	198	15	168	30	213	30	153
184	15	199	15	169	30	214	30	154
185	15	200	15	170	30	215	30	155
186	15	201	15	171	30	216	30	156
187	15	202	15	172	30	217	30	157
188	15	203	15	173	30	218	30	158
189	15	204	15	174	30	219	30	159
190	15	205	15	175	30	220	30	160
191	15	206	15	176	30	221	30	161
192	15	207	15	177	30	222	30	162
193	15	208	15	178	30	223	30	163
194	15	209	15	179	30	224	30	164
195	15	210	15	180	30	225	30	165
196	15	211	15	181	30	226	30	166
197	15	212	15	182	30	227	30	167
198	15	213	15	183	30	228	30	168
199	15	214	15	184	30	229	30	169
200	15	215	15	185	30	230	30	170
201	15	216	15	186	30	231	30	171
202	15	217	15	187	30	232	30	172
203	15	218	15	188	30	233	30	173
204	15	219	15	189	30	234	30	174
205	15	220	15	190	30	235	30	175
206	15	221	15	191	30	236	30	176
207	15	222	15	192	30	237	30	177
209	15	224	15	194	30	239	30	179
210	15	225	15	195	30	240	30	180
212	15	227	15	197	30	242	30	182
213	15	228	15	198	30	243	30	183
214	15	229	15	199	30	244	30	184
215	15	230	15	200	30	245	30	185
216	15	231	15	201	30	246	30	186
217	15	232	15	202	30	247	30	187
218	15	233	15	203	30	248	30	188
219	15	234	15	204	30	249	30	189
220	15	235	15	205	30	250	30	190
221	15	236	15	206	30	251	30	191
222	15	237	15	207	30	252	30	192

Life depth (metres)	*Standard excursions*				*Exceptional excursions*			
	Downward distances	*Downward depths*	*Upward distances*	*Upward depths*	*Downward distances*	*Downward depths*	*Upward distances*	*Upward depths*
223	15	238	15	208	30	253	30	193
224	15	239	15	209	30	254	30	194
225	15	240	15	210	30	255	30	195
226	15	241	15	211	30	256	30	196
227	15	242	15	212	30	257	30	197
228	15	243	15	213	30	258	30	198
229	15	244	15	214	30	259	30	199
230	15	245	15	215	30	260	30	200
231	15	246	15	216	30	261	30	201
232	15	247	15	217	30	262	30	202
233	15	248	15	218	30	263	30	203
234	15	249	15	219	30	264	30	204
235	15	250	15	220	30	265	30	205
236	15	251	15	221	30	266	30	206
237	15	252	15	222	30	267	30	207
238	15	253	15	223	30	268	30	208
239	15	254	15	224	30	269	30	209
240	15	255	15	225	30	270	30	210
241	15	256	15	226	30	271	30	211
242	15	257	15	227	30	272	30	212
243	15	258	15	228	30	273	30	213
244	15	259	15	229	30	274	30	214
245	15	260	15	230	30	275	30	215
246	15	261	15	231	30	276	30	216
247	15	262	15	232	30	277	30	217
248	15	263	15	233	30	278	30	218
249	15	264	15	234	30	279	30	219
250	15	265	15	235	30	280	30	220
251	15	266	15	236	30	281	30	221
252	15	267	15	237	30	282	30	222
253	15	268	15	238	30	283	30	223
254	15	269	15	239	30	284	30	224
255	15	270	15	240	30	285	30	225
256	15	271	15	241	30	286	30	226
257	15	272	15	242	30	287	30	227
258	15	273	15	243	30	288	30	228
259	15	274	15	244	30	289	30	229
260	15	275	15	245	30	290	30	230
261	15	276	15	246	30	291	30	231
262	15	277	15	247	30	292	30	232
263	15	278	15	248	30	293	30	233
264	15	279	15	249	30	294	30	234
265	15	280	15	250	30	295	30	235
266	15	281	15	251	30	296	30	236

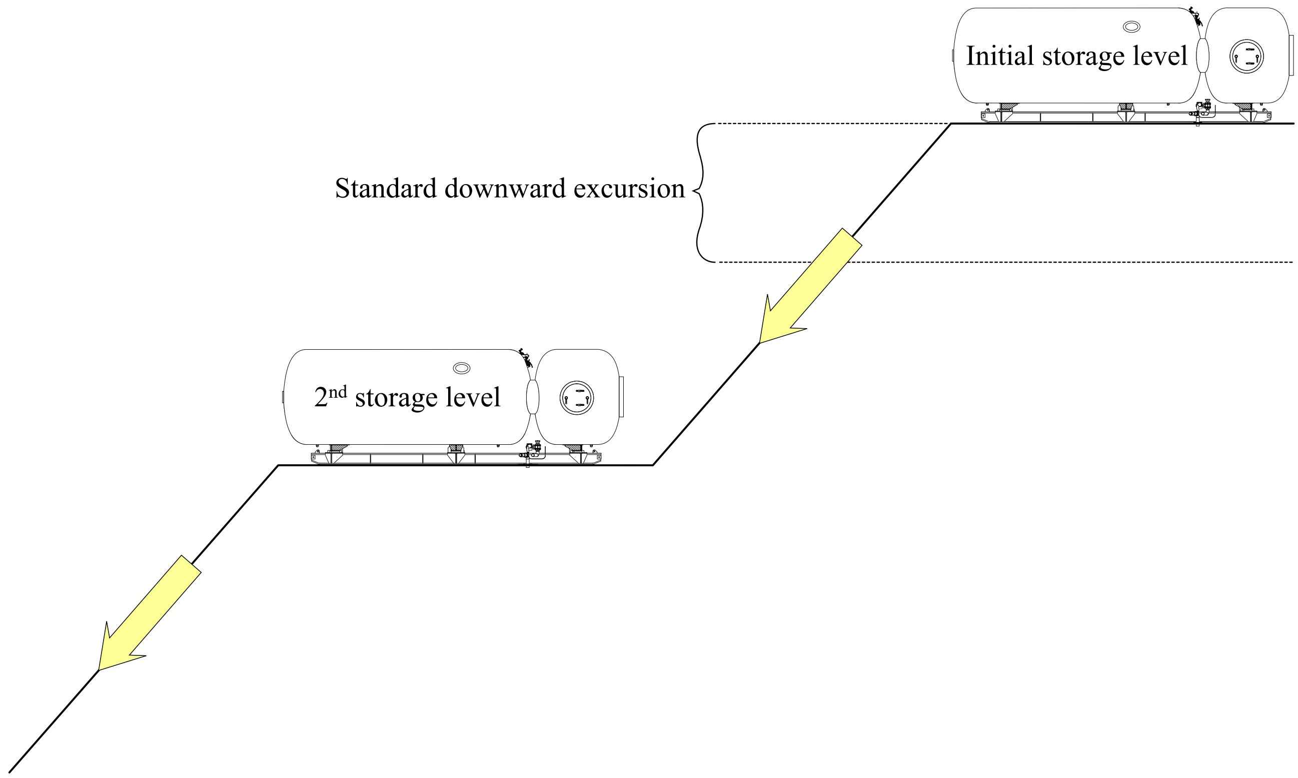
Life depth (metres)	Standard excursions				Exceptional excursions			
	Downward distances	Downward depths	Upward distances	Upward depths	Downward distances	Downward depths	Upward distances	Upward depths
267	15	282	15	252	30	297	30	237
268	15	283	15	253	30	298	30	238
269	15	284	15	254	30	299	30	239
270	15	285	15	255	30	300	30	240
271	15	286	15	256	29	300	30	241
272	15	287	15	257	28	300	30	242
273	15	288	15	258	27	300	30	243
274	15	289	15	259	26	300	30	244
275	15	290	15	260	25	300	30	245
276	15	291	15	261	24	300	30	246
277	15	292	15	262	23	300	30	247
278	15	293	15	263	22	300	30	248
279	15	294	15	264	21	300	30	249
280	15	295	15	265	20	300	30	250
281	15	296	15	266	19	300	30	251
282	15	297	15	267	18	300	30	252
283	15	298	15	268	17	300	30	253
284	15	299	15	269	16	300	30	254
285	15	300	15	270	15	300	30	255
286	14	300	14	272	14	300	25	261
287	13	300	13	274	13	300	25	262
288	12	300	12	276	12	300	25	263
289	11	300	11	278	11	300	25	264
290	10	300	10	280	10	300	25	265
291	10	301	10	281	Forbidden	–	25	266
292	10	302	10	282	Forbidden	–	25	267
293	10	303	10	283	Forbidden	–	25	268
294	10	304	10	284	Forbidden	–	25	269
295	10	305	10	285	Forbidden	–	25	270
296	10	306	10	286	Forbidden	–	25	271
297	10	307	10	287	Forbidden	–	25	272
298	10	308	10	288	Forbidden	–	25	273
299	10	309	10	289	Forbidden	–	25	274
300	10	310	10	290	Forbidden	–	25	275
301	10	311	10	291	Forbidden	–	Forbidden	–
302	10	312	10	292	Forbidden	–	Forbidden	–
303	10	313	10	293	Forbidden	–	Forbidden	–
304	10	314	10	294	Forbidden	–	Forbidden	–
305	10	315	10	295	Forbidden	–	Forbidden	–
306	10	316	10	296	Forbidden	–	Forbidden	–
307	10	317	10	297	Forbidden	–	Forbidden	–
308	10	318	10	298	Forbidden	–	Forbidden	–
309	10	319	10	299	Forbidden	–	Forbidden	–
310	10	320	10	300	Forbidden	–	Forbidden	–

Life depth (metres)	Standard excursions				Exceptional excursions			
	Downward distances	Downward depths	Upward distances	Upward depths	Downward distances	Downward depths	Upward distances	Upward depths
311	10	321	10	301	Forbidden	–	Forbidden	–
312	10	322	10	302	Forbidden	–	Forbidden	–
313	10	323	10	303	Forbidden	–	Forbidden	–
314	10	324	10	304	Forbidden	–	Forbidden	–
315	10	325	10	305	Forbidden	–	Forbidden	–
316	10	326	10	306	Forbidden	–	Forbidden	–
317	10	327	10	307	Forbidden	–	Forbidden	–
318	10	328	10	308	Forbidden	–	Forbidden	–
319	10	329	10	309	Forbidden	–	Forbidden	–
320	10	330	10	310	Forbidden	–	Forbidden	–
321	10	331	10	311	Forbidden	–	Forbidden	–
322	10	332	10	312	Forbidden	–	Forbidden	–
323	10	333	10	313	Forbidden	–	Forbidden	–
324	10	334	10	314	Forbidden	–	Forbidden	–
325	10	335	10	315	Forbidden	–	Forbidden	–
326	10	336	10	316	Forbidden	–	Forbidden	–
327	10	337	10	317	Forbidden	–	Forbidden	–
328	10	338	10	318	Forbidden	–	Forbidden	–
329	10	339	10	319	Forbidden	–	Forbidden	–
330	10	340	10	320	Forbidden	–	Forbidden	–
331	10	341	10	321	Forbidden	–	Forbidden	–
332	10	342	10	322	Forbidden	–	Forbidden	–
333	10	343	10	323	Forbidden	–	Forbidden	–
334	10	344	10	324	Forbidden	–	Forbidden	–
335	10	345	10	325	Forbidden	–	Forbidden	–
336	10	346	10	326	Forbidden	–	Forbidden	–
337	10	347	10	327	Forbidden	–	Forbidden	–
338	10	348	10	328	Forbidden	–	Forbidden	–
339	10	349	10	329	Forbidden	–	Forbidden	–
340	10	350	10	330	Forbidden	–	Forbidden	–
341	9	350	10	331	Forbidden	–	Forbidden	–
342	8	350	10	332	Forbidden	–	Forbidden	–
343	7	350	10	333	Forbidden	–	Forbidden	–
344	6	350	10	334	Forbidden	–	Forbidden	–
345	5	350	10	335	Forbidden	–	Forbidden	–
346	4	350	10	336	Forbidden	–	Forbidden	–
347	3	350	10	337	Forbidden	–	Forbidden	–
348	2	350	10	338	Forbidden	–	Forbidden	–
349	1	350	10	339	Forbidden	–	Forbidden	–
350	Forbidden	–	Forbidden	–	Forbidden	–	Forbidden	–

2.7 - Intermediate compressions and decompression

2.7.1 - intermediate compressions

The 1st storage depth may be the final life level from which the operations are organized. Nevertheless, it often happens that the chamber has to be readjusted to a depth that allows reaching a workplace that is beyond the range permitted by the downward excursions from the initial storage level.
The relocation of the chamber cannot be undertaken at the speed of 10 metres/minute used by the divers during excursions and a procedure similar to the one used for the 1st pressurization must be implemented.
Two scenarios may happen that are explained in this chapter: Pressurization of the chamber during a rest period and pressurization of the chamber during a bell run.



2.7.2 - Summary of the pressurization procedure of the chamber during a rest period

2.7.2.1 - Procedures for compressions starting within the standard saturation range

2.7.2.1.1 - Gas parameters

PP O2: 0.4 to 0.57 bar (400 to 570 mb)

PP CO2 : < 0.005 bar (< 5 mb)

2.7.2.1.2 - Pressurization speeds and stabilization stops

Amplitude of the pressurization	*Maximum compression speeds*	*Stabilization stops*
< 30 metres *Range:* from 10 m to above 210 m	- From 10 to 180 m: 1 minutes/metre - From 181 to 200 m: 4 minutes/metre - From 201 to 210 m: 6 minutes/metre	- No stabilization required, even in the case of transition to a deep saturation *(below 180 m).*
30 to < 50 metres *Range:* from 10 m to above 230 m	- From 10 to 180 m: 1 minutes/metre - From 181 to 200 m: 4 minutes/metre - From 201 to 230 m: 6 minutes/metre	- 2 hours stabilization when reaching the new saturation depth, not stopping at 200 m in case of a transition to a deep saturation *(below 180 m).*
> 50 metres *Range:* from 10 m to above 350 m	Apply the same procedure as for an initial compression: - From 10 to 180 m: 1 minutes/metre - From 181 to 200 m: 4 min/metre - From 201 to 300 m: 6 min/metre - From 301 to 350 m: 8 minutes/metre	Apply the same procedure as for an initial compression: - Depending on the final depth, apply the stabilization criteria of a standard or a deep saturation indicated in points 3.2.2.1, 3.2.2.2, and 3.2.23. - Start from the storage depth where the chamber is and apply the procedure from this point to the next depth .

2.7.2.2 - Procedures for compressions starting within the deep saturation range

2.7.2.2.1 - Gas parameters

PP O2: 0.4 to 0.57 bar (400 to 570 mb)

PP CO2 : < 0.005 bar (< 5 mb)

2.7.2.2.2 - Pressurization speeds and stabilization stops

Amplitude of the pressurization	*Maximum compression speed*	*Stabilization stops*
< 30 metres *Range:* from 181 m to above 330 m	- From 181 to 200 m: 4 minutes/metre - From 200 to 300 m: 6 minutes/metre	- No stabilization required.
31 to 50 metres *Range:* from 181 m to above 350 m	- From 181 to 200 m: 4 minutes/metre - From 200 to 300 m: 6 minutes/metre	- Two hours of stabilization when reaching the new saturation depth.
> 50 metres *Range:* from 181 m to above 350 m	Apply the same procedure as for an initial compression, but starting below 180 m: - From 181 to 200 m: 4 minutes/metre - From 200 to 300 m: 6 minutes/metre - From 300 to 350 m: 8 minutes/metre	Apply the same procedure as for an initial compression, but starting below 180 m: - Depending on the final depth, apply the stabilization criteria of a deep saturation indicated in points 3.2.2.2, and 3.2.2.3. - Start from the storage depth where the chamber is and apply the procedure from this point to the next depth .

2.7.2.3 - Procedures for compressions starting within the exceptional saturation range

2.7.2.3.1 - Gas parameters

PP O2: 0.4 to 0.57 bar (400 to 570 mb)

PP CO2 : < 0.005 bar (< 5 mb)

2.7.2.3.2 - Pressurization speeds and stabilization stops

Intermediate compressions should not be done in dives with storage depth (life level) between 300 and 350. However, if it is necessary for safety reasons, the speed for pressurization and the procedures for stabilization stops should be those of the initial pressurization that can be found in the table on the next page.

Compression rates and stabilization in the initial compression prior to start the diving operations

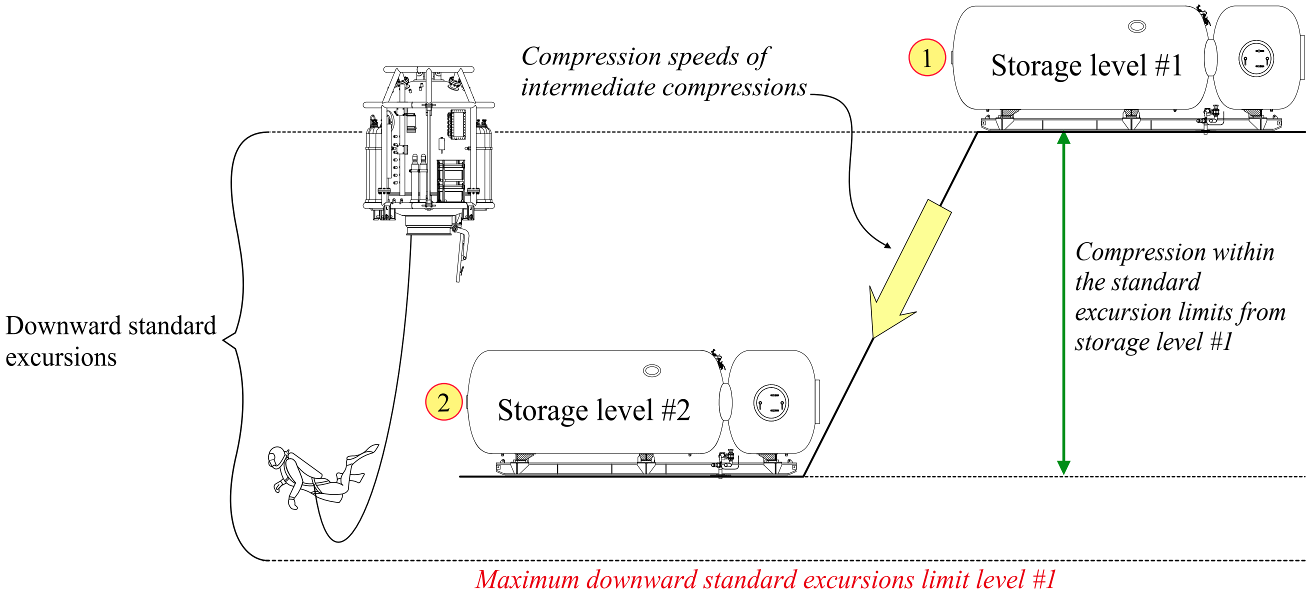
Saturation depth	***Maximum compression speed***	***Stabilization stops***
300 to 350 metres	- From 300 to 350 m: 8 minutes/metre (0.125 m/minute)	Stabilization stop of least 12 hours at the saturation depth

2.7.2.4 - Excursions upon arrival at the storage depth

Prior to undertaking excursions, the stabilization periods for compression distances superior to 30 m that can be read in the tables in point 2.1 must have been completed. After this initial rest period, upward and downward excursions are possible regardless of the depth in which the saturation is.

2.7.3 - Pressurization of the chamber during a bell run

It may happen that small readjustments of the chamber have to be performed during a bell run.
Change the chamber storage level to a deeper depth during a bell run is possible only if the new depth of the chamber is within the standard excursion limits of the divers at work.
Also, the divers at rest in the chamber must not have performed an exceptional upward excursion within the previous 12 hours.
The change of level must be performed at the compression speeds indicated in point 3.5.2.



2.7.4 - Decompression during a bell run and excursions after an intermediate decompression

2.7.4.1 - Decompress the chamber during a bell run

It may happen that small upward readjustments of the chamber have to be performed.

However, we must keep in mind that NORSOK standard U 100 says that "a decompression shall not start with a pressure reducing (upward) excursion", and that this point is also confirmed in the French decree of May 1992.

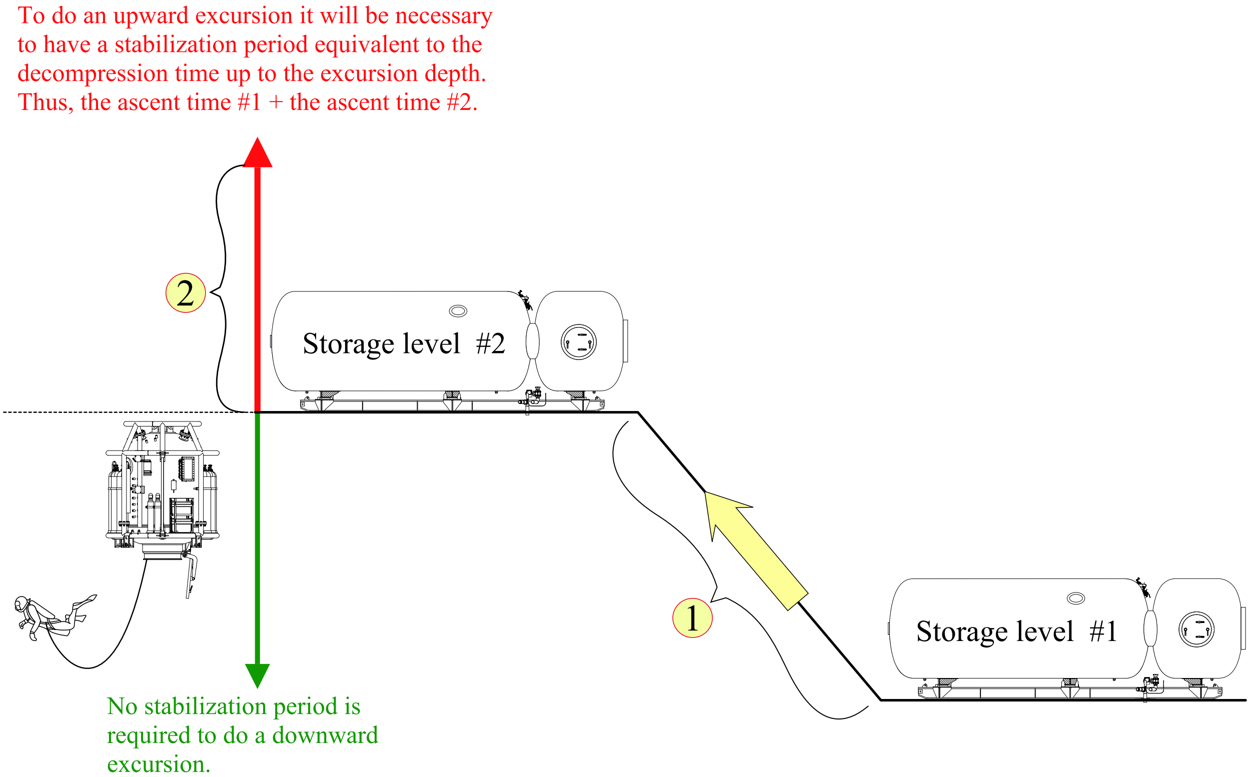
For these reasons, the chamber should never be decompressed during a bell run.

