ESDP Best Practice for using Closed-Circuit Rebreather for Scientific Diving at work

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And
European Scientific Diving Panel (ESDP)

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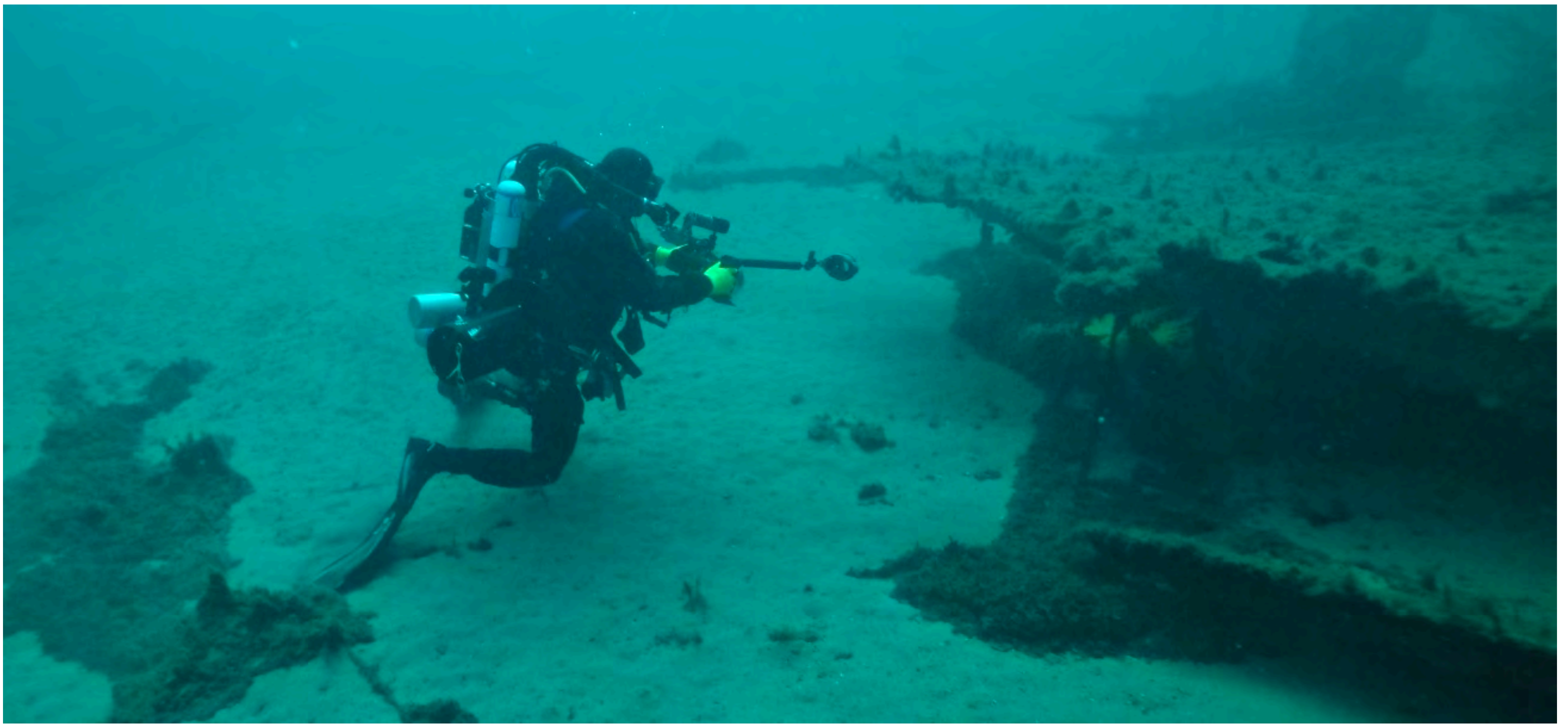


Scientific diver using CCR and documenting faunal inventory of a wreck. Photo Michel Lafontaine

About this document

The development of this 'living' document will be iterative, starting with this version of November 2021, resulting from the two first teleconferences organised on the topic in September and December 2020 and extended by the author. The foreseen workshop organised in September 2020 at Stareso-Corsica was cancelled and replaced by this remote working format to go forward according to Covid-19 pandemic rules and limitations. The composition of the working group can be found in the annex 1.

CCR Scientific divers at work. Photo provided by Régis Hocdé

Contents

A draft standard including two levels of qualification for scientific diving at work was issued at the end of the Banyuls sur Mer (France) meeting held in October 2000, a final version was issued by ESDP as an ESF Marine Board consultation document in September 2009 with the name "Common practices for recognition of European competency levels for scientific diving at work . European Scientific Diver (ESD) Advanced European Scientific Diver (AESD)". It has been revised in 2017 and published by the European Marine Board using the same name.
Today, there is a need to include into the 'standard' the use of Closed-Circuit Rebreather (CCR) when operating scientific diving at work.