2.7.4.2 - Excursions after an intermediate decompression

NORMAM-15 says:

After an intermediate decompression, no stabilization period is required to do a downward excursion upon arrival at the new depth.

However, to do an upward excursion, it will be necessary to have a stabilization period equivalent to the decompression time up to the excursion depth. In other words, the stabilization period must be equal to time needed to reach the shallower storage level (level #2) at an ascent speed of 50 minutes/metre (or 90 min/metre above 20 m) plus the time that should be necessary to reach the upper level of the planned excursion at the same speed.



Notes:

- After an ascent to a new storage depth, there is an increased risk of a decompression accident which will last several days. Thus, the upward excursions should be avoided or minimised for several days.
- As indicated in point 2.5.4 "*Recommendations for organizing bell runs and excursions",* it is preferable to establish a shallower storage depth rather than perform a series of repetitive upward excursions.

2.8 - Divers at work during the bell runs

- The divers leave the bell only when the supervisor permits them to do so.
- When leaving the bell, the divers ensure that the underwater conditions are practicable: The job site is easily reachable, the current is fair, their gear (helmet, hot water suit…) is working fine.
- The divers ensure at all times that their umbilicals are in a direct way to the bell and will not be entangled: The divers should be able to return quickly to the bell at any moment.
- If not already installed, the divers install the downline at the dedicated place.
- The installation of the job has to be done according to the task plan.
- Load transfers from the surface to the bottom or above the surface should not be performed when the bell and the divers are at the bottom and potentially underneath *(refer to point 1.2.6)*.
- The potential dangers such as water intakes, electrical, pipelines, and others, must be avoided by the divers… They must remind the divers before leaving the bell and when on the worksite: The supervisor must stop a diver coming towards dangerous areas.
- The diver must never be in front of devices which are or were under pressure or causing suction:
  - The approach must be from the side, even for devices indicated secured.
  - Before any action, the diver should ensure no residual pressure (rag at the end of a stick, "zero on gauge").
  - The supervisor must stop any diver working in a front of a device with potential suction or blow-out.
- The diver should not start any action if he is not 100% sure that it is safe.
- When working in the vicinity of an ROV, the divers and the supervisor ensure the position of the machine and that it is sufficiently far from the divers and their umbilicals.
- If working from a Dynamic Positioning vessel using a taut wire, the location of the taut wire must be remembered.
- The diver should be in direct communication with the supervisor all the time, and misunderstanding must be avoided:
  - The diver should always repeat the instructions given by the supervisor and report to him any action he is performing.
  - When the instructions are unclear, the diver requests clarification.
  - The diver should return to the bell if the communications set is not working properly: Trying to understand instructions or reports through a bad communication system can lead to misunderstanding, thus an accident.
  - If the diver does not perform the task correctly, the supervisor must stop him and ensure that the procedure explained during the toolbox talk is followed.
  - If the supervisor considers that he has no control of the diver, the supervisor must stop the dive.
- In case of an incident, even minor, the diver should report to the supervisor.

2.9 - Bell and helmets cleaning following the bell run.

2.9.1 - Bell cleansing

The bell may be dirtied during the bell run and must be cleaned at the end of it to ensure that the next team will operate in a clean bell without pollutants and pathogens. The procedure used will depend on the degrees of dirt of the bell. The bell is often soiled when the divers work on muddy bottoms. However, it can be nearly clean when the divers operate in clear water at mid-depth.

If the bell is not dirty, the procedure of cleaning can be similar to the one recommended in the document DMAC 26 for the cleaning and disinfection of chambers.

- Cleansing with disinfecting agents such as "Tego 103G", “Tego 2000”, or “Trigene” should be started at the top of the bell and continued downwards, with excess cleanser ultimately drained from the bottom. Relays of fresh clothes/sponges should be used on each occasion and discarded after limited use.
- The disinfectant agents selected should be very effective against the microbes known to flourish in the bell and be non-toxic to man. Additionally, they should be odourless, non-volatile, and be free from irritant and sensitising properties. "The advantage of Tego products compared with others is that they combine the requirements above. These 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.
- Note that the reclaim system must be regularly cleaned, which includes the regular cleaning of the water traps.

If the bell is dirty, or the diving operations have been performed in contaminated waters, the procedure above will be insufficient to return it as it should be. In this case, a substantial quantity of water may be necessary, in addition to more working time. For this reason, it may be advantageous to recover the unit to the surface and disconnect it to allow the surface assistants to do it with more appropriate tools such as soft water jets.

- When the bell is opened, the water jet is used to clean all the soiled parts. That includes the umbilicals.
- When the dirt has been removed, the bell must be disinfected. The products to be used and the procedures for final cleaning and disinfection are the same as those indicated above.
- When the full disinfection is completed, the bell can be returned to service.

2.9.2 - 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.
13. When the tests are satisfactory, The helmet is protected from contamination in a sealed bag and then be transferred into the system when required.

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3) Emergency procedures

The scenarios indicated below are only some of the numerous scenarios which could happen during a bell run. It must be remembered that when an undesirable event happens, it may not be exactly as indicated in the scenario considered and is often cumulated with another undesirable event.

3.1 - Principles for injured or unconscious diver recovery

3.1.1 - Diver injured but conscious

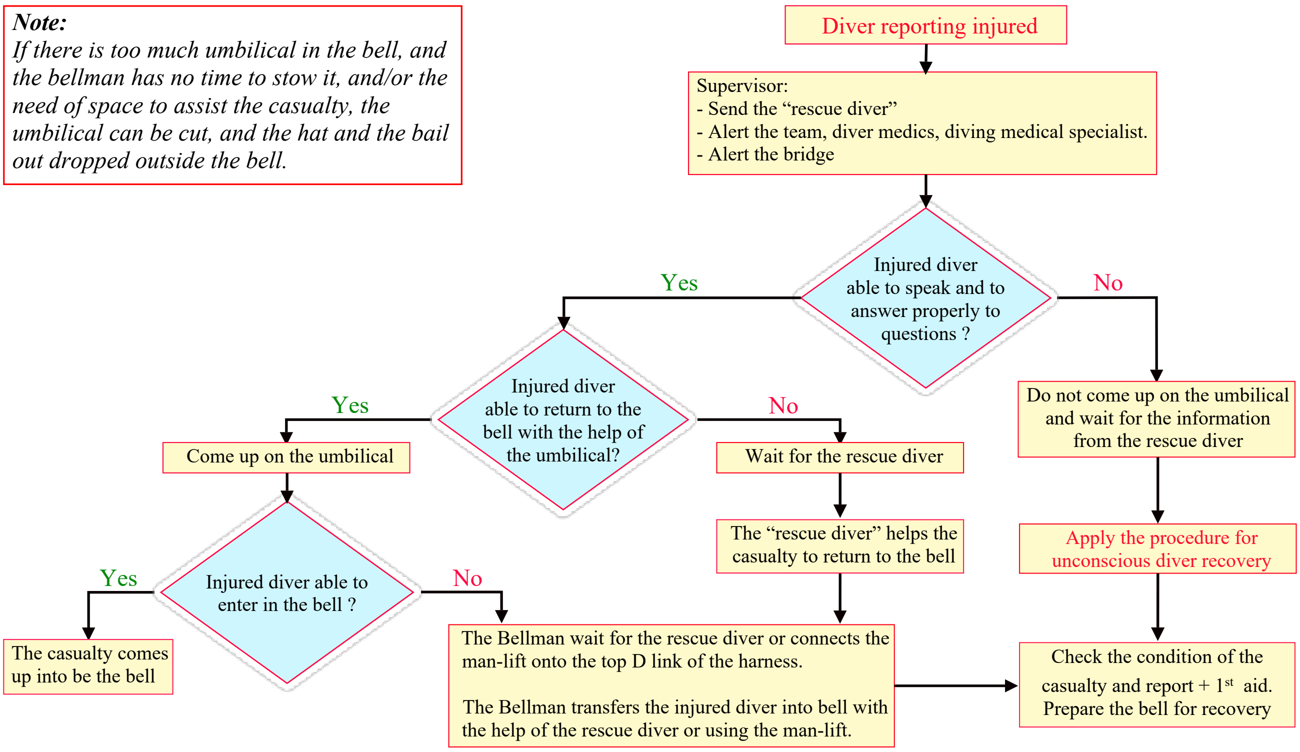
3.1.1.1 - Potential consequences

- Diver suffering
- Panic
- Unable to return to the bell
- It must be kept in mind that the situation can quickly change and a person conscious, can quickly fall unconscious.

3.1.1.2 - Actions to control

Action diver	Action bellman	Action surface
- Inform the surface. - Give a status of his situation. - Try to return to the basket if he can do it.	- Deploy the man-lift & flood the bottom of the bell. - Prepare for rescue if required and wait for instructions from the supervisor. - Follow the instructions from the supervisor (rescue or umbilical). - Recover the casualty in the bell, check the condition of the casualty, and report to surface + 1st aid (Diver medic), secure the casualty (If necessary put the casualty on BIBS with rich mix). - Prepare for recovering. Close and seal the bottom door, and prepare for transfer. - When the bell is connected to the system, help the injured diver to transfer in the TL.	- Depending on the depth and availability, the 2nd diver, the bellman, or the standby diver is warned in case assistance is needed - Alert the team, diver medics (chamber and outside) contact the diving medical specialist (Ask the diver medic to do it). - Alert the bridge. - Instruct the bellman to come up on the umbilical if the injured diver is able to speak and give clear indications. Apply the procedure for unconscious diver if the casualty does not answer properly to the questions. - When the casualty is in the bell, inform the diver medic and give a 1st status. - Recover the bell and transfer the casualty to the chamber (hospital).

Note:
If there is too much umbilical in the bell, and the bellman has no time to stow it, and/or the need of space to assist the casualty, the umbilical can be cut, and the hat and the bail out dropped outside the bell.



3.1.2 - Diver unconscious due to wrong gas, loss of supply, or other reason

3.1.2.1 - Potential consequences

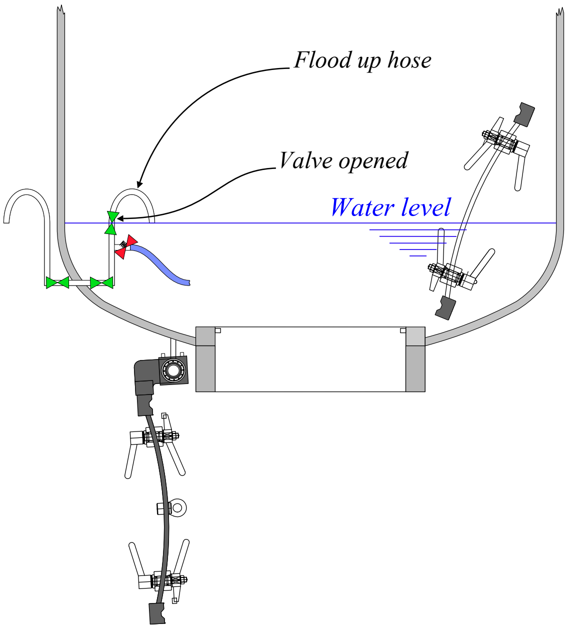
Depending on the reasons:
- Asphyxia
- Hat off / Drowning
- Injuries
- Fatality if nothing is undertaken

3.1.2.2 - Summary of the actions to control

Action diver (rescue)	Action bellman	Action surface / In chamber
Diver (Casualty) : Unconscious Rescue diver: - Follow diver's umbilical to locate diver. - Once the casualty is reached, open the free flow to flush the line. - Report the status to the surface - Drag the diver to the bell and upon arrival , hook the man-lift onto the D link (top of harness). - Recover diver into the bell as soon as possible. (If the rescue diver is the bellman , he has to return in the bell 1st) *Warning:* *It could be possible that in case of 2 divers at work, the 2 divers become unconscious. In this case, the first priority is to restore a correct gas supply to the unconscious divers prior to recovering into the bell. This is the worse scenario, and in this case, the ROV may be used to help.*	- If not informed by the supervisor that the back up supply from surface is on line, change the divers supply to the onboard gas. - Deploy the man-lift & flood the bottom of the bell - Prepare for rescue if required, and wait for instructions form the supervisor. - Follow the instructions from the supervisor (rescue or umbilical).- Recover the casualty into the bell (with the help of the rescue diver or alone). When the casualty is in the bell: - Secure him and remove his hat ASAP. - Check the casualty. - Install a semi-rigid collard and a guedel tube on the casualty to free the airways and drain the mouth. Start assisted ventilation and CPR if necessary *(see next page).* Follow the instructions. - Recover and store the umbilicals, close and seal the door, prepare for ascent and report when ready. - Put the casualty on rich mix gas, and watch him during the ascent. Perform CPR if necessary. - Transfer the casualty to the TL when the bell is back on the system.	Supervisor: - Switch on backup supply and inform the bellman that the diver is unresponsive and the supply on back up. - Depending on possibilities send: The 2nd diver, the bellman or the standby diver. - Request monitoring from the ROV - When the rescue diver is on the casualty, request him to flush the mask (to be sure that there is no wrong gas in the line). - Record the status and inform LSS/LST & the diver medic in chamber. - When the casualty is in the bell, prepare the team for bell recovery and the transfer of the casualty to the chamber. Diver medic in TL & chamber: - Remove the casualty from the bell. - check airways, CPR may be necessary. - Put the casualty on BIBS with rich mix. - Report status to surface and wait for instructions from the diving medical specialist.

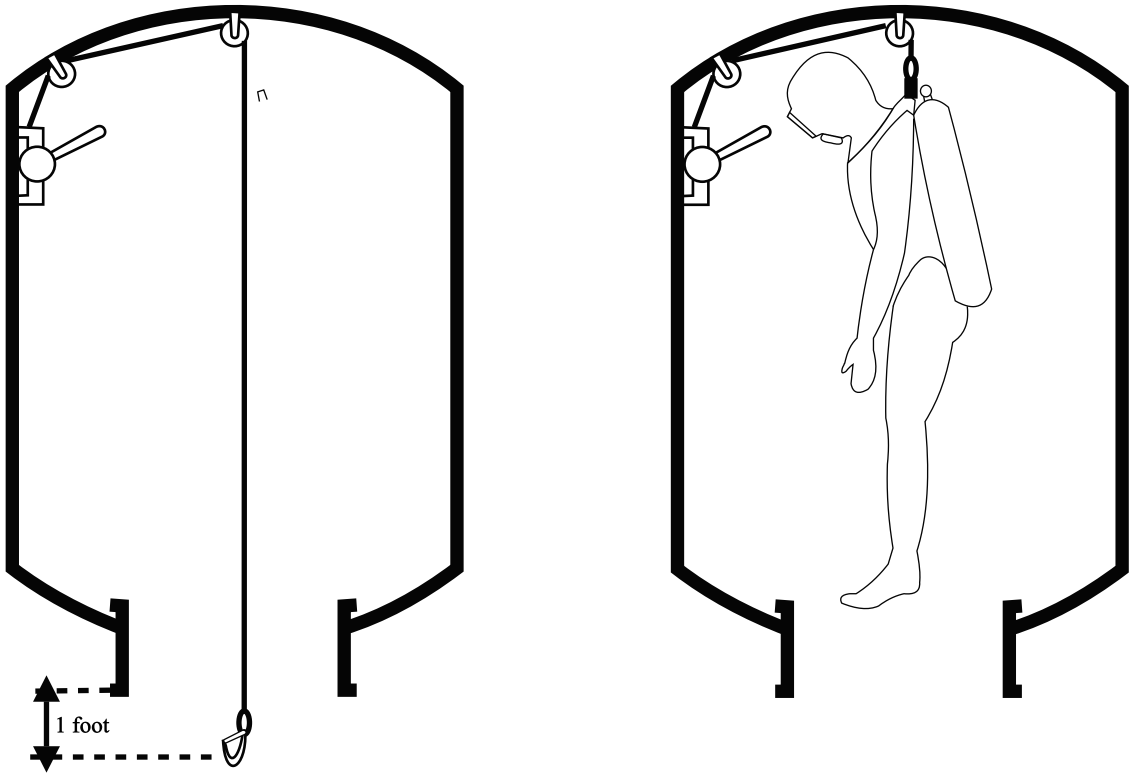
3.1.2.3 - Water level control before leaving the bell

Note that this topic is already discussed in point 1.1.2, "Diving bell", of this document.
The transfer of an unconscious casualty through the bottom hatch requires strenuous efforts that, depending on the size and weight of the casualty, the bellman may not be able to provide. Also, the bell may not be equipped with a standoff frame or a clump weight designed to be used as a stair.
Raising the water level inside the bell can help in this matter, as a higher water level will help the bellman or the divers climbing back inside. Note that if the bellman forgets to raise the level before leaving the bell, he may have great difficulty getting back inside.
Also, care must be taken not to flood equipment such as the scrubber unit and communications systems.
The partial flooding system's function is to avoid the bell to be totally flooded if the valve is left open by mistake while the bellman is leaving the bell to rescue the diver.
When the divers are back in the bell, the excess water is flushed out by activating the pressurization valve. For this reason, this system is gas consuming.

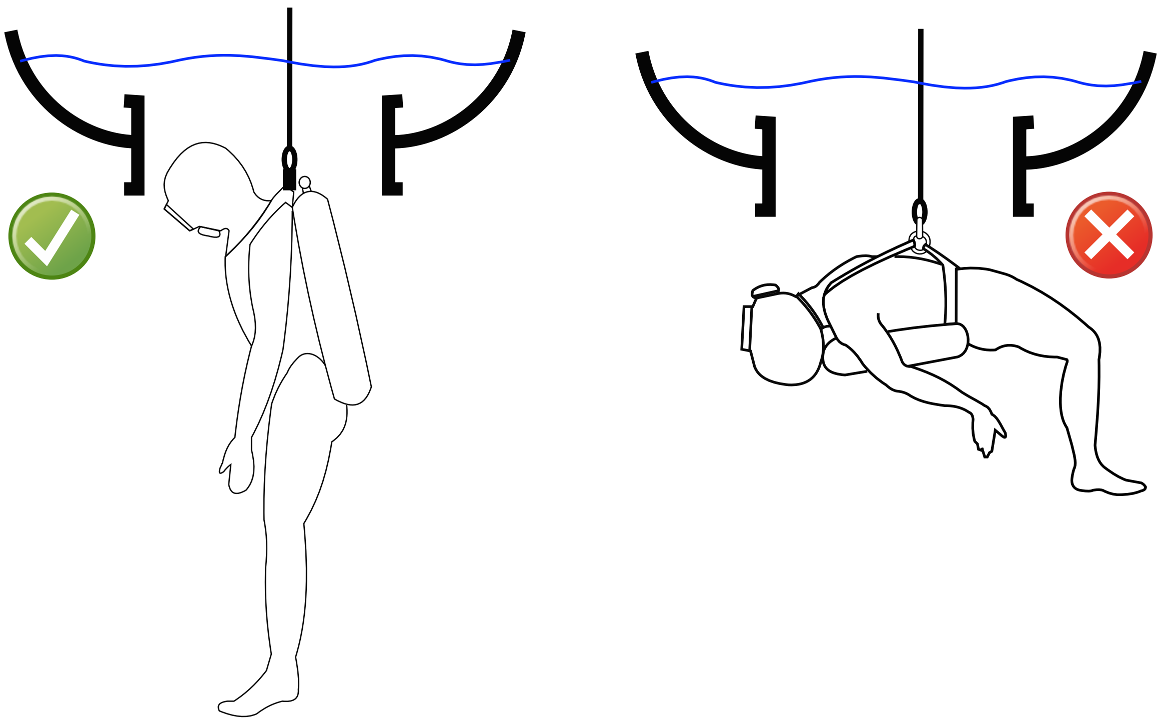


3.1.2.4 - Transfer an unconscious diver into the bell

There must be a mechanical lifting device installed in the bell to secure the casualty and lift him as high as possible inside the bell to clear the trunking. During the bell run, the lifting device's hook should be deployed and adjusted around 1 foot below the hatch.



The hook of the lifting device must be connected to the D link on the top of the harness as another lifting point could compromise the recover of the unconscious diver into the bell. *(see picture below)*



3.1.2.5 - Priorities

Experience has shown that bringing the man inside the bell, clearing him from the trunking, closing and sealing the door, can take a surprisingly long time, and therefore the helmet needs to be removed as soon as possible after the diver is secured in the bell. Note that the resuscitation must take place first.

3.1.2.6 - Assessing the state of the diver *(Source: COMEX medical book)*

When the casualty is back and secured inside the bell, the bellman/diver medic should assess the state of the diver:

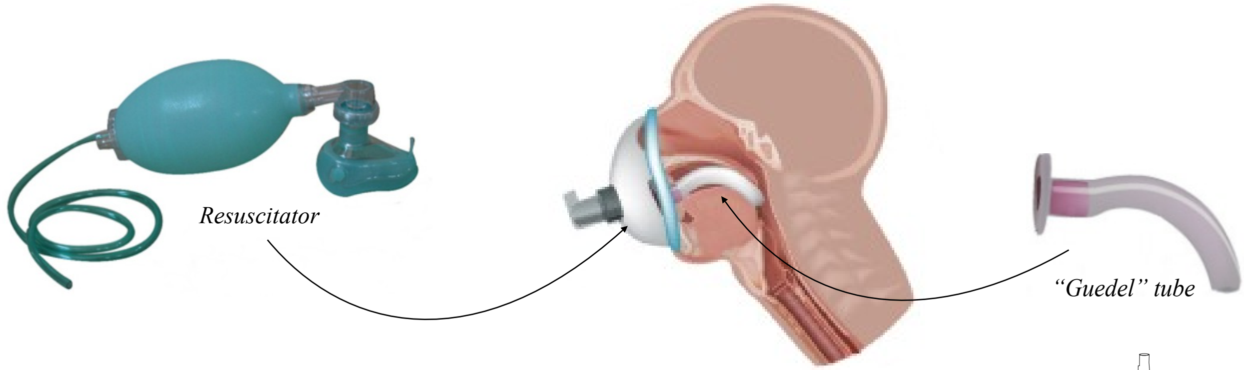
- Breathing may have stopped. Presence of breathing will be confirmed or not as soon as his mask is removed.
- Heart beat may have ceased. Cardiac function will have to be checked at the carotid artery.
- He can present some visible injuries.
- Note that the casualty may recover consciousness.

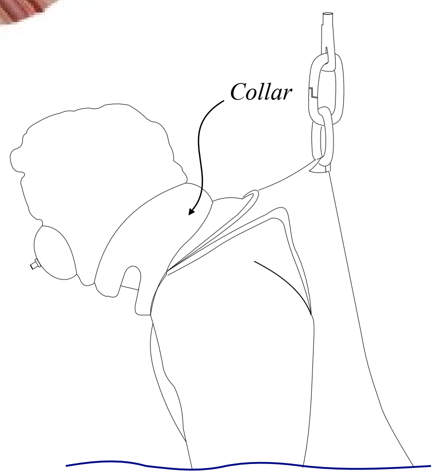
The state of the diver should be immediately reported to the diver medic at the surface who should be in touch with the Diving Medical Specialist.

3.1.2.7 - Assisted ventilation *(Main source: COMEX medical book)*

When it has been established that the diver is not breathing:

- Airway must be cleared of vomit or other foreign matter.
- Respiration must be restored.
- The rigid collar fitted around the neck will raise the chin and open the airway.
- The Guedel tube (*oropharyngeal airway*) must be inserted (A screw type mouth opener should be provided in the medical kit DMAC 15):
    - It will ensure the tongue is "out of the way"
    - It will ensure a free airway
- The resuscitator can be then installed if possible. (Resuscitator is preferable than mouth to mouth)





Water level kept high to prevent pooling of blood in the legs.

- Then, assisted ventilation can be started along with cardiac massage if necessary.
- It is recommended to keep the water level high to prevent pooling of blood in the legs, as the blood density is similar to that of sea water.
- It is important that the Dive Supervisor keep the communication to a minimum

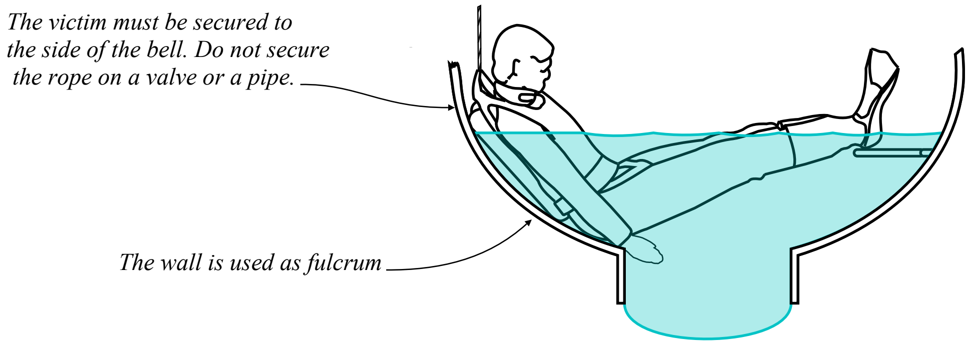
at this point so the bell man can concentrate on the rescue.

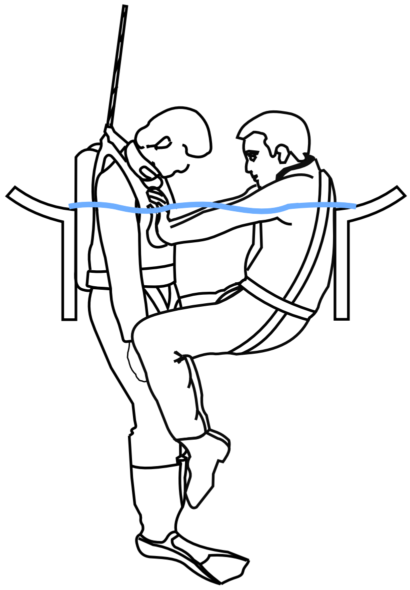
3.1.2.8 - External cardiac massage

The main problem in a diving bell is the limited space to manage a casualty. If the casualty is hanged and a pressure is applied without fulcrum, the result will be the victim swinging and inefficient massage, as a cardiac massage cannot be performed if there is no fulcrum.

Several procedures can be used to answer to these problems.

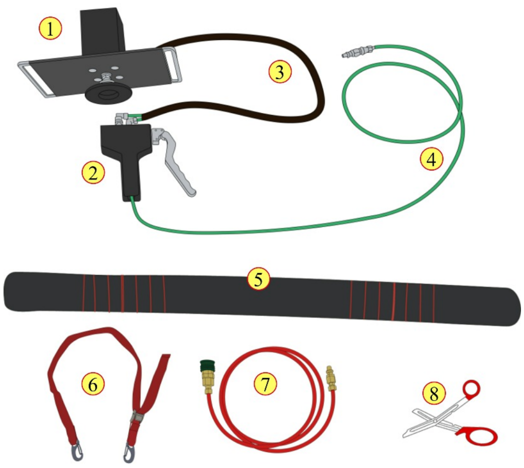
- The first procedure consists of seating the patient in the lower part of the bell, which may be partially flooded or not, or on a seat. The legs can be raised to improve blood supply to the vital organs (heart, brain) and to gain some space. The patient can be maintained in position by his harness, which is secured to the wall of the bell if necessary. This procedure is possible only if the bell is sufficiently broad and the patient can be secured to prevent falling into the trunk.





- The 2nd procedure is taught by some diving schools, and consists to maintain the patient suspended in the bottom trunk and perform the CPR there:
    - Push the casualty to the side of the trunk with your legs and maintain him in this position.
    - Start the compression when the side of the trunk can be used as fulcrum.

These techniques allow for performing cardiac massage upon the recovery of the unconscious diver to the bell, thereby saving precious seconds.
Other techniques that have been commonly taught were head-to-chest and knee-to-chest compressions. However, these methods were not supported by efficacy data, and recent tests discussed in a document titled *"Delivering Manual Cardiopulmonary Resuscitation (CPR) in a Diving Bell: An Analysis of Head-to-Chest and Knee-to-Chest Compression Techniques"* by Dr. Graham Johnson, Dr. Philip Bryson, Dr. Nicholas Tilbury, Dr. Benjamin McGregor, Dr. Alistair Wesson, Dr. Gareth D. Hughes, Dr. Gareth R. Hughes, and Dr. Andrew Tabner conclude that these two techniques are poorly effective. Also the head-to-chest technique has been found to cause harm to providers and should no longer be taught. For this reason, these two techniques are no longer discussed.
In another document titled *"An Evaluation of the NUI Compact Chest Compression Device (NCCD), a Mechanical CPR Device Suitable for Use in the Saturation Diving Environment"*, which is, in fact, the continuation of the above one, the same team of scientists has compared the efficiency of the Compact Chest Compression Device (NCCD), a CPR device developed by the Norwegian Underwater Institute (NUI), with classical CPR techniques performed by experts. In addition to providing guidelines for implementing this device, the authors conclude that it is efficient. We can, therefore, suggest that such devices should be systematically included in the bell's medical kit.
the Compact Chest Compression Device (NCCD) is powered by compressed gas at a pressure of 10 bar above the ambient pressure of the bell. Finding a gas supply source in the bell is not a problem, so the availability problem is solved. The manufacturer recommends not using mixtures with more than 22% PPO2 (NORSOK standard limit is 22%) and continuously monitoring the PPO2 and ambient pressure of the bell, which any trained supervisor is accustomed to doing at all times. The machine consists of the following parts, stored in a reinforced sealed box:



1. Compression unit, which includes the piston house, the bottom plate, and the piston foot that transmit the movements of the piston
2. Hand control unit that allows starting and stopping the compressions
3. Supply hose from the hand control
4. Supply hose of the hand control unit.
5. Velcro strap with adjustment markings to secure the unit in place.
6. Adjustable support strap designed to prevent the compression unit from sliding down.
7. Extension hose of 1.5 m.
8. Scissors that are strong enough to cut fabrics.

NCCD manual and commercial services: https://www.nui.no/nccd/

3.1.2.9 - Use of defibrillators (Source: DMAC, Helix, & manufactures)

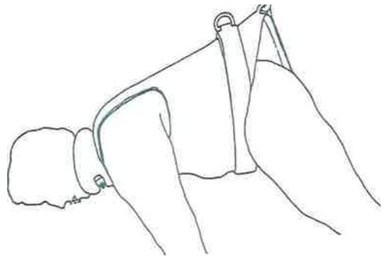
The Diving Medical Advisory Committee (DMAC) has published the *"Report on Tests of Zoll Automatic External Defibrillator Function in Hyperbaric Heliox Conditions"* from Helix Energy Solutions. This well-documented report indicates that the equipment tested experienced some malfunctions when used in fully autonomous mode within the test chamber. The authors recommend that the preferred solution to address this issue is to install the unit outside the chamber and connect its external plug to an electrical penetrator with a corresponding internal plug, to which the defibrillator electrodes can be connected. Unfortunately, such a solution is currently not applicable to a bell, as it necessitates studying and implementing specific system modifications.
Other articles regarding hyperbaric defibrillation in medical hyperbaric chambers exist mostly written by medics or manufacturers. However, the tools described in these publications are not designed for the pressures in saturation systems. Nevertheless, the progress of technology may quickly change this status.

3.1.2.10 - When cardiac and respiratory functions are restored (Source: COMEX medical book)

If the man is still not conscious, priority should then be given to:
- Clear him off the trunking
- Lower the water level
- Close and secure the hatch
- Check the patient again.

When the hatch is closed, the bell can be lifted up and the bellman can devote all his attention to the patient.

He should not be left hanging in the vertical position. Attempts should be made to sit him up.

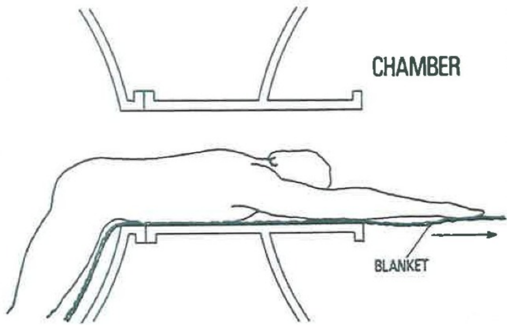


Unconsciousness is a sign that blood circulation may not yet be normal, and that not enough blood is reaching the brain.
In order to help in this respect, another manoeuvre can be attempted, which will consist of re-lifting the man by means of the mechanical lifting device, but this time, from one of the lifting eyes fitted on his harness at the belt or bottom level.
This manoeuvre may be restricted by the size of the bell but should allow a sufficient flow of blood to reach the brain.

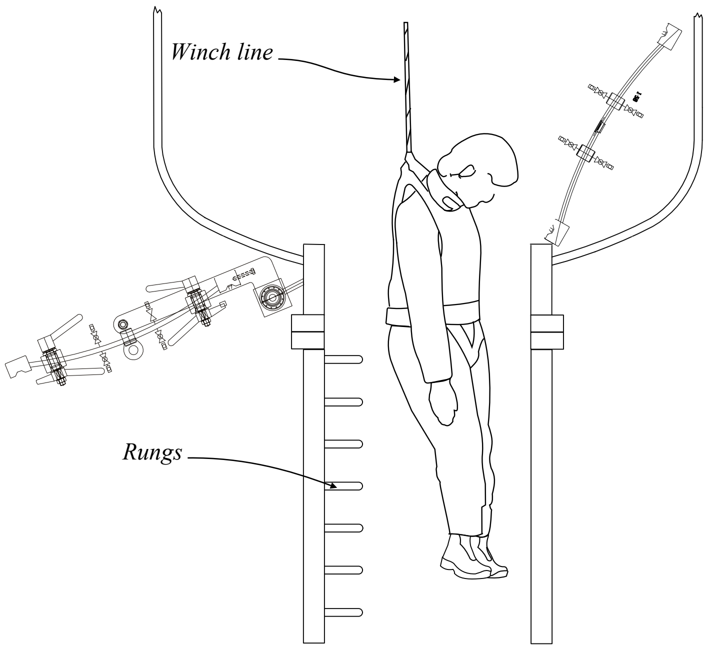
3.1.2.11 - Transfer the patient to the chamber (Source: COMEX medical book/ CCO Ltd)

If the bell is connected laterally, the patient is passed through the lateral hub after mating the bell to the chamber, as follows:
- A blanket is laid in the hub,
- The diver is laid on the blanket,
- The blanket is gently pulled into the chamber.

While waiting for instruction from the Diving Medical Specialist, put the patient on BIBS with high PO_2 breathing mixture.



If the bell is connected through the bottom hatch, the patient is lowered through the connecting trunk using the dedicated winch and his harness.
In this case, there must be some precautions to ensure that the casualty will not be caught by the rungs and adequately managed:
- The limbs should be arranged such that they cannot be passed behind a rung (eventually attach them).
- The body should be adequately oriented and is guided during the lowering to the transfer lock.
- A diver should be present in the trunk to control the casualty during the descent phase.



3.2 - Incidents during the launching & recovery, and when the bell is at depth

3.2.1 - Incidents during the launching & recovery of the bell

3.2.1.1 - Uncontrollable bell movements during 1st lift

- Potential consequences:
  - Shocks whith may result of damages to the bell, winches, and lifting cables.
  - Damages to other equipment.
  - Personnel injured.
  - Falls to deck or at sea.
- Actions to implement:

Action divers	Action bellman	Action surface
- Stay in their seats and secure their safety belts or harnesses.	- Stay in his seat and secure his safety belt or harness. - Report uncomfortable condition.	- Stop the action and return the bell to the initial position. Use tag lines for controlling the bell if possible. - In case of shocks, make sure they have not damaged the bell, particularly the flanges, clamp, and seal. - Ensure the divers are in their seats.

3.2.1.2 - Too many waves in the splash zone

- Potential consequences:
  - Bell tossed by the waves and damaged as a result of shocks to the hull.
  - Divers uncomfortable or injured.
  - The standby diver cannot be launched.
  - The rescue ROV cannot be launched.
- Actions to implement:

Action divers	Action bellman	Action surface
- Stay in their seats and secure their safety belts or harnesses.	- Requests aborting the dive immediately. - Stay in his seat and secure his safety belt or harness. - In case of shocks, perform a checklist and report to the supervisor.	- Stop the dive and recover the bell immediately, or use the aerator system if available *(see point 1.1.10.8)*. - Ensure that the divers are secured in their seats and not injured. - Check the bell to make sure that shocks have not damaged the bell, particularly the flanges, clamps and seals.

3.2.1.3 - Strong current detected when the bell arrives at depth

- Potential consequences
  - Fatigue
  - Hypercapnia
  - Intervention of the rescue diver dangerous or impossible.
  - ROV launching and bell rescue difficult or impossible.
- Actions to implement

Action divers	Action bellman	Action surface
- Send the information to the supervisor as soon as detected. - Return to the bell.	- Send the information to the supervisor as soon as detected. - If the diver has been launched, recover the diver when instructed to do so. - Wait for instructions.	- Stop the descent if strong currents are reported during the descent. - Stand by for improvement in the bell if it is at the bottom and the rescue of the bell using ROV is possible. - Abort the bell run if there is too much current and the deployment of rescue divers or ROV is not possible.

3.2.2.4 - Loss of bell pressure when it is at the surface

- Potential consequences:
  - Uncontrolled loss of pressure is one of the most critical incidents which can happen with a bell. It must be kept in mind that such an incident can trigger a decompression accident, or worse, an explosive decompression. *(See the report of "Byford Dolphin" accident in Book #4 "Diving accidents").*

- The actions to control the situation will depend on:
  - The nature of the leak. (what is affected, where it is, the quantity of gas lost).
  - Where the bell is (at depth or the surface).
  - Whether the problem can be solved or controlled.
  - Whether there are sufficient gas reserves to perform a transfer to the chamber despite the leak.
  - Whether a wet transfer can take place or not.

Notes:

All hollow penetrators of a bell must be fitted with protection valves or other devices to stop catastrophic pressure loss *(IMCA D 024 /section 5/ point 5.5 & section 6 / point 6.4).*

There should be spare O-seals in the bell.

Viewports are sensitive parts: Viewports in the lower half should have protective covers both internal and external. Other viewports require external protective covers only. This protection may be accomplished by the installation of plastic covers (or similar) over the viewports *(IMCA D 024 / section 2/ point 2.2)*. In addition, blank flanges should be available in the bell to cover damaged portholes.

- Possible actions if the incident occurs at the surface

Action divers	Action bellman	Action surface
- Assist the bellman	- Inform the surface and check for leaks. - If the problem is from a valve unintentionally opened, close it. - If the problem is from a damaged pipe, close the valve designed to isolate this part of the bell. - If the problem is from a porthole, install the blank. - If the problem cannot be solved, standby for instruction. - When the bell is locked on, transfer from the bell as quickly as possible and close the trunking door.	Maintain the pressure of the bell. - Ask the divers and the deck to identify the reason for the leak. - If the leak cannot be dealt with, depending on the situation (bell above the surface, in the process of locking on, etc...), evaluate whether it is better to lock on the system and perform a quick transfer or to send the bell to the working depth for a wet transfer. - If the transfer to the TL is the chosen option, alert the LSS/LST and divers in the chambers to prepare the TL for quick transfer and ensure that all door and vent valves are closed.

3.2.2 - Incidents when the bell is at depth

3.2.2.1 - Underwater current coming up during the dive

- Potential consequences:
  - CO2 poisoning (Hypercapnia) / Fatigue
  - Inability to return to the bell / Possible panic
  - Launching of the rescue diver compromised *(Rescue diver: Bellman or Diver #2, or surface stand-by if possible)*

- Actions to implement:

Action divers	Action bellman	Action surface
- If not informed by the surface: Inform the supervisor that the status of the current is changing, and return to the bell. - If informed by the surface: Return to the bell when requested	- Recover the diver(s) in the bell and wait for instructions.	Information by: - Indicators on deck (current meter) - Breathing rate of the divers - Information from the divers. Action: - Recover the divers as soon as possible - The dive must be stopped if the stand-by / bellman cannot be launched.

3.2.2.2 - Swell and sea motion increasing / Sudden bad weather (squall)

- Potential consequences:
  - Swell/waves effects may result that the bell becomes unstable.
  - Surface support becoming unstable, or not able to hold its position safely.
  - Recovery becoming difficult and potentially dangerous.
  - Launching the standby diver or the ROV becomes difficult or impossible.

- Actions to implement:

Action divers	Action bellman	Action surface
- Return to the bell as soon as instructed	- Recover the diver(s) in the bell - Prepare for recovery - Close and seal the bottom door - Report ready for recovery and prepare for possible difficult transfer.	- Recover the diver(s) without delay. - Warn the team regarding the movements of the bell during the recovery. - If diving from a DP vessel, and if possible, request the DP officer to change the heading to a more stable position for the recovery of the bell. Note: The moonpool aerator system allows for more comfortable launching and recovery during bad weather.

3.2.2.3 - Poor visibility or no visibility

- Potential consequences:
  - Diver lost (he may be near dangerous appliances).
  - Panic
  - Loss of production.

- Actions to implement:

Action divers	Action bellman	Action surface
- The divers follow their umbilical and return to the bell if lost. - Ensure that their umbilicals are not entangled or damaged.	- Ensure that the bell is illuminated. - Recover the umbilical (pickup the slack).	- The supervisor recovers the divers to the bell and ensures that the umbilicals are not entangled or damaged and the divers are OK. **Note:** The supervisor should ensure that the divers are sufficiently trained to work without visibility. - The ROV should be away and cold.

3.2.2.4 - Diver entangled in fishing lines, net, or other lines

- Potential consequences:
  - Diver unable to return to the bell.
  - Injuries due to fishing hooks.
  - Panic
- Actions to implement:

Action divers	Action bellman	Action surface
- The diver informs the surface of his situation. - Stay calm and try to cut the lines methodically.	- Follow the instructions. *(Recover the umbilical or rescue)*	- Inform the bellman of the situation - Send a rescue diver *(depending on the situation: 2nd diver, bellman, standby diver)* to assist the diver, instruct the rescue diver to approach prudently. - Keep in communication with the diver and reassure him. - The ROV can be used for monitoring.

3.2.2.5 - Snagged umbilical

- Potential consequences:
  - Diver unable to return to the bell.
  - Panic.
- Actions to implement:

Action divers	Action bellman	Action surface
- Report to the supervisor - Try to sort out the situation, ensure that the umbilical is not entangled, and goes in a direct way to the bell.	- Follow the instructions. *(Recover the umbilical or rescue)*	- Inform the bellman of the situation. - Warn and prepare the rescue diver. - Send the rescue diver to assist if the diver has difficulty sorting out the situation.

3.2.2.6 - Conflicts with ROV

- Potential consequences:
  - Caught by thruster.
  - Umbilical entanglement.
  - Divers injured by collision.
  - Electrocution.
  - Damaged or severed umbilical.
  - Note: See Book #1 / point 10 *"Diving with Remotely Operated Vehicles (ROV)"*
- Actions to implement:

Action divers	Action bellman	Action surface
- Apply the guidelines for injured or unconscious diver recovery given in points 3.1.1 & 3.1.2. - Before any intervention in direct proximity of the ROV, request the ROV to be stopped and "cold".	- Apply the guidelines for injured or unconscious diver recovery given in points 3.1.1 & 3.1.2.	- Note that safe procedures consist of keeping the ROV away from divers. - Order the ROV pilot to make the machine "cold". - Apply the guidelines for injured or unconscious diver recovery given in points 3.1.1 & 3.1.2.

3.2.2.7 - Accident due to pressurized, in depression, or electrical devices

Note: Such incident should not happen if the hazard identification process has been correctly documented and the control measures are implemented.

- Potential consequences:
  - Injuries or fatalities.

- Actions to implement:

Action divers	Action bell man	Action surface
- Apply the guidelines for injured or unconscious diver recovery given in points 3.1.1 & 3.1.2.	- Apply the guidelines for injured or unconscious diver recovery given in points 3.1.1 & 3.1.2.	- Contact the bridge / facility to shut down the device, and make sure the rescue diver will be safe. - Apply the guidelines for injured or unconscious diver recovery given in points 3.1.1 & 3.1.2.

3.2.2.8 - Bell atmosphere contaminated by hydrocarbons from the worksite

Note: The work site should be inspected using ROV and samples of the bottom should be analysed prior to start the diving operations. Also, the hydrocarbon analyser should always be activated.

- Potential consequences:
  - Divers in the bell affected (lungs, brain), falling unconscious, death may follow.
  - Reclaim polluted.
  - Risk to affect the whole complex when reconnecting the bell.

- Actions to implement:

Action divers	Action bellman	Action surface
- Return to the bell when instructed. - Remove their helmets only when instructed. - Go on BIBS immediately if the pollution happens before launching the dive. - Discard suits and equipment that are suspected to be the source of contamination outside the bell.	- If not alerted by the surface, alert the supervisor and go on BIBS immediately. - Flush the bell. - Check that the atmosphere is back to normal values. - Investigate the reason(s) of the contamination. - Recover the divers when instructed and when possible. Do not remove their helmets if the atmosphere is not purified. - When instructed, close the bell, and prepare for ascent.	- Alert the bellman, and ask him to go on BIBS and flush the bell. - Instruct the divers to return to the bell. - Ensure that the bell atmosphere is back to normal values. - Investigate the reason for the contamination, and if detected, implement corrective action. - If the reason for contamination is not identified or the contamination likely to start again, abort the dive. - Ensure of the bell atmosphere and warn the LSS before connecting the bell.

3.2.2.9 - Gas supply to divers contaminated *(divers not yet affected)*

The supervisor can be alerted by the divers (Strange taste, or bad feeling, etc.), the change of breath rate of the divers, or the change of gas values.

- Potential consequences:
  - Divers intoxicated
  - The initial intoxication can lead to loss of conscious

- Actions to implement:

Action divers	Action bellman	Action surface
- Indicate to the supervisor any bad taste, or feeling - Switch the bailout on and return to the bell - When on backup or onboard gas, flush their hat and return to the bell	- If not informed by the surface that the supply is on backup, closes the surface supply, and switch to onboard gas. - Switches to onboard gas if instructed. - Makes sure of the gas values in the bell. If any doubt, go on BIBS and flush the bell. - Recover the divers - When instructed, close and seal the bell, and prepare for ascent	- Switch to backup supply (close the main) or instruct the bellman to open the onboard gas. - Asks the divers to flush their hat and to return to the bell. - Informs the bell-man. If not sure of the backup , asks him to close the surface supply and activate the onboard gas. - Ensures that the bell atmosphere is at normal values. - Investigates the reason for the contamination, (technician + LSS/LST) - Abort the dive and recover the bell to surface.

3.2.2.10 - Loss of the gas supply of the bell

Note: The onboard emergency panel should switch automatically to onboard gas.

- Potential consequences
  - The diver is on onboard gas reserve. Normally, the divers should not notice any change when the changeover valve is switched on, but there should be an alarm fitted to alert the bellman if the divers supply switches over to the onboard gas.
- Actions to implement

Action divers	Action bellman	Action surface
- Return immediately to the bell	- The bellman should be warned of the changeover valve switching over to the on-board supply by the indicator's red status. - Notify the diving supervisor and recover the divers to the bell as soon as possible. - Once the divers are back in the bell, Prepare for recovery & wait for instruction. - If the supply is not reestablished, close the door, make a seal, and inform the surface that the door is secured and the team is ready for ascent.	- The supervisor switches on backup supply on panel . - Instruct the divers to return to the bell. - Warn the bellman. - If the reason is not identifiable on panel, ask the technician & LSS/LST to investigate the problem. - The dive must be aborted if the reason for the break down is not immediately identified, or the problem due to an incorrect checklist, or/and the reserves of onboard gas partially consumed. - The reason for the incident will have to be solved before launching another dive.

3.2.2.11 - Loss of the gas supply of the divers

Note: If one umbilical is severed or damaged, the bellman should be warned by the change over valve isolating the 2nd half of the emergency panel, and the indicator switching from green to red.

- Potential consequences:
  - One diver can be deprived of gas supply, resulting in panic, asphyxia, or drowning. It could be the two divers in case of a malfunction of the system.
- Actions to implement:

Action divers	Action bellman	Action surface
- Open the bail out - Report to surface - Return immediately to the bell Note: The gas can return online after the opening of the bailout, and the diver is on his way back to the bell. In this case, the bailout should be closed, and the diver should continue to return to the bell. - If two divers are in the water and the problem is due to an umbilical being severed or damaged, the 2nd diver should assist the diver in trouble.	- The bellman quickly investigates from where the problem is (valve not open, regulator not working...) and makes corrective action if possible. - Recover the divers as soon as possible, and prepare for rescue if necessary. - When the divers are in the bell, check the bail out pressures and report to the supervisor, and wait for instruction - If the problem cannot be solved immediately or the bailout(s) pressure(s) are too low, close and seal the door and prepare for bell recovery.	- The supervisor asks the divers to return as soon as possible to the bell - Warn the bellman - Request support from the tech and LSS/LST to investigate the reason for the break down. - If the problem is due to the umbilical being severed or damaged , ask the 2nd diver or the bellman to assist the diver in trouble. - The dive should be aborted if the reason for the breakdown is not immediately identified, or the problem is due to an incorrect checklist, or/and the bailouts with insufficient range (pressure).

3.2.2.12 - Regulator not working properly

- Potential consequences:
  - Difficulties to breathe.
  - Fatigue
  - Hypercapnia
  - Panic
- Actions to implement:

Action divers	Action bellman	Action surface
- Open the free flow - Inform the surface and return to the bell - Dive aborted - Note: The problem can be from the reclaim. In this case, activate the "open circuit" and return to the bell.	- Check whether the problem is not coming from the onboard panel (improper regulator setting, valve half closed, etc.). - Recover the diver to the bell - Prepare for intervention if needed - Wait for instructions	- The supervisor switches to backup supply line on panel to make sure that the problem is not due to the supply from surface. - Recover the diver to the bell - The 2nd diver or the bellman or the standby diver is warned in case assistance is needed. - Request support from the tech and LSS/LST to investigate the reason of the break down. - The dive should be aborted if the reason for the break down is not immediately identified, or the problem is due to an incorrect check list.

3.2.2.13 - Leaks on diver's helmet supply fittings

- Potential consequences *(Depending on the importance of the leak):*
    - Incorrect gas supply with possible difficulties to breathe.
    - Risk of hose parting with loss of gas supply.
- Actions to implement:

Action divers	Action bellman	Action surface
- Inform the surface - Return immediately to the bell - Open the bailout if necessary - Dive aborted	- Recover the diver as soon as possible - Prepare for intervention if needed - Wait for instructions	- Instruct the diver to return to the bell. - The 2nd diver or the bellman or the standby diver is warned in case assistance is needed - With the assistance of the tech make sure whether the problem can be solved safely. - The dive should be aborted if the breakdown is not immediately solved, or the problem is due to an incorrect checklist or/and the bailouts with insufficient range (pressure).

3.2.2.14 - Loss of communications

- Potential consequences:
    - No instruction and information coming to and from the diver, and/or to and from the bell.
- Actions to implement:

Action divers	Action bellman	Action surface
- Attract the bellman's attention using line (umbilical) and supervisor using video signals if they are not aware, and return to the bell as soon as possible.	- If the problem is from the bell and the surface is not aware: Attract the attention of the supervisor and use the sound powered phone if possible. Also, attract the attention of the divers and recover them as soon as possible - When the divers are back in the bell and a communication is established: Stand by for instruction. - When the divers are back in the bell and if no communication is established, close the bottom door, make a seal, and indicate by signals through the video (if working) that the team is ready for transfer. Then standby.	If the problem is from the communications to the divers: - Ask the bellman to recover the divers. The divers' attention can be attracted using flash signals, pull signals, and flash signals by the ROV. If the problem is from communications to the bell: - Ask the divers to return to the bell. - Contact the Bellman using the sound-powered phone. If the sound-powered phone is not working, deploy, and use through water communications. Then: *See on the next page*

Action divers	Action bellman	Action surface
Continuation from the previous page	Continuation from the previous page	Then: - Ask the technician to check whether the problem can be easily solved. The dive should be aborted if the breakdown is not immediately solved or the problem is due to an incorrect checklist. - To recover the bell, use the ROV to check whether the bottom door is sealed and the bell is not leaking. Try to get information from the divers through the internal video.

3.2.2.15 - Loss of hot water supply

Note: The hot water system is fitted with alarms, alerting the technician in charge, and the diving supervisor. The bellman should be alerted by improper temperature reading or improper flow. Note that a backup machine should be available.
Also, the divers may not realize that they have become hypothermic and may have to be re-warmed.

- Potential consequences:
  - Diver quickly hypothermic
  - If used to heat the regulator; regulator freezing
  - Bell heating system not working
- Actions to implement:

Action divers	Action bellman	Action surface
- Alert the surface and return to the bell if needed.	- Alert the surface and standby to recover the divers - Report the condition of the divers (hypothermic or or not) - Stand by for instruction - Prepare to close the door if required	- Instruct the diver(s) of the problem and tell him to return to the bell. - Alert the bellman - Switch to the secondary system if available. - Call upon the dive technician to solve the problem or start the 2nd heating unit. The dive should be aborted if the breakdown is not immediately solved or the problem is due to an incorrect checklist. - If the divers are hypothermic, the dive should be aborted.

3.2.2.16 - Loss electrical supply

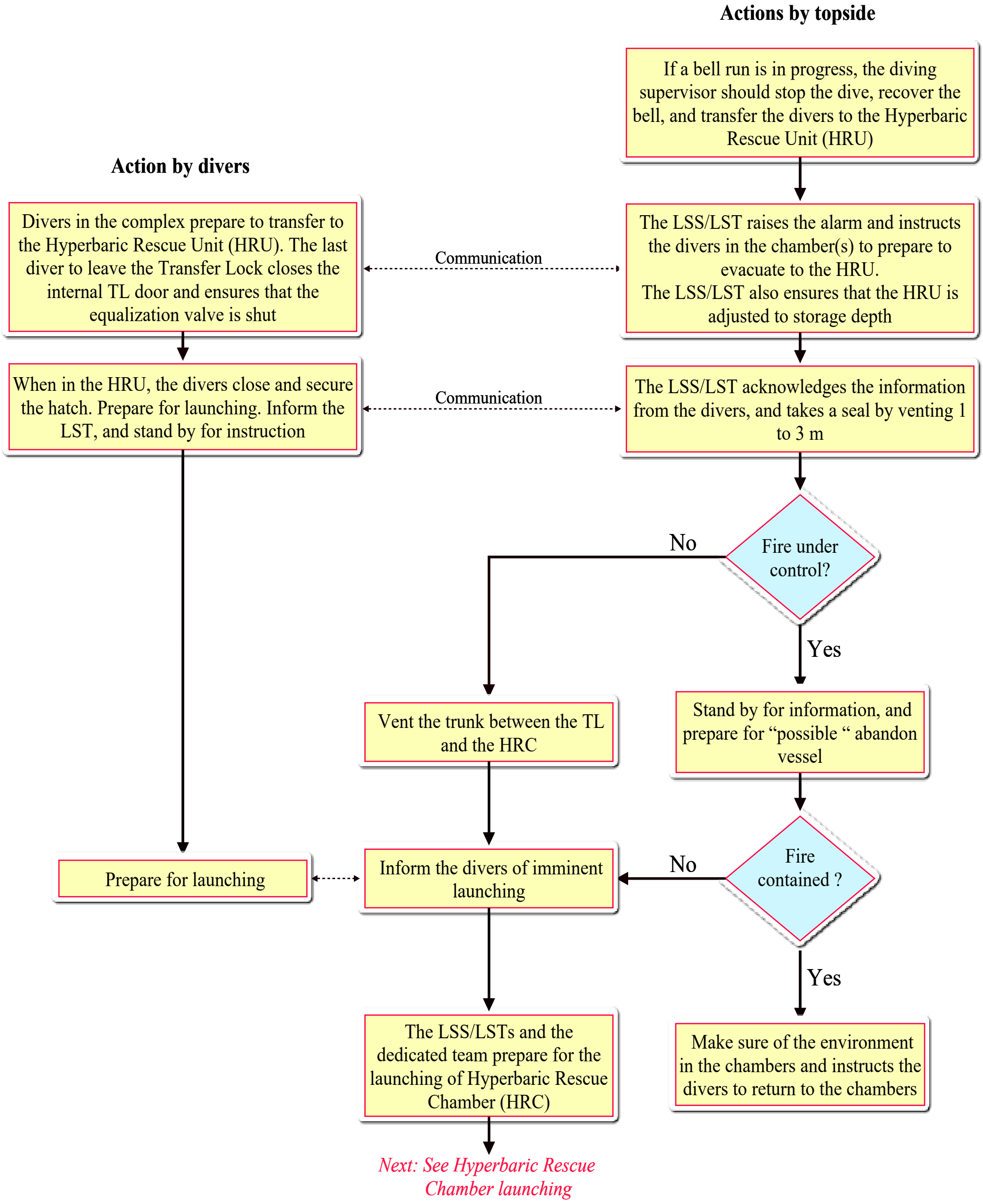
Notes:
The communications to the divers and the bell should be fitted with a backup power source (batteries) and continue to work *(see IMCA D 024 section 2 /point 2.4)*. Also, the recording system should be fed from a UPS or other system to ensure continued operation for at least 30 minutes in the event of loss of main power *(see IMCA D 024)*.

- Potential consequences:
  - No lights, scrubber, and heater, etc.
- Actions to implement:

Action divers	Action bell man	Action surface
- Alert the surface and return to the bell as soon as possible.	- Switch on the emergency power supply if it is not done automatically. - Inform the surface and recover the diver as soon as possible. - Stand by for instruction. - Prepare to close the door if required. - If no communication (which should not happen), close the hatch, make a seal and prepare for recovering.	- Instruct the divers to return to the bell. - Depending on the source of the problem, switch on the backup power supply. - Ask the technician to check whether the problem can be easily solved. - The dive should be aborted if the breakdown is not immediately solved or the problem is due to an incorrect checklist.

3.2.2.17 - Fire in proximity of the dive control / chamber system

- Potential consequences:
  - Abandon ship is necessary if the chambers cannot be used anymore.
  - Lock on impossible.
- Actions to implement:
  - If the bell can be connected to the complex, the divers should transfer to the Hyperbaric rescue unit as quickly as possible and follow the procedure given in Book #2.



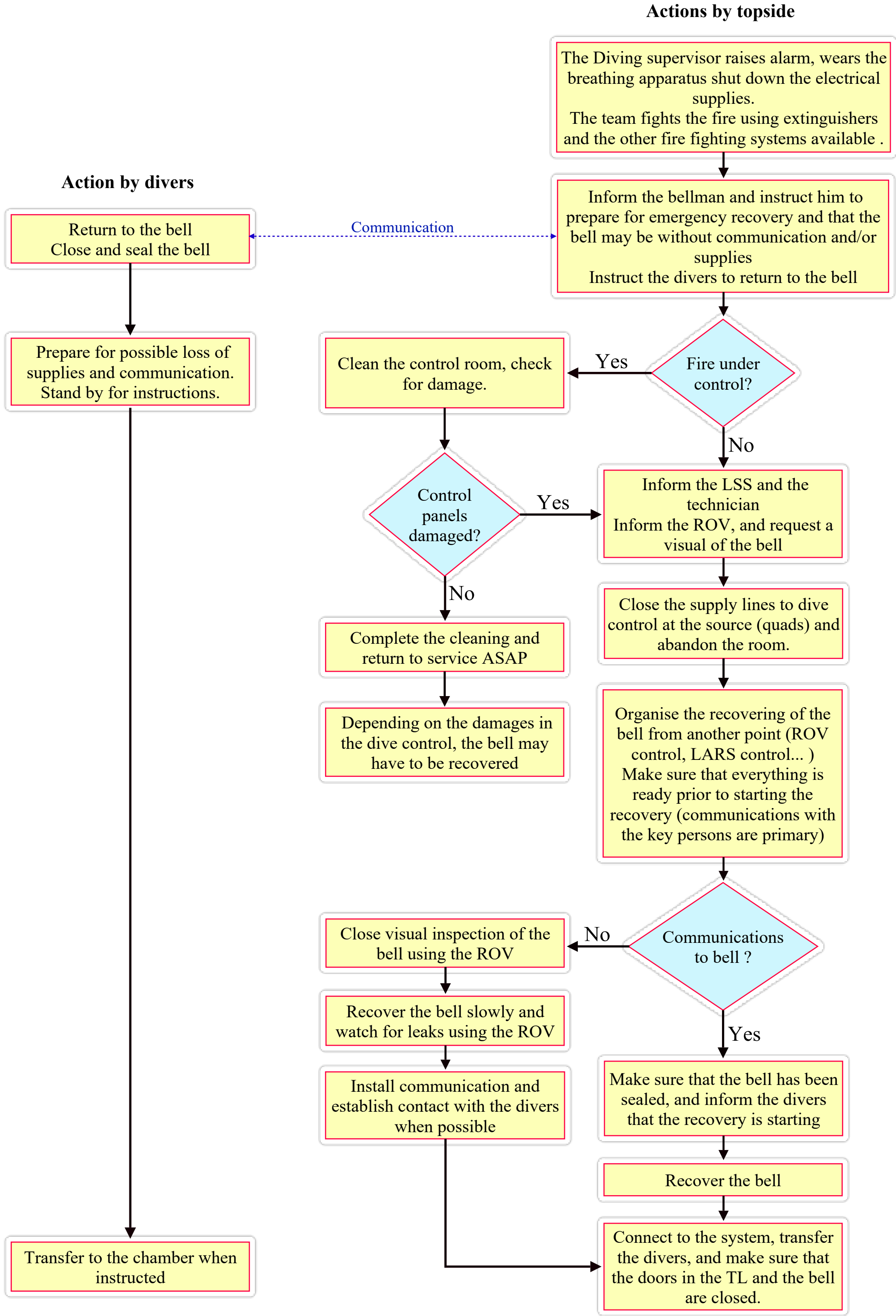
- If the bell cannot be locked on the system, evaluate whether it is preferable to:
  - Wait for the fire to be extinguished.
  - Start an emergency decompression.
  - Prepare the bell for abandon vessel: Transfer the bell to another vessel and then the rescue facility. In this case, the procedure is the same as for the transfer of the HRU *(The ballast should be released if the option is to send the bell from the deck in a similar manner as the HRU)*.

3.2.1.18 - Fire in the dive control

- Potential consequences:
  - Diving supervisor unable to manage the dive.
  - Possible loss of communication.
  - The dive control/dive system may be damaged.
  - Bell recovery impossible from the dive control.

- The divers are protected as long they are in the bell and the onboard gas allows 24 hours to recover them into the complex.

- Actions to implement:



3.2.2.19 - Loss of bell pressure during the diving operations

- Potential consequences:
  - Uncontrolled loss of pressure is one of the most critical incidents which can happen with a bell. It must be kept in mind that such an incident can trigger a decompression accident, or worse, an explosive decompression. *(See the report of "Byford Dolphin" accident in Book #4 "Diving accidents").*

- The actions to control the situation will depend on:
  - The nature of the leak. (what is affected, where it is, the quantity of gas lost).
  - Where the bell is (at depth or the surface).
  - Whether the problem can be solved or controlled.

- Whether there are sufficient gas reserves to perform a transfer to the chamber despite the leak.
- Whether a wet transfer can take place or not.

Notes:

All hollow penetrators of a bell must be fitted with protection valves or other devices to stop catastrophic pressure loss *(IMCA D 024 /section 5/ point 5.5 & section 6 / point 6.4).*

There should be spare O-seals in the bell.

Viewports are sensitive parts: Viewports in the lower half should have protective covers both internal and external. Other viewports require external protective covers only. This protection may be accomplished by the installation of plastic covers (or similar) over the viewports *(IMCA D 024 / section 2/ point 2.2)*. In addition, blank flanges should be available in the bell to cover damaged portholes.

- Possible actions:

Action divers	Action bellman	Action surface
- Assist the bellman , and try to find the leak on the outside	- Inform the surface and check for leaks. - If the problem is from a valve unintentionally opened, close it - If the problem is from a damaged pipe, close the valve designed to isolate this part of the bell. - If the seal cannot be obtained on the bottom hatch, change the O-Seal. - If the problem is from a porthole, install the blank. - Pressurise the bell 1 to 3 m to ensure the problem is solved. - If the problem cannot be solved, standby for instruction.	- Maintain the pressure of the bell. Keeping the bell at depth allows balancing the pressures. - Ask the divers to identify where the leak is. The ROV can be used to perform a close visual inspection of the bell. - If the problem cannot be dealt with, organize a wet transfer if possible (see "lost bell procedures"). - If the wet transfer is not possible, a solution is to calculate the potential gas loss and put sufficient gas on line to maintain the pressure during the transfer of the divers into the saturation complex. Emergency decompression in the bell can be another option.

3.2.1.20 - Failure of the mooring

- Potential consequences:
  - Collision with the structure with possible damage to the dive station.
  - Diver pulled off due to surface support adrift and erratic.
  - Vessel and passengers endangered.

- Actions to implement:

Action divers	Action bellman	Action surface
- Return immediately to the bell , and prepare for quick recovery. - Inform the supervisor if injured.	- Recover the divers. - Close and seal the bell. - Prepare for transfer.	- Alert and instruct the divers to return immediately to the bell. - Alert the bellman and instruct him to recover the divers and prepare for emergency recovery. - Alert the bridge. - Recover the bell as soon as possible and transfer the divers to the chamber. - In case of an injured or unconscious diver, send the rescue diver, and recover accordingly.

3.2.1.21 - Dynamic Positioning yellow alarm

- Potential consequences:
  - A failure in a sub-system has occurred, causing a loss of position.
  - The vessel's position keeping performance is deteriorating and/or unstable.
  - The vessel's indicated position deviates beyond limits.
  - The risk of collision exists from another vessel.
  - Weather conditions are judged as becoming unsuitable for diving.
  - Any condition which could reduce the status from normal.

- Actions to implement:

Action divers	Action bellman	Action surface
- Suspend the work and move to a safe location as instructed by the supervisor (it should be close to the bell) - Ensure that they can move quickly into the bell if required.	- Adjust the divers umbilicals - Prepare for quick recovery if needed	- The diving supervisor should instruct the divers to suspend operations and move to a safe location close to the bell. - The diving supervisor contacts the bridge to be informed of the evolution of the status. - If the diving supervisor cannot get clear advice from the DPO, he instructs divers to return to the bell.

3.2.1.22 - Dynamic Positioning red alarm

- Potential consequences
  - Inability to maintain a 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 position”.
- Actions to implement

Action divers	Action bellman	Action surface
- Suspend the work and move to the bell as quickly as possible	- Recover the divers as quickly as possible - Close and seal the bell - Inform the surface when ready - Stand by for transfer	- The diving supervisor instructs the divers to return immediately to the bell. - Recover as soon as possible after due consideration of the hazards involved in the recovery.

3.3 - Lost bell procedures

3.3.1 - Reminder of bell survival equipment

All bells should be fitted with a minimum survival equipment: Note that the equipment described are also discussed in point 1.1 “Diving bells” and the document IMCA D 024.

3.3.1.1 - Communications

- A communications connection might also be available. *(IMCA D 024 / section 5/point 5.14).*
- A copy of the AODC/IMCA bell tapping code must be mounted on the outside of the bell in a clearly visible position, and available for the occupants. *(IMCA D 024 / section 5/points 5.15 & 6.55).*
- Two-way voice communications between the supervisor and each diver including the standby diver (bellman) must be provided. *(IMCA D 024 / section 5/point 6.40).*
- A means of through water communications must be available to allow the supervisor to talk to the divers inside the bell when it is in the water. *(IMCA D 024 / section 5/point 6.41).*
- A sound powered phone should be fitted to allow the supervisor to talk to the divers in the bell. *(IMCA D 024 / section 5/point 6.42).*

3.3.1.2 - Bell localization

- A transponder operating on 37.5 kHz must be fitted to the bell to aid in location in an emergency. A means of testing and interrogating this transponder must be readily available on the surface at the dive site. *(See AODC 19 & IMCA D 024 /section 5/points 5.19).*
- A strobe light with a minimum operating duration of 24 hours must be fitted to the bell to assist in location in an emergency. *(IMCA D 024 / section 5/point 5.20).*
- External lights must be provided which illuminate the bell over 360 degrees. These lights must be wired in such a way that failure of one does not extinguish the others. *(IMCA D 024 / section 5/point 5.39).*

3.3.1.3 - Secondary Lifting

- There should be a secondary attachment point on the diving bell if the main one is damaged. This secondary point should also be a properly designed pad eye or similar. It may be a second hole in the same pad eye. *(IMCA D 024 / section 5/point 5.17).*
- A lifting sling should be pre-installed for quick connection to a crane hook or similar device (ROV or diver).

3.3.1.4 - Onboard gas

- There must be an emergency supply of breathing gas carried on board sufficient to support each working diver plus the bellman outside the bell for a minimum of 30 minutes at a breathing rate of 40 litres/minute at the maximum depth of the diving operation according to IMCA D 024 / section 5/point 5.23. As explained previously, the breathing rate should be between 50 and 75 litres per minute. However, the bell may have been built according to IMCA rates.
- Sufficient oxygen must be available for metabolic consumption by the maximum number of divers at 0.5 litres/minute per diver for at least 24 hours at the end of a bell run. *(IMCA D 024 / section 5/point 5.24).*

3.3.1.5 - Onboard power supply

- There must be sufficient energy in the onboard batteries to supply the backup lighting system for at least 24 hours.
- Several portable lights should be available in case of failure of the main backup system

3.3.1.6 - Survival equipment

- There should be means provided, independent of surface supplies, to maintain the diver’s body temperature and reduce CO_2 for a minimum period of 24 hours in an emergency. This will normally be by means of survival bags and emergency scrubbers.
  1) Isolation: The Diver's Insulation System consists of a special survival bag and thick under suit.
  2) Regenerators: This pack contains a carbon dioxide scrubber, and a thermal regenerator assembly (not required for shallow dives in tropical areas).
  3) Food, water and hygiene: There should be sufficient food and drinks and hygiene bags for at least 24 hrs. Note that the snacks and drinks recommended for the bell run are not part of this kit.
     - The food should consist to high energy and compact meals in sealed bags similar to those designed for combat rations.
     - Fluid intake needs to be maintained. 100-150 ml of water per man per hour should be provided for at least 24 hours. Isotonic drinks can be given to the divers to help counteract the effects of electrolytic imbalance.
     - Toilet activities should be possible in sealable gel bags. Urinary sheaths should be considered to transport urine to a gel bag without opening the suit. Vomit bags should also be provided.
     - Because the divers will be motionless, anti-embolic stockings should be included in the survival equipment.

3.3.1.7 - Emergency umbilical and connectors

This equipment is also described in point 1.1.2.6

- An emergency umbilical should be ready all the time. A manifold should be provided on the bell for connection of basic supplies in an emergency. As a minimum this should provide two connections as laid down by IMO:
  - ¾" NPT (female) for hot water
  - ½" NPT (female) for breathing gas
- The document NORSOK U 100 recommends more connectors than those required by IMO, and considers some connectors to be installed by ROV. This recommendation can be used as reference to provide more functions to the bell in emergency situation:

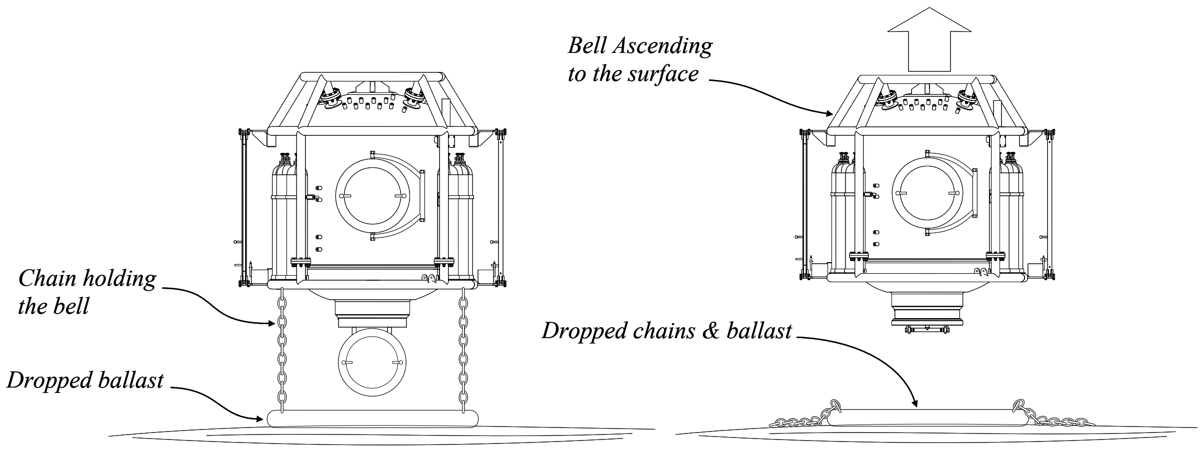
Item	Diver operable	Diver and ROV operable
Breathing gas	1/2" NPT Female	1/2" Male Snaptite SVHN-8
Hot water/heating	3/4" NPT Female	3/4" Male Snaptite SVHN-12
Depth	1/4" NPT Female	1/4" Male Snaptite SVHN-4
Communication	8-contact-4-pins-EO connector (Contacts 1 and 2 used, others n.c.)	8-contact-4-pins-EO connector (Contacts 1 and 2 used, others n.c.)
Emergency power	4-contact-4-pins-EO-connector (Pin 1: 24V, pin 2: 0V, pin 3: ground, pin 4: n.c.)	4-contact-4-pins-EO-connector (Pin 1: 24V, pin 2: 0V, pin 3: ground, pin 4: n.c.)
Gas analysis	1/4" NPT Female	1/4" Male Snaptite SVHN-4

Keys:
- EO: "Electro Oceanics"- trade mark - underwater electrical connector
- n.c.: not connected
- NPT: National (standard) Pipe Tapered (threads)
- Snaptite SVHN: trade mark and type designation

3.3.1.8 - Buoyant ascent procedure

Bell ballast release system is an optional equipment described in point 1.1.2.4 of this book.

The ballast of some bells is designed to be released, allowing it to float, thus return to the surface. Nevertheless, this operation can be very critical and requires methodology.



AODC 61 gives guide lines which should be considered for the ballast release operation and the buoyant ascent of the bell being performed successfully:

a) The bell's ascent should not be impeded or prevented by the proximity of debris and associated lifting equipment (such as severed wires etc.) and its path to the surface should be free from obstructions, including the support vessel.

b) There should pressure integrity inside the bell.

c) There should be a safe procedure for attaching a lift wire for the recovery of the bell at the surface.

Many other factors should be considered. Because of the inherent difficulties in meeting all the requirements, the buoyant ascent of the bell is regarded as the least desirable option. Emergency procedures should consider all other available means of the bell recovery in preference to releasing the ballast.

The decision on whether or not to use ballast release systems rest with the company management after full consideration of all relevant factors.

If the decision is to not use the weight release system, then this decision must be clearly recorded in the appropriate documents and made known to all on the work site.
The emergency procedures must also clearly identify the alternative method selected (typically a second diving bell). The ballast weights must be secured such that they cannot accidentally come off.

When the bell is equipped with a ballast release system, the recommendation is to keep this possibility but to consider all other procedures of recovery in preference, as recommended by AODC 61.
The ballast release system gives the advantage to clear the bell from the bottom to let the divers enter or leave it, if needed. This can be very useful in the eventuality that the bell is laid on the bottom, even for bells designed to sit on their clump weight or standoff frame with the bottom door open, as this system could be damaged or laid on it's side.

- The system must be capable of release from inside the bell, and the release mechanism must be protected against accidental release.
  - Two independent actions must be needed to release the weights:
    - The first step is to release two short flat bars that enable the bell to raise by 2 meters and then allow the divers to enter or exit the bell in case the bell lays on the sea floor.
    - The second step is to release the 2 long chains, freeing the bell which begins its buoyant ascent.
  - The weights must not be capable of being shed accidentally, for example if the bell is inadvertently tilted.
  - If the system utilises only one weight, then there must be no single component whose failure could cause the weight to become detached. This requirement does not apply if there are two or more weights operating independently.

3.3.1.9 - Cutters or release mechanisms for the main bell umbilical and/or the main lift wire

Optional cutters or release mechanisms of the umbilical and lift wires operated from inside the bell are also discussed in point 1.1.28.

These systems' function is to cut the umbilical and the wires to avoid sending the diver to free the bell from these elements. Nevertheless, many bells in use are not fitted with these mechanisms, and in this case, the operation should be performed by the diver or the ROV.

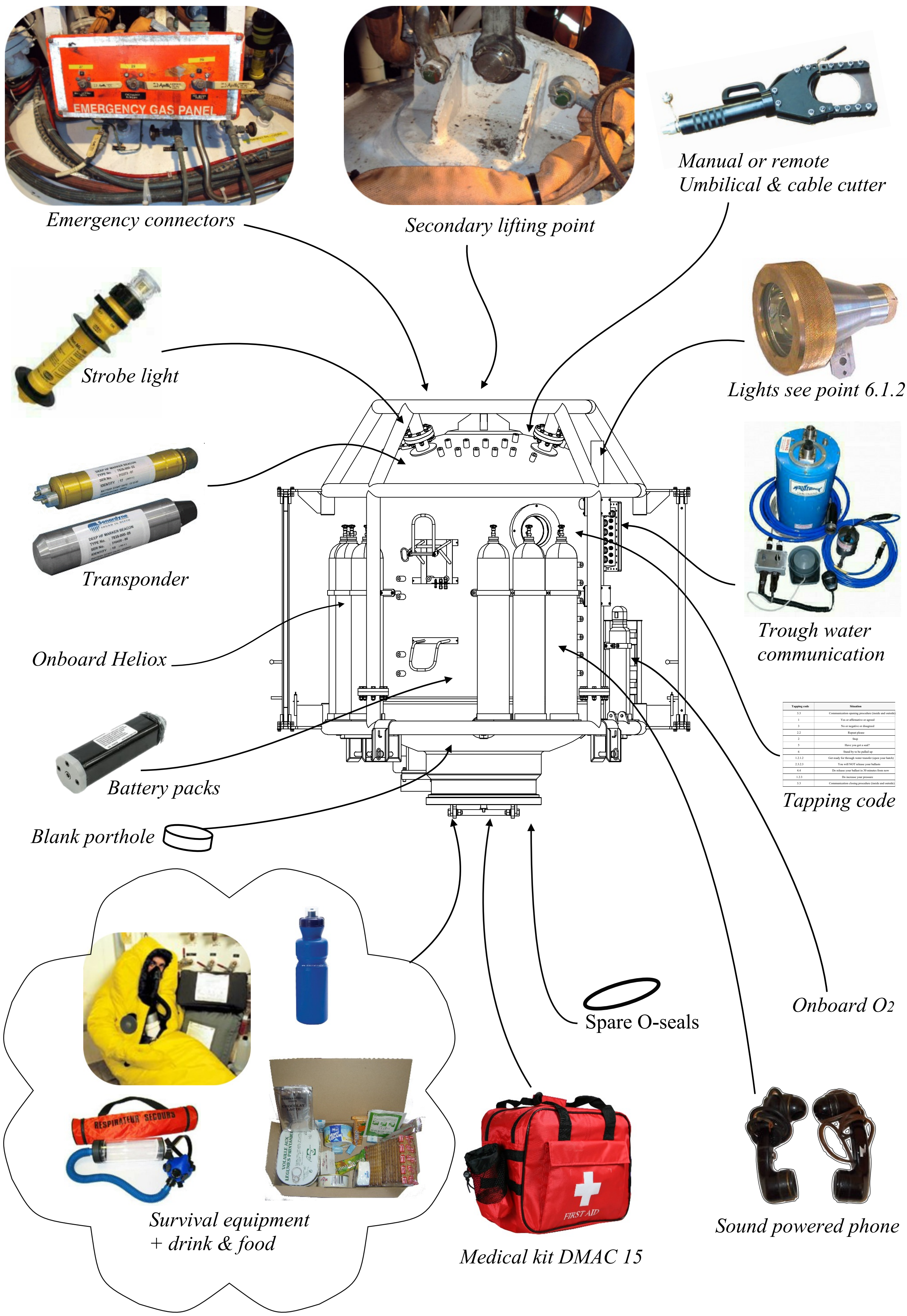
- The system must be capable of operation from inside the bell, and the operating mechanism must be protected against accidental operation.
- Two independent actions must be needed to operate the cutter(s) or release mechanism.
- If the cutter(s) or release mechanism are operated by means of pressurisation (gas or hydraulic), then isolations need to be in place such that it cannot be activated accidentally by external water pressure or internal gas pressure.

3.3.1.10 - Medical kit DMAC 15

The bell medical kit DMAC 15 is a part of the full kit available at the surface that should be stored in a sealed container. Its content should be listed (use plastic boards for that) and regularly checked by the diver medics.

Description		Description
1 Arterial tourniquet (e.g. CAT tourniquet)		1 Roll of 1 inch adhesive tape
3 Polythene bags – these can be used to cover burns or as waste bags		2 Crepe bandages – 3 inch
1 Resuscitation face mask (preferably with a silicone filled face seal and a non-return valve) or shield, for mouth-to-mouth ventilation		2 Pairs of non-sterile gloves (non-latex if possible, appropriately sized)
2 Oropharyngeal airway size 3 and 4 (e.g. Guedel type)		1 Watertight bag
1 Tuf cut scissors		1 Suction catheters: sizes 12 and 14
1 Medium dressing		1 Adult adjustable cervical spine collar
1 Large dressing		1 Hand operated suction pump
2 Triangular bandages		2 Space blankets

3.3.1.11 - Overview of bell emergency equipment



Note:
It is of primary importance to ensure that the elements listed previously and summarised above are in the bell and in good condition prior to any dive. In case elements are missing or not in perfect condition, the dive should not be launched.

3.3.2 - Use of ROV

3.3.2.1 - Type of ROV to be used

ROVS are described in point 10.3 of book #1. They are usually classified in six classes taking into account their characteristics and function.
ROVs are efficient means for recovering a diving bell. Nevertheless, it is admitted that a machine that can rescue a bell must be sufficiently powerful to energize the tools needed for such operations and that an observation class, even with payload option, is not sufficiently powerful to do it.
For this reason, only "work class" machines are really suitable for rescuing a diving bell, provided that they are equipped with the relevant tools such as cable cutter, saw and grinder to cut the umbilical if necessary, and 2 multifunction manipulators to remove debris and connect a crane if necessary.
It must be noted that some clients agree for the use of light work class ROVs (Class 3A IMCA & NORSOK) fitted with the relevant tools described above, while others prefer using heavy work class (Class 3B IMCA & NORSOK) only.
Regarding this point, we can logically say that having powerful machines is always preferable.
Thus, except when rescue divers can be safely launched to recover the bell (tween bell system, or shallow dive), class 1 or 2 ROVs are not regarded as machines able to rescue a bell.

Heavy work class

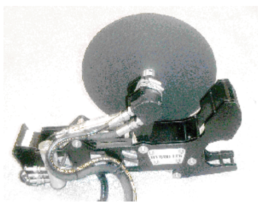
Light work class

3.3.2.2 - Tools mandatory for bell rescue

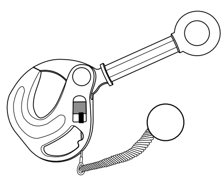
- Four or five functions manipulator:
  These tools are generally used to grab objects and maintain the ROV in position when using the 2nd manipulator or another tool.

- Seven functions manipulator:
  These tools are designed to perform all the movements which could be possible by a human arm, except the hand has 2 fingers (the thumb and the 4 remaining grouped in one), and unfortunately, no sense of touch for the moment. They are used to perform precise tasks.

- Cable cutter:
  It must be capable to cut at least the main and the guide wires of the bell. Some models are designed to cut the umbilical with opening up to 270 mm exist *(see on the side)* and are recommended. They are normally installed at the end of one arm.



- Grinder:
  These tools can be used to cut any debris other than cables. The use of diamond disks is recommended.



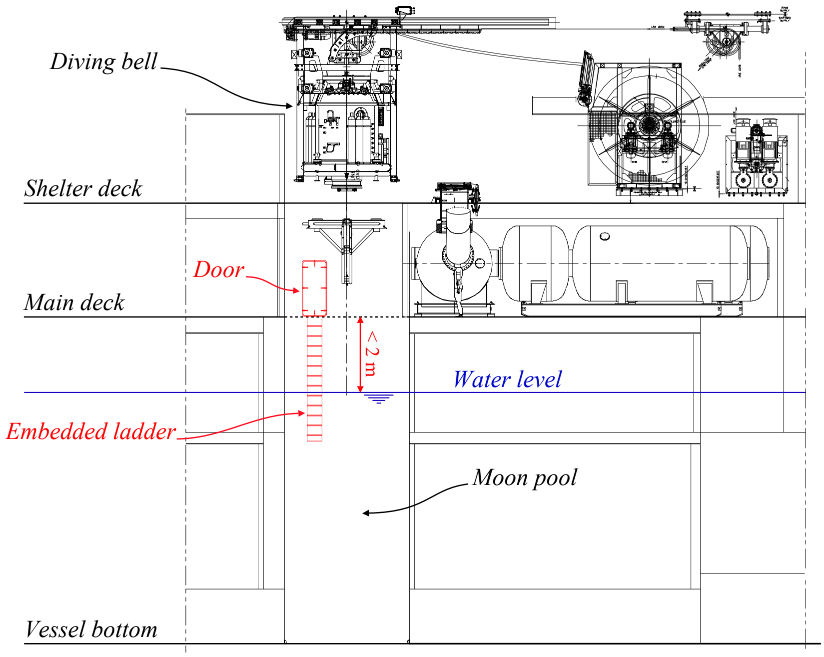
- Hooks and shackles:
  If hooks and shackles are planned to be used, they should be designed for an ROV.

3.3.3 - Surface standby diver

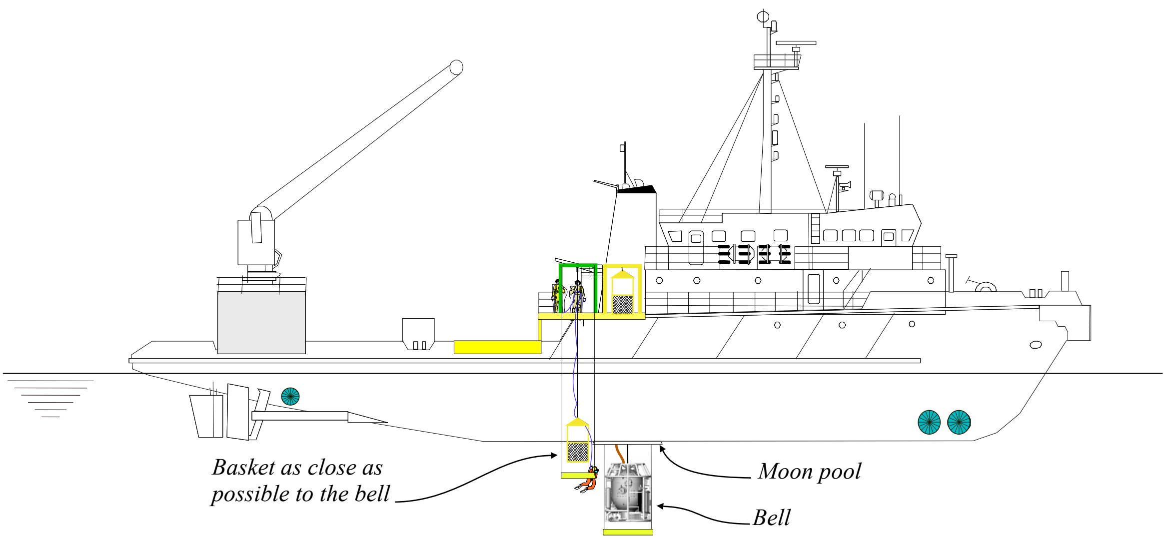
3.3.3.1 - Types of interventions

A surface-supplied rescue diver should be ready to intervene during the bell run. However, it is admitted that he does not need to be fully dressed for immediate action as with surface-orientated diving operations. The reason is that the purpose of his intervention is the recovery of the bell, which is provided with gas reserves for at least 24 hours. For this reason, the intervention of the surface rescue diver should be organized in complement of the other means of rescue available and in conformance to suitable practices for surface orientated diving operations:

- If the saturation system has two bells, the intervention of the surface standby diver can be limited to depths where long no-decompression dives are possible. In this case, the rescue diver may be used to solve a technical problem that prevents a bell from entering its moon pool, connecting and disconnecting emergency supplies and ropes to facilitate the recovery of the bell, and similar interventions.
  It is usually accepted that a scuba replacement pack is used for such operations. Of course, the diving procedures implemented should be those in force with such a system.
  Note that the deployment of the diver through a moon pool is possible and usually performed using a ladder. However, that must be done according to good practices. Thus, the distance from the level of deployment and the surface of the sea must be limited to 2 m maximum. For this reason, some moon pools of saturation systems installed at more than 2 m above the water level are equipped with lateral doors allowing to launch the rescue dive from less than 2 m above the water level (see the drawing below). Embedded ladders are in place to descent and return to and from the water. These embedded ladders are designed not to disturb the deployment and recovery of the bells. As for every diving operation, relevant systems must be provided to recover an unconscious diver.



If the moon pool is not equipped to allow the deployment of the rescue diver using a ladder from less than 2 m above the surface of the sea, the deployment can be organized from the side of the vessel. In this case, a basket is recommended even though the ship is not a dynamic positioning unit, as using a ladder may limit the deployment of the bell to weather conditions suitable for scuba replacement diving. The basket should be installed as close as possible to the bell, as indicated in the drawing below.



It is usually accepted that a Dynamic Positioning vessel can be oriented to a heading that protects the dive station when the weather conditions limit the deployment of the rescue divers. Another possibility is to move slowly to a sheltered place where the deployment of the divers will be possible. However, this sheltered place must be identified, and the possibility of reaching it sufficiently early at a slow speed should be assessed. It can be an offshore facility behind which the vessel can be positioned. If these procedures cannot be implemented, the bell should only be launched when the weather conditions allow for the deployment of the surface rescue diver.
It is also usually accepted that a chamber of the saturation system can be used, provided that this chamber is available and is reachable within 15 minutes. If these conditions are not in place, installing an additional deck decompression chamber will be necessary.

- Subject to a risk assessment, if the rescue of the bell is planned with an ROV that is equipped with all the tools described previously and has the capacity to install the emergency backup umbilical safely, it can be considered acceptable to limit the intervention of the surface rescue diver to the tasks described previously using the same diving equipment. Note that when this solution is selected, the team must ensure that the ROV can install the rescue umbilical properly.
- If the rescue of the bell is planned to be done by an ROV that is not equipped with the tools to install the emergency umbilical, the bell will be supplied by its onboard gas only, and without heating, electrical supply, and wired communications, as long as these emergency supplies are not connected. For this reason, it will be necessary to do it by a diver as soon as possible. In this case, the depth of intervention of the diver will depend on the means of deployment available, and the diving procedures to be in force must be those that must be implemented when using these systems for standard interventions:
    - The dives can be organized to 75 m maximum using wet bells supplied with heliox.
    - If only baskets are present, the interventions can be scheduled to 50 m maximum.
    - Note that the means of deployment of the stand-by diver of the diver(s) rescuing the bell must provide the same level of safety as the primary deployment system. For example, using a basket to rescue a wet bell lowered below 50 m is not acceptable.

  It is commonly accepted that the bell is freed and connected to the crane by the ROV, and the emergency umbilical is installed by the rescue diver when the bell is above his maximum operational depth. The rules for the deployment of the rescue diver during unfavorable weather conditions are those explained above. Note that this procedure has the inconvenience that the emergency umbilical cannot be installed at the very beginning of the rescue.
- It is also acceptable to use the surface rescue divers as primary means of intervention for rescuing the bell if the diving operations are organized within their operational range. Note that this method requires sufficient divers to answer situations where the bell has to be freed from the bottom. Depending on the events, this operation can be very long. Also, depths below 30 m limit the duration of bottom times and are not favorable for back-to-back diving. Another point to consider is that the weather conditions for the deployment of the bell must be those of the surface rescue divers.

3.3.3.2 - Tools

- Cable cutter:
It must be capable to cut at least the main and the guide wires of the bell. Some models are designed to cut the umbilical with opening up to 270 mm *(see on the side)* and are recommended. They can be manually or remotely operated.

- Portable hydraulic grinder:
These tools can be used to cut any debris other than cables and the main umbilical if necessary. They must be sufficiently light to allow for easy use. Also, the use of diamond disks is recommended.

- Hand tools:
They consist of spanners, pliers, hammers, crowbars, etc. The spanners and pliers must be adapted to the connectors to install. Replacement tools must be available in case of loss during the rescue operations.

- Lift bags:
Lift bags should be ready with their means for inflation if the divers need to free the bell from debris, dropped umbilical or cables, etc. Note that 1000 kg, 500 kg, and 100 kg units are easy to install and deploy to the bottom.

- Crane + slings
The crane must be ready for use with the appropriate hook and spare slings.

3.3.4 - Loss bell scenarios

3.3.4.1 - Scope of the lost bell procedures scenarios presented

As indicated in the previous scenarios, it is impossible to write a document that encompasses all situations and eventualities that may arise due to unplanned and catastrophic incidents.

The purpose of the following scenarios is to offer guidelines that can be used by project teams to formulate their "project emergency response plan" and train the diving teams accordingly prior to starting the planned diving operations.
It must be understood that the emergency procedures should be adapted to the characteristics of the project, which include the location where it is undertaken, the material available and logistics, the team, the planned weather conditions, the working depth, and many other elements. Because the scenarios presented here are generic, they may not be fully adapted to the project, and some modifications may have to be discussed and implemented. Also, additional control measures may be found by the team. Ensuring that the safety procedures conform to the best practices is the most important responsibility of the diving superintendent.

Most small and middle-size diving companies use portable systems with only one bell installed on vessels of opportunity as they do not have the resources to buy and maintain proper Diving Support Vessels. Also, apart from those operating in places where a lot of saturation diving operations are undertaken at each other's proximity, they generally work in isolated areas, far from areas where a potential rescue boat can be found. It should be considered that such conditions represent more than 80% of the saturations operations undertaken in the world. For these reasons, the scenarios described in this document have been adapted to these diving conditions, so a diving system with one bell only operating alone.
Also note that these scenarios highlight that using built-in twin bells saturation systems such as those described at the beginning of this book is advantageous in terms of capacity to recover divers trapped in a lost bell and offer better flexibility and availability.
Considering the elements discussed above, the following scenarios which can happen alone or be cumulated with others have been considered:

- *Loss of main bell wire with umbilical intact (see point 3.3.3.2).*
- *Loss of main bell wire and umbilical (see point 3.3.3.3).*
- *Loss of main bell wire , umbilical and clump weight (see point 3.3.3.4).*
- *Clump weight lost or damaged (see point 3.3.3.5).*
- *Entrapment of the bell and clump weight (see point 3.3.3.6).*

- Remarks

- The DP DSV / Barge are presumed to be still functional and capable of carrying out a diving bell rescue.
- A lot of modern bells are designed to sit on their clump weight with the door open, and this option has been taken into account in these procedures. Another option described in this document is the use of a standoff frame. However, some bells may be designed differently. The procedure described to clear the bell from the bottom using the bell ballast release system should be used in this case. A similar procedure should also be used if the clump weight has been damaged or the bell is laid on the bottom with an insufficient gap to open the bottom door.
- Considerations should be given to the wind direction and strength, currents, and sea state.
- Consideration should be given to mooring lines and any obstructions that may disturb the deployment of rescue devices and the bell's recovery.
- Consideration should be given to whether other diving or ROV support vessels are in the area and whether they may render assistance (for example, wet transfer). Nevertheless, when writing the emergency procedures, this option must not be considered a primary option. Such vessels' intervention will depend on their availability and distance from the accident site.- Close visual inspections
- In all scenarios, and of course if possible, the divers and the ROV should carry out a visual survey of the bell, and report the status of the following:
  - The main lifting wire and the guide wires that may be damaged or cut and laid on the bell and the bottom.
  - The condition of the main umbilical and of its attachments to the bell. Similarly to lifting and guide wires, the umbilical may be severed and laid on the bottom.
  - The condition of the secondary lifting padeye and rigging.
  - Whether the clump weight is trapped.
  - The condition of the viewports.
  - The condition of the emergency connectors.
  - The condition of all external pipe-works especially those that may have been damaged by shocks resulting from falling objects, or the contact with the bottom or an obstruction.
  - The condition of batteries, junction boxes, and electrical wires, especially when shocks and tractions have been exerted.
  - Any signs of gaseous escape from hull penetrators, valves, and other devices.
  - Any other abnormalities that may result from the incident.

3.3.4.2 - Loss of main bell wire with umbilical intact

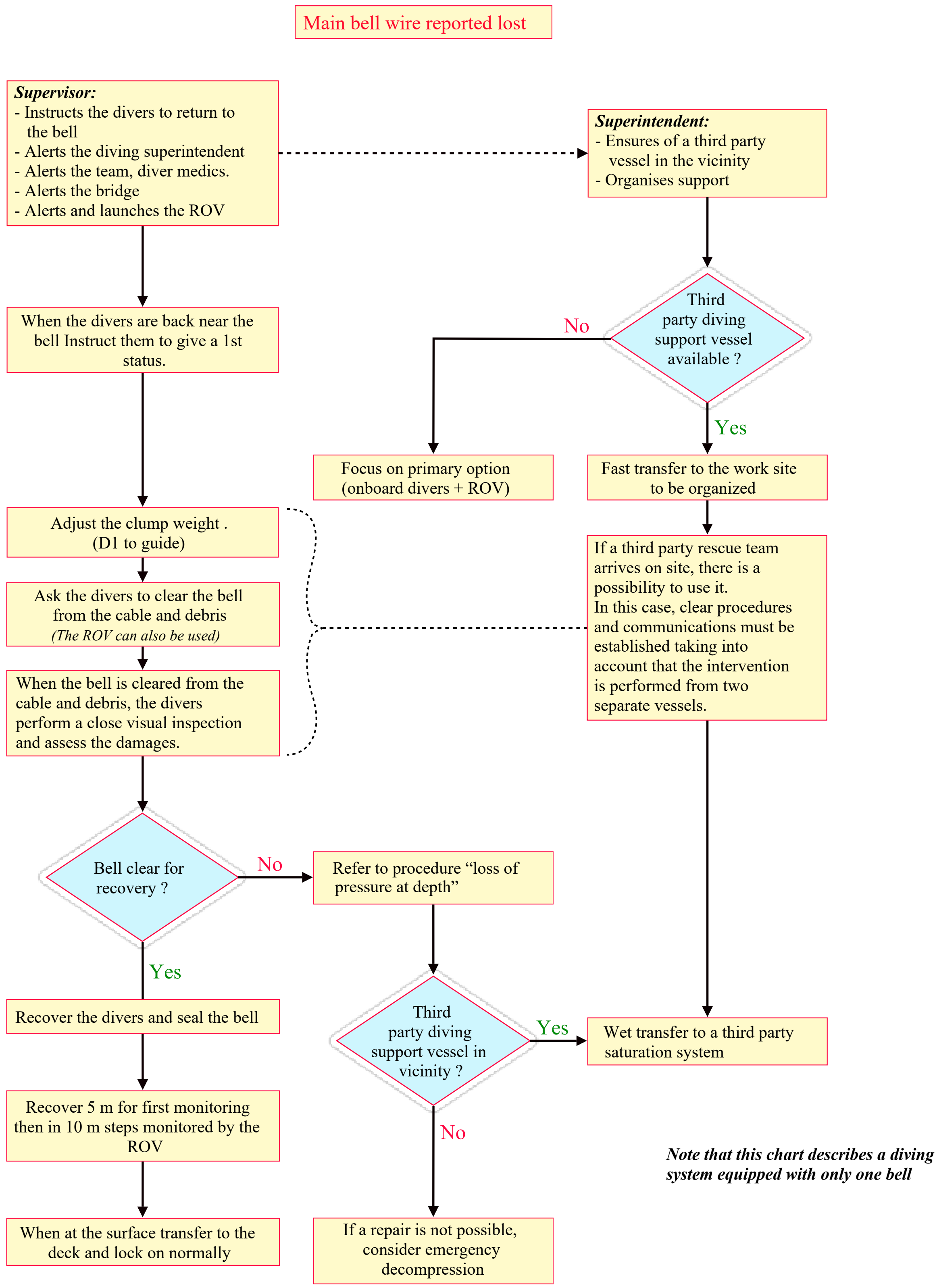
- Potential consequences:
  - The bellman should notice the sudden movement of the bell resulting in:
    - The bell rests on its clump-weight
    - The bell may be at an angle
    - Partial flooding of bell
  - The surface team can be alerted by increased tension in the umbilical and the angle of the main wire which may not be parallel to the guide wires.
  - The bell is normally supplied

- Actions to implement:

No	Action divers, bellman & ROV	Action surface
1	- The bellman informs the supervisor of the situation - The bellman checks the status in the bell (uses checklist) - Recovers the divers *Note: If there is no standoff frame, the divers must not position below the bell (potential crush-point).*	- The supervisor instructs the divers to return to the bell, assess the situation, and report findings - Alerts the surface rescue team (standby diver) - The supervisor informs the bridge and the diving superintendent of the situation. - The saturation control is to be informed along with the medic and the DMT(s) in the chamber. - The ROV team is asked to launch, or if the machine is already in the water, proceed to the site to monitor the bell and divers with caution and from a safe distance until the situation is assessed.
2	- The divers or/and the ROV start a visual survey of the bell and its wires and report the status to the surface	- The diving superintendent contacts other vessels that can render assistance if necessary. (This possibility should be planned in the emergency response plan).
3	- Diver 1 guides the adjustment of the clump weight.	- Under Diver 1 or ROV instruction, adjust the clump weight to remove the main wire as comfortably as possible. *Note: Be sure that the cable can be clearly seen*
4	- The divers must disconnect wire from the bell and discard it to the seabed. When the parted main lift wire is laid on the bell, the bell can normally be recovered,	- Monitor the divers or ROV, and prepare the rigging and tools which may be needed. *Note: A secondary lifting system may be connected to assist the clump weight during the ascent (as an example the crane).*
5	- Carry on a proper damage assessment, particularly to valve fittings, penetrators, and viewports.	- The supervisor should require a proper damage assessment of the bell, particularly to valve fittings, penetrators, and viewports. Mechanical & Electrical Technicians are to be involved for guidance to the supervisor and the divers. - *Note: In case of damages the team should decide wether the bell can be recovered or not. In the case that recovery is impossible, refer to procedure "Loss of pressure at depth"*
6	- Diver 2 returns in the bell	- Ask the bellman to recover Diver 2 inside the bell (if appropriate)
7	- Diver 1 stows the bellman's umbilical.	- Ask to disconnect and stow the bellman's umbilical.
8	- Diver 1 returns in the bell	- Give the order to recover diver 1
9	- The bellman flushes the water from the bell.	- The supervisor asks the bellman to flush the bell (or flushes it).
10	- The external and internal bell doors are closed. - A seal of 1 - 3 m over the bell depth is established.	- Ask the divers to close and seal the bell.
11	- The divers standby in the sealed bell. - The ROV is used to watch and report the status of the bell and the condition of the doors.	- The supervisor prepares to recover the bell to the surface using the clump weight system. The umbilical must be recovered at the same time. - Send the ROV to watch and report the bell's status and ensure that the external door is closed and that the bell is sealed.
12	- The ROV team ensures that the cable is out of the way of the bell. *Note: This phase can be undertaken earlier.*	- Ask the ROV to ensure that the parted main lift wire is recovered or moved out of the way of the bell not to create any trouble during the recovery. *Note: A site-specific solution for removing the lift wire and main umbilical shall be formulated as part of the site-specific emergency response procedure to allow unfettered access for the bell.*

Hyperlink Tables of contents

No	Action divers, bellman & ROV	Action surface
13	- The ROV team observes the bell and reports the depth during the 1st phase of lifting.	- Lift the bell 5 metres above the seabed using the clump weight system. Check the depth, and ask the ROV to monitor the operation. - Watch for leaks.
14	- The ROV monitors the bell's lifting to the surface, paying attention to leaks and the wires' condition, and the umbilical.	- Recover the bell in 10 metres steps and monitor it with the ROV. *Note: If needed, the surface standby diver can be launched when the bell is in his range of intervention.*
15	- Recover the ROV.	- Once at the surface, the bell is locked-on, and the divers are transferred to the chamber in accordance with the normal procedures.



As previously indicated, a twin bell system provides the advantage of not depending on another vessel for a wet transfer.

3.3.4.3 - Loss of main bell wire and umbilical

- Potential consequences
  - The bell man should feel sudden movements of the bell resulting in:
    - The bell rests on its clump-weight
    - The bell may be at an angle
    - Partial flooding of bell
    - Loss of electrical power, normal communications & sound powered phone
    - Loss of main gas

Note: The onboard emergency panel should switch automatically to onboard gas.

- Actions to implement

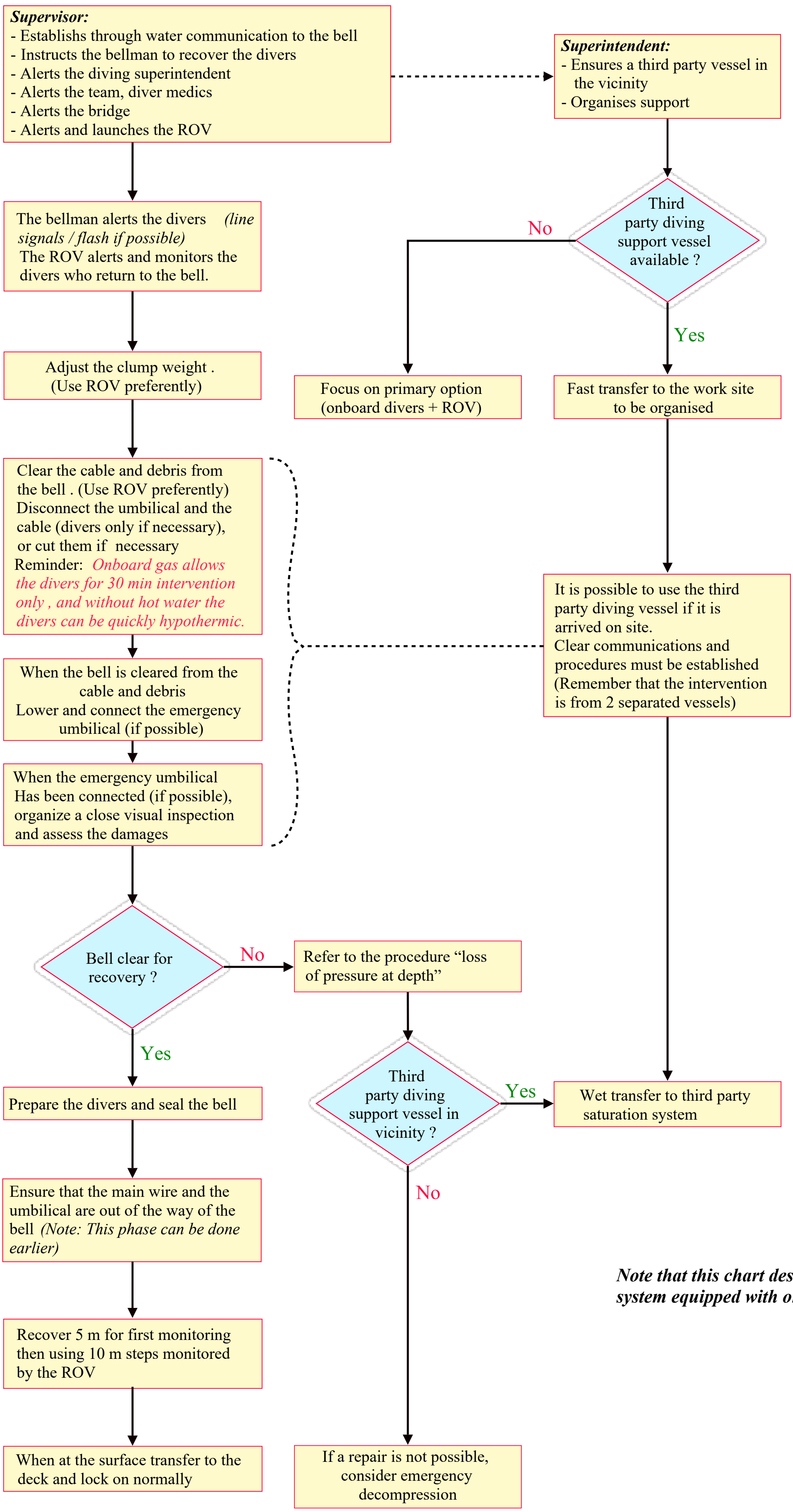
No	Action divers, bellman & ROV	Action surface
1	- The bellman confirms that the emergency gas panel has switched to onboard gas reserve. - The bellman switches on emergency power if not automatic. - The bellman switches off all surface supplies - The bellman ensures that the through water communication set is working (should be..), and answers to the supervisor.	- The supervisor secures the gas supplies to the bell from main panel. - Establishes Through Water Communications, with the bellman, and confirms the well-being in the bell. - Ask the bellman to recover the divers ASAP - Informs the bridge and the diving superintendent - Informs the LSS/LST along with the medic and diver medics - Alerts the deck team - Alerts the rescue team (standby diver) - Alerts and launch the ROV if not already in the water. - The diving superintendent contacts diving vessels that are available to render assistance if needed.
2	- The bellman alerts the divers (flashing if possible and umbilical signals). - The ROV alerts the divers (flashing) and monitors the recovery.	- Monitor the recovery of the divers through the ROV screen. - Prepare for inspection (call the technicians for assistance). - Prepare the surface team for recovery.
3	- Once the ROV has arrived, he assesses the situation: Checks if any wire /umbilical is attached or lying over the bell. - If the divers are outside the bell, they should return into it as soon as possible. - When entering into the bell, the divers assess the condition of the external door.	- Because of no communication with the divers, the supervisor should assess the condition of the bell using the ROV. Note: Because the supplies from surface are severed, depending on the temperature of the water, the divers can quickly become hypothermic and short of gas. The wise decision should be to avoid exposing them. - The parts of umbilical and cable on the seabed will have to be disconnected from the bell.
4	- If the ROV is not equipped with cutting tools (as an example, ROV at depth when the incident has happened), it is recovered to the surface for this purpose.	- Ensure that the ROV is equipped with cutting tools *Note: Be sure that the external door will not come into contact with the clump-weight when lifted.*
5	- The clump weight is adjusted to clarify the position of the wire and umbilical to remove. - The parts of cables and using its manipulators and other tools, such as the crane)	- Readjust the clump weight to ensure that the bell wire and the umbilical can be easily removed. - Prepare the emergency umbilical. - Prepare the tools to clear the bell from the wire, debris, and the umbilical. - The crane may be necessary to assist, if no crane, a winch can be used.
6	- The ROV reassess the situation and the elements to discard.	- The diving supervisor assess the situation with the ROV pilot.
7	- The ROV cuts the parts of the wire and the umbilical to be discarded. - If requested, and if they can, the divers move out of the bell to disconnect the main lift wire from the delta plate, and discard it to the sea-bed. Then, they remove the main umbilical and discard it to the sea-bed *(Remember the limited reserves of gas and the absence of heating that may make this not realistic).*	- If the ROV is unable to clear the parted main lift wire and umbilical that is lying on the bell, the supervisor can: • Ask the divers to disconnect the main lift wire from the delta plate and the main umbilical from the hull-valves, and discard them to the sea-bed. • Cut the cables and the umbilical in several parts to clear them more easily (divers can be use for that, but the ROV is more appropriate for this task). *Note: Use the divers only when absolutely necessary as they are on onboard gas with limited range (30 min), and that there is no hot water supply.*
8	- The ROV, or the divers if necessary and possible, connect the backup umbilical. - Once the umbilical is connected the bellman restores the basic functions of the bell.	- When the bell is cleared from the main cable, debris and the main umbilical, the secondary umbilical is lowered and connected by the ROV, or the divers if possible and necessary. - Activate the function of the bell when it is confirmed connected.

No	Action divers, bellman & ROV	Action surface
9	- The divers prepare for the recovery of the bell.	- When the basic functions of the bell are restored, prepare it for the final recovery - If it is not possible to connect the emergency umbilical, the recovery should be done using onboard gas. *Note: The emergency umbilical can be connected later on during the ascent (Surface standby diver) or when the bell will be at the surface. This will be depending on the speed of recovery and/or the possibility to launch the standby diver.*
10	- A proper damage assessment should be carried on, particularly valves, fittings, penetrators and viewports.	- Mechanical & Electrical Technicians should be involved to help the supervisor. - Use the ROV to perform another inspection of the bell to have a clear idea of damages that may not been seen during the 1st assessment. Also ask the divers to report the condition inside the bell using through water communications if the backup umbilical is not connected. *Note: In case of damages, the team should decide wether the bell can be recovered or not. In the case that recovery is impossible, refer to procedure "Loss of pressure at depth".*
11	- The standby diver umbilical must be disconnected from the mask.	- Ask the divers to disconnect the standby diver umbilical from the mask.
12	- If possible, Diver 1 stows the bellman's umbilical. - If it is not possible to stow it outside the bell, the divers throw it out and secure it near the bottom door if possible.	- If possible ask to stow the bellman's on the outside of the bell. - If it is not possible to stow the bellman umbilical outside the bell, ask the divers to throw it out and to secure it near the bottom door if possible.
13	- The bellman flushes the bell.	- Ask the bellman to flush the bell. If the function is restored it is done using the gas from the surface.
14	- Close external and internal bell doors - Seal the bell 1 - 3 m over the bell depth.	- Ask the divers to close and seal the bell.
15	- The divers standby for instruction. - If the bell is on onboard gas, the divers prepare the lung powered scrubbers. - The ROV team watches and report the status of the bell.	- Prepare to lift the bell to the surface using the clump weight system. (Note that the crane or a 2nd winch could also be used). - Send the ROV to watch and report the status of the bell and make sure that the external door is closed and will not come into contact with the clump-weight when lifted.
16	The ROV team ensures that the cable and the umbilical are out of the way of the bell (Note that this phase can be undertaken earlier). - If the bell is on onboard gas, the bellman monitors the CO_2 and PPO_2 levels, injects O_2 if necessary (O_2 make up system) during the ascent. - If the basic functions of the bell are restored, normal monitoring is performed.	- Ensure that the hanging parts of the main lift wire and the umbilical are recovered or moved out of the way of the bell to prevent any trouble during the recovery. *Note: A site-specific solution for the removal of the remaining parts of the main bell wire and umbilical should be formulated as part of the site-specific emergency response procedure to allow unfettered access for the bell to mate.* Examples: • If deployed over the side, the LARS can be used. The crane can also be considered for the recovery. • If the bell is deployed from a hangar through a moon-pool, a winch can be used.
17	- The ROV teams monitors the bell for leaks and reports its depth.	- Lift the bell 5 metres, check its depth, and ensure it holds pressure - Ask the ROV to monitor the bell for leaks.
18	- The ROV monitors the ascent of the bell to the surface, paying attention to the wires, the umbilical and potential leaks.	- Recover the bell by 10 metres steps. - Monitor the bell using the ROV. Note: If needed the surface standby diver can be launched when the bell is in his range of intervention to connect the emergency umbilical, or assist for the recovery.
19	- The ROV team recovers the machine when instructed to do it.	- Once at the surface, the bell is locked-on the system, and the divers are transferred in the chamber in accordance with the normal procedures.

Note that if the bell cannot be recovered, the wet transfer should be considered: In this case, the 2nd vessel is to be at the proximity, or the only option is accelerated decompression.

This procedure shows the advantage of having two bells, as in this case, a wet transfer is always possible, and the divers in the 2nd bell can be used to perform the ROV work. Note that a diver usually works 3 times faster than an ROV.

Main bell wire and umbilical



Note that this chart describe a diving system equipped with only one bell

3.3.4.4 - Loss of main bell wire, umbilical and clump weight

- Potential consequences

This scenario will most likely result from a vessel loss of position or unplanned movement. It is considered the absolute worst case.

The actual management of an occurrence of this nature will largely depend on the bell's as-found conditions on the sea bed. For example:

- The depth of the bottom and the depth from which the bell has fallen.
- The proximity of subsea infrastructures.
- Whether the bell has fallen on a subsea structure or inside a subsea structure.
- Whether the bell is up-right and sat on the sea-bed.
- Whether the bell is laid on the side and partially flooded.
- Whether the bell is inverted and completely flooded.
- Whether the bell is intact or damaged, and in this case, the extends of the damages.
- Whether the divers are conscious.
- Whether some divers are incapacitated.
- Whether the ROV have free, unfettered access to the bell.
- Whether through water communications can be used.

Note: The onboard emergency panel should switch automatically to onboard gas.

Due to the multiple variations and possible scenarios, the below sequence is to be used as general best practice guidance to which the project team must adapt the response based on the as found situation.

For convenience, the following scenario is based on the assumption that the divers and the bellman report well, the bell is upright on the bottom and the divers can return into it.

- Actions to control

No	Action divers, bellman & ROV	Action surface
1	If the bellman is unharmed: - He confirms that the emergency panel has switched to an onboard gas reserve. - He switches on the emergency power if not automatic. - He switches off all surface supplies - He ensures that the through water communication system is working and answers to the supervisor. - If possible, he flushes the bell (even partially), to avoid becoming hypothermic.	If the incident is related to an unplanned movement, or loss of position, the vessel must regain control. - Secure all the supplies from the main panel to the bell. - Establish the through Water communication system and contact the divers in the bell. - Inform the bridge and the diving superintendent - Inform the LSS/LST, the medic, and diver medics - Alert the rescue team (standby diver) on deck - Alerts and launches the ROV if not already in the water. The diving superintendent ensures whether other Diving Support Vessels are available to render assistance through a wet transfer?
2	- If the divers are unharmed, they return to the bell. In case of injuries, they assist each other, or the standby diver is launched to help their return. - The ROV locates the bell wires / umbilical and fly to depth to confirm the bell's status. - The transponder may be used to locate the bell. The approach should be prudent.	- Interrogates the transponder of the bell to locate it. *Note: If the bridge and the survey team have a contact through the Emergency Locator Beacon, this information is to be plotted on the Nav-Screen.* - If the contract using the through water communication system is successful, ensure that the bellman is recovering the diver. - Once the bell and the divers are located by the ROV, ensure their condition and that they are able to return to the bell.
3	- The ROV confirms the bell orientation (in this example, upright), and investigates for damages - When back into the bell, the divers assist the bellman.	- Order the surface team to deploys the crane (preferred option), when ready. - Prepare the emergency umbilical. *Note: If the bell is sitting on the bottom and the divers cannot return to it, install the crane immediately to clear it from the seabed and allow access inside it. The 2nd option is to partially release the ballast with the weight still attached to the bell by the chains (1st step only), but the bell must be free of debris, and it must be considered that a mistake will be catastrophic.*
4	- If the ROV is not equipped with a cutter, it is recovered to the surface to install it. - The ROV clears the wires and the umbilical from the bell using its manipulators and other tools. (Crane / cutters).	- If the ROV is not equipped with cutters, recover it to surface for this purpose - The diving supervisor assesses the situation with the ROV pilot. - Use the divers only when necessary as onboard gas reserves offer limited time in the water (30 min), and there is no hot water supply.

No	Action divers, bellman & ROV	Action surface
5	- If possible, the divers move out of the bell to disconnect the main lift wire from the delta plate and discard it to the sea-bed. Then disconnect the main umbilical and discard it to the sea-bed. - If required, the ROV cut the wire and the umbilical in several parts and discard them to the sea bed (the divers can partially do that, but think of the limited reserves of gas and no heating).	- If the ROV is unable to clear the parted main lift wire and umbilical that is lying on the bell, the supervisor can: • Ask the divers to disconnect the main lift wire from the delta plate, disconnect the guidewire, disconnect the umbilical, and discard them to the sea-bed. Cut the cables and the umbilical in several parts to clear them more easily (Depending on the environmental conditions, divers can be used for that, but the ROV is more appropriate for this task). *Note: Use the divers only when necessary, as they are on onboard gas with limited range (30 min), and there is no hot water supply.*
6	- If possible, the divers release the Bell Emergency pick-up sling from its storage. If the divers cannot do it, use the ROV. - The ROV may be recovered to the deck to remove the cutting tool and reinstall the manipulator.	- Prior to deploying the crane, ensure that there is a clear area on the main deck where the bell can be recovered. - Then, the vessel's crane is to be made ready for deployment with: • Appropriate stinger complete with ROV hook • Bell Emergency Umbilical • Locator Beacon & strobe Light - Recover the ROV to reinstall the manipulator in place of the cutting tool.
7	- The ROV spots the crane and directs it to the bell location.	- The crane is deployed over the ROV location.
8	- The Divers or the ROV recover the end of the Bell Emergency Umbilical and connect it to the bell emergency panel on the bell if accessible and open hull valves.	- The supervisor installs the basic functions of the bell. *(The basic functions are gas supply and hot water. Depending on the system, there could be power supply and communication.)*
9	- The divers or the ROV attach the emergency pick-up sling to the crane. - If communications are still unavailable, the divers return to the bell to inform the ROV by sign that the bell is ready to be lifted, and return in the bell.	- Monitor the installation through the ROV CCTV. - Acknowledge information from the ROV, and confirm it with the bellman when the divers are back in the bell.
10	- The ROV positions to observe the lifting of the bell. Then, using hand-signals to the ROV (if communications not available), guide the crane, which comes up slowly to approximately 5 metres above the seabed.	- Under the ROV observation,come-up the bell approximately 5 metres above the seabed and stop *Note: The ROV must not communicate with the crane, but only with the diving supervisor.*
11	- A proper damage assessment is carried out, particularly to valve fittings, penetrators, doors, and viewports.	- Require a proper damage assessment of the bell, particularly the valves, fittings, penetrators, doors, and viewports. - Mechanical & Electrical Technicians are to be involved to help the supervisor. - To have a clear vision, use the ROV to check outside the bell, and the divers to report what happens inside the bell. *Note: In case of damages, the team should decide whether the bell can be recovered or not. In the case that recovery is impossible, refer to procedure "Loss of pressure at depth".*
12	- If outside the bell, the divers returns into it.	- Recover the divers in the bell if outside the bell.
13	- Disconnect the standby diver mask.	- Ask to disconnect the mask of the standby diver.
14	- If possible, diver 1 stow the stand by diver umbilical. If not possible throw it out of the bell and secure it near the door.	- If the bellman's umbilical is stowed at the external ask to stow it or throw it outside the bell.
15	- The bellman flushes the bell.	- Ask the bellman to flush the bell.
16	- Close external and internal bell doors - Seal the bell 1 to 3 m over bell depth	- Ask the divers to close and seal the bell.
17	- The divers standby for instruction. - If the bell is on onboard gas, the divers use the lung powered scrubbers. - The ROV watches and reports the status of the bell and the condition of the doors	- Prepares to lift the bell to the surface using the crane. - Use the ROV to watch and report the bell's status and make sure that the external door is closed and that there are no leaks.

<table>
<tr><th>No</th><th>Action divers, bellman & ROV</th><th>Action surface</th></tr>
<tr><td>18</td><td>- The ROV ensures that the cables and the umbilical are out of the way of the bell (This phase can be undertaken earlier).
- If the bell is on onboard gas, the bellman monitors the CO2 and PPO2 levels and inject O2 if necessary (O2 make up system) during the ascent.
- If the basic functions of the bell are restored, normal monitoring is performed.</td><td>- The hanging wires and the umbilical are recovered or moved out of the way of the bell, not to create any trouble during the recovery.
Note: A site-specific solution for removing the hanging main bell wire and umbilical should be formulated as part of the site-specific emergency response procedure to allow unfettered access for the bell to mate.</td></tr>
<tr><td>19</td><td>- The ROV monitors the bell and reports the depth.</td><td>- Lift the bell 5 metres. Check the depth inside and outside the bell. The ROV can be used in addition to the bell gauges.
- Watch for leaks.</td></tr>
<tr><td>20</td><td>- The ROV monitors the ascent of the bell to the surface, paying attention to the wires and the umbilical.</td><td>- Recover the bell in 10 meters steps. Monitor with ROV.
Note: If needed, the standby diver can be launched when the bell in his range of intervention.
If not installed on the bottom, the emergency umbilical can be lowered and connected by the Air divers at this point.</td></tr>
<tr><td>21</td><td>- Depending on the weather conditions, the splash zone can be uncomfortable for the ROV. If no problem was detected before, the ROV does not follow the bell in this zone</td><td>- The weather conditions are to be considered when bringing the bell through the splash zone, and the ROV is not comfortable in such an area. In this case, it is preferable not to follow the bell in this zone.</td></tr>
<tr><td>22</td><td>- The ROV can be recovered when the bell is on deck.</td><td>- The bell is to be landed on the designated lay-down position.</td></tr>
<tr><td>23</td><td></td><td>- To transfer the divers to the saturation system, the following points (but not limited to) should be considered:
• Cooling of the bell during the preparation phase (Sunshades Deluge Systems) and food and water transfer to the divers.
• Procedure for cutting-back the bell main lift wire, removing the damaged section, and re-terminating.
• Procedure to reconnect the bell to the system (transfer in the water and recovery through the LARS.
• Vessel heading control to minimize pitch heave and roll.
• Communications with the bell occupants, bell dive control, and saturation control during the TUP</td></tr>
<tr><td>24</td><td></td><td>- Once reconnected to the LARS, the bell is locked-on, and the divers are transferred to the chamber in accordance with normal procedures.</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>25</td><td colspan="2">Bell drop weight release option
In this procedure, partial weight release (1st step release) with the weights still secured to the chains' bell has been considered possible. However, a loss of control during the procedure could lead to the full release of the weight and the bell moving up full speed.
For recovery options based on the full release of bell weights (Drop ballast), the Project team must compile specific procedures based on the Project Equipment / Bell type and configurations and consider all other procedures of recovering in preference, as recommended by AODC 61.
The points to note in the planning and writing of procedures are, but not limited too:
• The specific bell drops weight release procedure.
• Specific bell main lift wire, guide wires, and the umbilical internal release systems, if the bell is fitted with.
• Removal of damaged bell main lift wire and umbilical from the bell, which could obstruct the bell's ascent.
• The proximity of fixed structures and assets to the projected ascent path. ROV to survey before release.
• Tide patterns and direction.
• Vessel positioning during the operation and ensuring the ascent path is clear.
• The use of surface swimmers and small rescue craft/vessels.
• The ROV positioning during the free ascent of the bell.
• Surface lookouts to spot the bell as it breaks the surface.
• Attachment of tow/restraining line from the small craft/vessel to the bell.
• Bell divers role in the ascent.
• Re-establishment of communications/ hot water / gas.
• Characteristics of the available crane and lay down areas.
• Surveying the bell on the surface for damage, paying particular attention to the ports, penetrators, and sealing faces of the mating flange.</td></tr>
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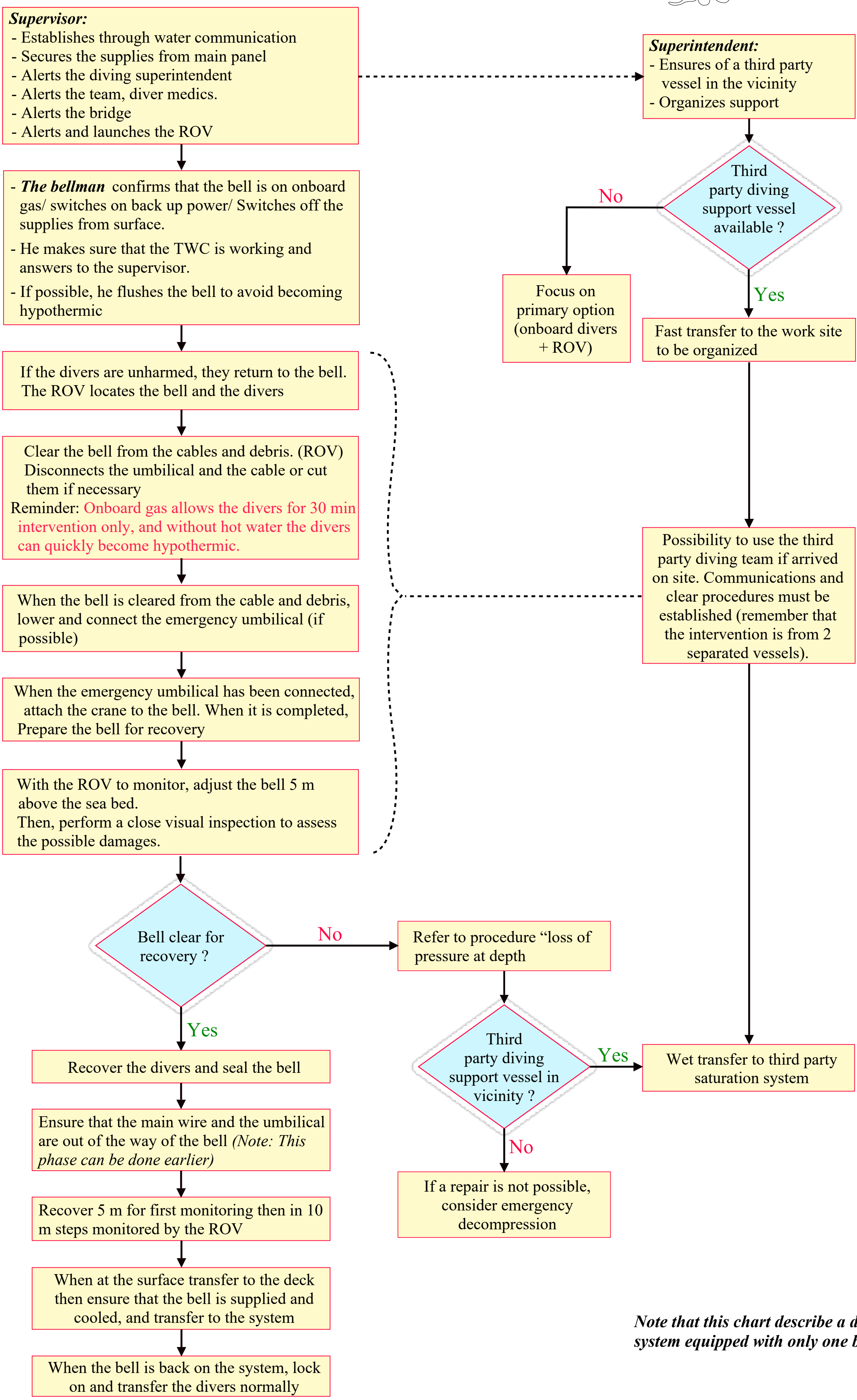


Note that this chart describe a diving system equipped with only one bell

This procedure shows the advantage of having two bells, as in this case, a wet transfer is always possible, and the divers in the 2nd bell can be used to perform the ROV work. Note that a diver usually works 3 times faster than an ROV.

3.3.4.5 - Clump weight lost or damaged

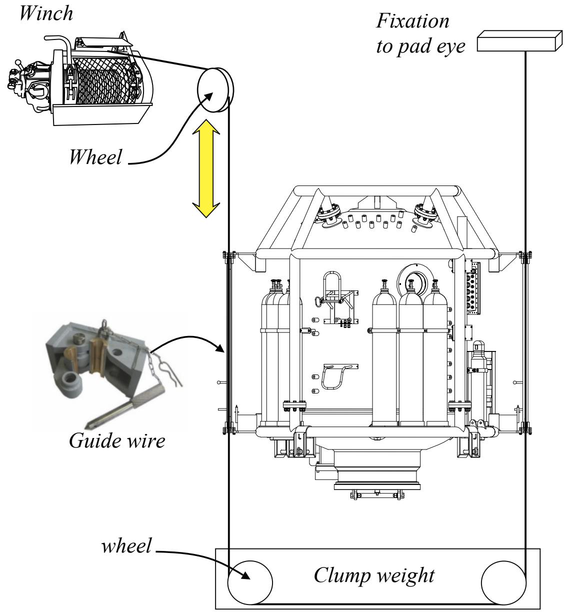
Such situations could arise from:

- Wire damaged or severed following contact with a subsea structure or the sea bed.
- Defective wire

- Potential consequences:

- The bell is rotating due to the action of the currents and the motions of the vessel.
- Clump weight lost or laid on the bottom.

Clump weights are described in point 1.1.2.2 “Anti gyration systems”.
The clump weight of a lot of bells consist of a beam, or a frame that can be adjusted to facilitate the access into the bell. This structure is lowered and recovered by means of a wire passing through 2 wheels (one each side of the beam) with one end fastened to a pad eye on the top of the frame of the Launch And Rescue System (LARS), and the other end to a winch on the other side of the LARS. If this cable is severed, the clamp falls to the bottom. As explained in point 1.1.2.2, note that some bells have 2 separated weights controlled by separated winches. This system has the advantage of keeping a partial control of the bell rotation if one weight is lost.
A clump weight lost should not compromise the recovery of the bell if the cable has been cut below the bell, but there may be damages to the bell if the cable has been cut above, because the cable may fall on it.
The situation could be more critical, and result in damages to the Launch And Recovery System (LARS) and the bell if the clump weight is trapped on the bottom or inside a structure.



- Actions to control:

No	Action divers, bellman & ROV	Action surface
1	- Check the status in the bell (use checklist) - Recover the divers - When back near the bell, the divers start the investigation: If the cable has been cut above the bell, the divers start a visual survey of the top of the Bell and report the bell's status. If the cable is cut below the bell, ensure whether the cable is fouled, and assess the possibility of recovering the clump weight.	- The supervisor instructs the divers to return to the bell, assess the situation, and report findings. - Alerts the surface rescue team (standby diver) - The supervisor informs the bridge and the diving superintendent of the situation. - Saturation control to be informed along with medic and DMT(s) in the chamber. - ROV instructed to launch, or if already in the water, to proceed to the bell to monitor the bell and divers with caution and from a safe distance until the situation is assessed.
2	- If the clump weight can be recovered using its wire or another means, organize for the recovery. - If the cable is laid on the top of the bell, clear the cable (can be cut and discarded).	- If the clump weight is accessible by the divers • Make sure whether it can be recovered using its wire. • If the recovery using the guidewire appears not possible, a secondary lifting system (crane) may recover it. - If the recovery of the clump weight by the divers is not possible, organise the recovery using the ROV later on. - Ensure that the bell is freed from any cable, which could compromise its recovery.
3	- If it is possible to recover it, the divers guide the recovery of the clump weight.	- Under Diver 1 instruction, recover the clump weight with its wire, and move it away to recover it after the bell's recovery.
4	- If possible, diver #1 and /or the ROV guides the recovery of the guide wires.	- If necessary and possible, under Diver 1 or/and ROV instruction, recover the parts of guide wires, which can be recovered.
5	- A proper damage assessment is carried on, particularly to valve fittings, penetrators and viewports.	- The supervisor should require a proper damage assessment of the bell, particularly to valve fittings, penetrators, and viewports... Mechanical & Electrical Technicians are to be involved for guidance to the supervisor and the divers. *Note: In case of damages, the team should decide whether the bell can be recovered or not. In the case that recovery is impossible, refer to procedure "Loss of pressure at depth".*

No	Action divers, bellman & ROV	Action surface
6	- The divers return in the bell, and disconnect the bellman's mask.	- Recover the divers (one diver stays outside the bell if the bellman umbilical is stowed outside the bell.)
7	- Diver 1 stows the bellman's umbilical	- If the bellman's umbilical is stowed at the external ask to stow it.
8	- Diver 1 returns into the bell	- Recover diver 1
9	- Supervisor / bellman flushes the Bell	- Supervisor / bellman flushes the Bell
10	- The bellman closes the doors. - The bellman seals the bell 1 - 3 m over the bell depth	- Ask the divers to close and seal the bell.
11	- The divers standby for instruction. - The ROV monitors the bell and reports its status and the condition of the doors.	- Prepare to lift the bell to the surface. - Send the ROV to watch and report the status of the bell.
12	- The ROV observes the bell and reports its depth and condition.	- Lift the bell 5 metres. Check the depth in the bell and with ROV (the depth of the ROV should be visible on the video screen). - Watch for leaks
13	- The ROV monitors the lifting of the bell to the surface, paying attention to the wires and the umbilical.	- Recover the bell in 10 metres steps, and monitor with the ROV. *Note: If needed, the standby diver can be launched when the bell in his range of intervention.*
14	- Recover the ROV	- Once at the surface the bell is locked-on, and the divers are transferred in the chamber in accordance with the normal procedures. Note: Tag lines will be necessary to control the bell.

3.3.4.6 - Entrapment of the bell and/or clump weight

- Such situations could arise from, but are not limited to:

- Poor or incorrect information relating to existing sites, especially the older fields where the as-built documentation has not been updated and does not include past ad-hoc additions to the structure.
- Defective or out of calibration survey information could put the bell closer to a subsea asset than is depicted on the Nav-Screens.
- Fishing Nets and other commercial trawling equipment.
- Previous and unreported damage to structures.
- Overboard scaffolding is present at the diving location. The potential collapse is always a threat, especially if the vessel suffers a loss of position episode.
- Bell pushed by strong currents and waves and trapped under the hull. (This can happen with square-shaped hulls or moonpools badly designed).

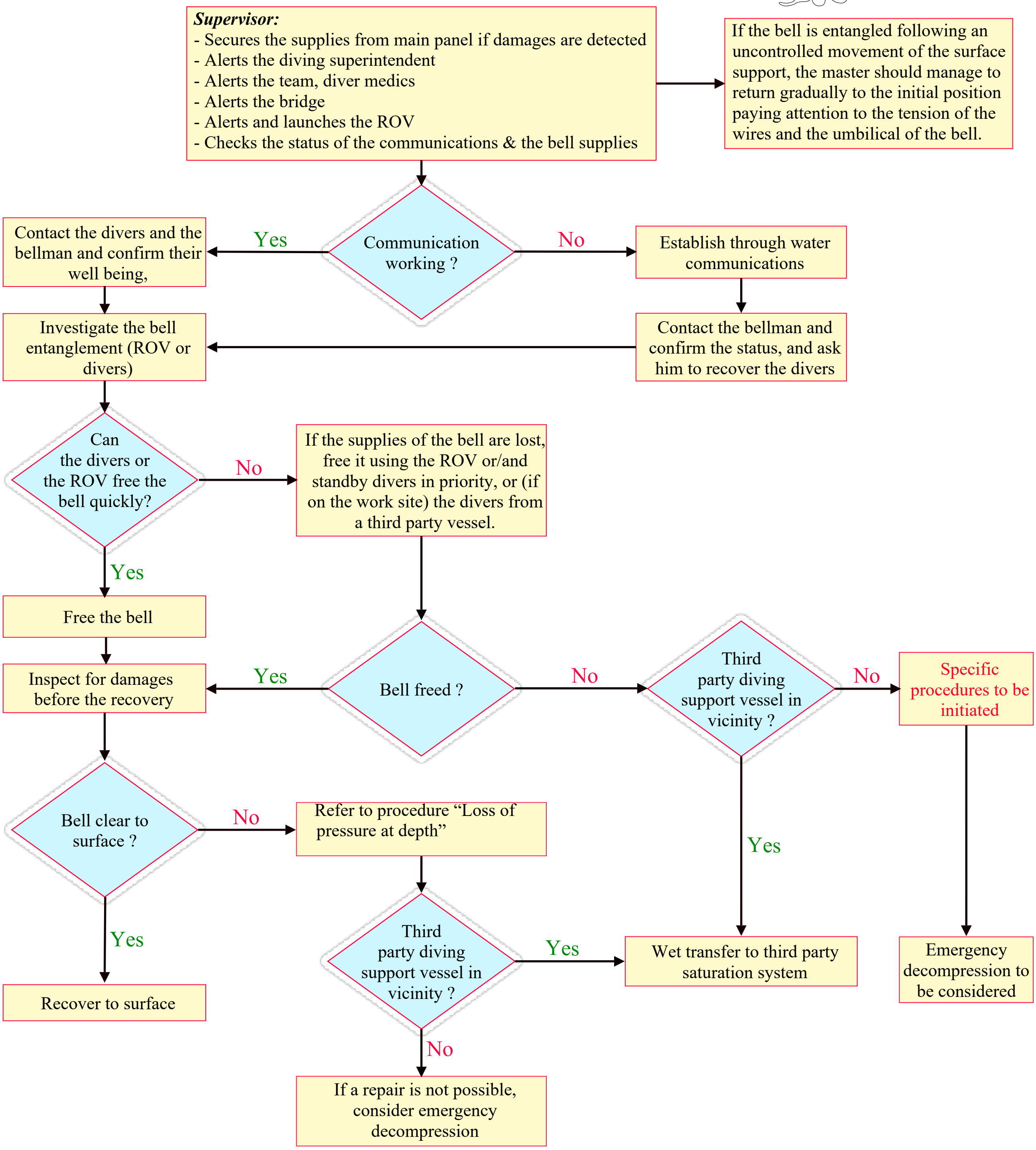
- Potential consequences:

- The bell cannot be recovered
- Bell wires tight or slack with abnormal angles
- Bell damaged, with a potential for the situations indicated before:
  - Loss of main wire
  - Loss of umbilical
  - Loss of clump weight
  - Lost bell

- Actions to control:

The actions should be organized according to one or several scenarios described before. As already indicated, providing a precise procedure is impossible as there are thousands of possible scenarios. What is important is to establish guidelines that can be adapted to the situation encountered.

Note: The chart next page is based on the assumption that the divers are not injured. The situation could be critical in case of injuries or/and damages to the bell.



Supervisor:
- Secures the supplies from main panel if damages are detected
- Alerts the diving superintendent
- Alerts the team, diver medics
- Alerts the bridge
- Alerts and launches the ROV
- Checks the status of the communications & the bell supplies
If the bell is entangled following an uncontrolled movement of the surface support, the master should manage to return gradually to the initial position paying attention to the tension of the wires and the umbilical of the bell.
Communication working ?
Yes
Contact the divers and the bellman and confirm their well being,
No
Establish through water communications
Contact the bellman and confirm the status, and ask him to recover the divers
Investigate the bell entanglement (ROV or divers)
Can the divers or the ROV free the bell quickly?
No
If the supplies of the bell are lost, free it using the ROV or/and standby divers in priority, or (if on the work site) the divers from a third party vessel.
Yes
Free the bell
Inspect for damages before the recovery
Bell freed ?
Yes
No
Third party diving support vessel in vicinity ?
No
Specific procedures to be initiated
Yes
Wet transfer to third party saturation system
Emergency decompression to be considered
Bell clear to surface ?
No
Refer to procedure “Loss of pressure at depth”
Yes
Recover to surface
Third party diving support vessel in vicinity ?
Yes
No
If a repair is not possible, consider emergency decompression

3.3.5 - Wet transfer

3.3.5.1 - Considerations for wet transfer to the 2nd bell of a twin bell vessel

This procedure is in force on twin bell vessels, where the 2nd bell can be used to rescue the occupants of the 1st one. Because the bells are very close, with a known distance and coming from the same vessel, this recovery procedure can be easily and safely organized. Nevertheless, some considerations should be given to:

- The reason which has triggered the need for bell transfer (bell trapped, bell damaged…).
- The subsea obstructions.
- If the bell is lost, whether its position is known and the vessel can hold the position above it.
- Whether the communication is established with the bell.
- The condition of the bell.
- If the bell is without supplies, the time spent without supplies.
- Whether an emergency umbilical has been connected, or if not, whether it can be connected.
- The number and condition of the divers to rescue.
- The number of divers the 2nd bell can transfer.
- The weather conditions and underwater visibility.

3.3.5.2 - Considerations for wet transfer to another vessel

The procedure is more difficult to implement from a 2nd vessel as the vessels are separated, and additional consideration should be given to:

- The protocol of communications between the 2 vessels.
- The supervisor in charge (should be the rescue team).
- The frequency of the through water communication of the bell.
- The distance between the vessels and whether the bell to rescue is safely reachable.
- Whether there is an anchor pattern (4 point mooring/barges).
- The access to the worksite, and the obstructions.
- Whether the vessels' positioning systems will conflict and if the vessels will be able to hold their position.

3.3.5.3 - Considerations during the transfer

The safety of the rescuers must not be jeopardized:

- The rescue diver carries a spare helmet and umbilical to the stranded bell and brings the stranded divers back one at a time.
- If there is a long swim or a current, he should rig a swim line between the bells.
- If the stranded divers are suffering from hypothermia, they should be re-warmed gradually. Connecting them directly to the hot water supply could lead to collapse.
- The number of divers to transfer should be considered: If the swim line is established and the lost bell supplied by an emergency umbilical, it may be safer to organize several quick bell runs.
- A welcome must be organized in the chamber to ensure a medical check-up, and if hypothermic, of a gradual warming of the occupants of the lost bell.

3.3.6 - Bell tapping code

This code must be printed on a rigid plastic board and secured to the top of the bell. It must also be provided to the rescue divers and people involved in the bell rescue.

Code	***Situation***
3 . 3 .3	*Communication opening procedure (inside and outside)*
1	*Yes or Affirmative or Agreed*
3	*No or Negative or Disagreed*
2 . 2	*Repeat please*
2	*Stop*
5	*Have you got a seal?*
6	*Stand by to be pulled up*
1 . 2 . 1 . 2	*Get ready for through water transfer (open your hatch)*
2 . 3 . 2 . 3	*You will NOT release your ballasts*
4 . 4	*Do release your ballast in 30 minutes from now*
1 . 2 .3	*Do increase your pressure*
3 . 3 .3	*Communication closing procedure (inside and outside)*

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4) Bibliography & addresses

4.1 - Bibliography

- JP Imbert - Deep diving: The COMEX experiencee

- CCO Ltd - Implement NORMAM-15 saturation diving procedures

- ADCI - International consensus standards for commercial diving and underwater operations

- Health and Safety Executive - Diving at Work Regulations 1997: Approved Code of Practice and guidance

- French ministry of Labour: Regles relatives aux travaux hyperbare effectues en milieu subaquatique - 14 Mai 2019
Rules related to hyperbaric works performed in subaquatic surrounding - 14 May 2019

- French ministry of Labour: Travaux en milieu hyperbare - 15 Mai 1992 & 4 Aout 1995
Works in the hyperbaric surrounding - 15 May 1992 & 4 August 1995

- NORSOK U100 - Manned underwater operations - Website: www.standard.no/petroleum .

- Brazilian Navy Directorate of ports and coasts - NORMAM-15 DPC rev. 2

- DMAC 02 - In-water diver monitoring

- DMAC 04 - Oxygen content in open circuit bail-out bottles for heliox saturation diving

- DMAC 05 - Recommendation on minimum level of O2 in helium supplied offshore

- DMAC 08 - Thermal stress in relation to diving (Report of a workshop held in March 1981)

- DMAC 15 - Medical equipment to be held at the site of an offshore diving operation

- DMAC 20 - Duration of bell lockouts

- DMAC 28 - The provision of emergency medical care for divers in saturation

- DMAC 31 - Accelerated Emergency Decompression (AED) from Saturation

- DMAC - Report on tests of Zoll automatic external defibrillator function in hyperbaric heliox conditions - Helix Well Ops (February 2014)

- DMAC - Statement on Deep Saturation Diving Conducted Using Appropriate Procedures (updated March 2019)

- IMCA D 007 - Overboard scaffolding operations and their effect on diving safety

- IMCA D 008 - Testing of through-water communications

- IMCA D 010 - Diving operations from vessels operating in dynamically positioned mode

- IMCA D 014 - IMCA international code of practice for offshore diving

- IMCA D 022 - Guidance for diving supervisors

- IMCA D 024 - DESIGN for saturation (bell) diving systems

- IMCA D 032 - Cross-hauling of bells *- Note: Such procedures should not be used -*

- IMCA D 054 - Remotely operated vehicle intervention during diving operations

- IMCA D 058 - Diver attachment to structures by means of a weak link

- IMCA D 002 - Battery packs in pressure housings

- AODC 009 - Emergency isolation of gas circuits in the event of a ruptured bell umbilical

- AODC 038 - Guidance on the use of inert gases

- AODC 047 - The effects of underwater currents on divers' performance and safety

- AODC 055 - Protection of water intake points for diver safety

- AODC 061 - Bell ballast release systems and buoyant ascent in offshore diving operations

- UK Health and safety Executive - Diving at Work Regulations 1997 - Approved Code of Practice and guidance

- UK Health and safety Executive - The provision of breathing gas to divers in emergency situations *(RR1073)*

- UK Health and safety Executive - diving information sheet #12 - Cleaning of diving equipment

- National Oceanic and Atmospheric Administration (NOAA) - diving manual -

- U.S. Navy Diving Manual

- UK Health and safety Executive - Excursion tables in saturation diving - decompression implications of current UK practice

- DNV-GL AS: DNV-GL-RP-F107 - Risk assessment of pipeline protection

- Sina Taghizadeh Edmollaii , Pedram Edalat, and Mojtaba Dyanati - Reliability sensitivity analysis of dropped object on submarine pipelines

- Alf O. Brubakk, John A.S. Ross, and Stephen R. Thom - Saturation Diving; Physiology and Pathophysiology

4.2 - Addresses

- CCO Ltd -
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- **Lloyd's Register** -
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