This document is added to the ESDP 'Common practices for the recognition of European competency levels for scientific diving at work. European Scientific Diver (ESD) Advanced

European Scientific Diver (AESD) ' edition 2017. It addresses the specific use of CCR as breathing apparatus when operating occupational scientific diving activities.
A note on specific training for rebreather diving will be added in the document, based on the ISO standards today under development. (ISO, 2020)

Consideration of scientific methods that could be further used and/or deployed using CCR shall be part of the document. Such methods may include: Underwater positioning, data transmission, transport means (DPV) for transect, survey, underwater transport of equipment, etc…

The Redline for CCR use during scientific diving activities at work is th*e safety of the activity*. Therefore, how can CCR *add value* to the sciences and/or to the safety of the dive/diver ?

Why using CCR for occupational scientific diving at work?

The use of the CCR breathing apparatus for scientific diving at work is relevant for all depth zones depending on the targeted objectives (to approach the wildlife in the river, for behavioural studies of ichthyofauna, to implement sensors or perform core sampling, for eDNA sampling by pumping in the MCE…). The recommendations will have to concern all the profiles of divers, with differentiated parts according to the level of engagement[1]. Underwater sound measurements of marine life (fishes) used rebreather for a long time (Lobel, 2009), while the exploration of the twilight zone by R.Pyle (Pyle, 1999) highlighted the deep occupational scientific diving work using CCR.

Best practice

In this part, we address numerous points of attention/questions concerning the best practice of using CCR for occupational scientific diving. Those items are not ranked, nor limited and will be extended in successive editions of this document. It is not intended to re-write existing procedures for technical diving but to highlight what is essential for the sector of occupational scientific diving.

-Is the planned use of CCR for occupational scientific diving is increasing the risk of the activity?

If one has got the impression that using CCR will increase the risk of diving, the participant highlights the fact that using CCR will in fact increase the safety of the scientific diving activity (Norro, 2016) on many aspects with the first one being the gas efficiency of the CCR breathing apparatus. Other advantages are the breathing of a warm and humid gas, the gas efficiency -unlike OC with very limited volume- and the reduction of

[1] Engagement can be defined as P*SQRT(t) with P the pressure and t the time

induced stress, a better hearing of its team members by absence of self-generated noise, the absence of bubbles in some special situations (under a ceiling or in presence of particles), an optimised decompression taking advantage of the constant oxygen partial pressure concept the CCR is built on, etc… (Anonymous 2015, Hocdé 2015, Hocdé et al 2017).
It must be clear that it is mandatory to achieve a CCR training of good quality and strictly following the standard to achieve this 'reduced risk' effect. In the CCR sector, contrary to the OC scuba diving sector, the CCR manufacturers are acknowledging the training programs/organisation. Too often, shortcuts are taken into the training of technical CCR diver, and that may result in accidents. Martin Parker highlighted that there were 24 rebreather diving fatalities in 2019, making that year one of the worst from the start of the use of CCR by the technical diving sector. Martin Parker questions the quality of the training to explain that situation. Furthermore Fock, 2013 highlighted the relation between the quality of the training and the level of risk taken (accepted ???) by the diver. It is known that for the sector of occupational scientific diving (Dardeaux et al., 2012, Sellers (2016) the diving accident rate is lower than in recreational or commercial diving and This is in all probability due to the level of education of the participants as well as their willingness to follow existing safe procedures included in strict training.

-Diving as a pair

Is a procedure seen as increasing the safety of occupational scientific diving using CCR. Even adding a third diver when the pair of divers are busy gathering data is an added safety. The task of the third diver is then only to take care of the execution of the dive planning. (S)He is also in charge of the overall safety of the team during the dive. The team can exchange the roles on the next dive. One can remark that often in legislation, there is a minimum team of three persons, but only one is underwater.

-Group of divers with different CCR equipment

If the divers in the same dive team are using a different kinds of CCR's during an expedition, that could be seen as an increased risk for the activity, which must be included in the risk analysis. A way to compensate for that new risk is to have the same type of CCR for all the divers or having them following a cross-over training to the other kind of CCR used during the hyperbaric operations or expedition. If that risk mitigation measure is used, the additional training must be followed before the first dive takes place.

-Configuration

Some divers like to have the bailout tank attached 'direct' on the side of the CCR box/frame, while others prefer to carry the bailout tanks in side-mount configuration (high or low). As a basic recommendation, the configuration is left at the discretion of the diver as long as it can be proven safe and efficient for the proposed scientific task.

- Safety person (team) at the surface

It is essential to highlight that the safety team must have the same experience/skills/qualification as working divers. The safety person must be ready to act before the first diver enters the water. As a reminder, in many if not all legal text concerning occupational diving, a safety person/team must be present on-site during the dive.

- Composition and quality of the breathing gas

a/ recommendation of trimix diluent below the depth of 40 m to increase safety (nitrogen decompression, reduction of gas density (see below) and narcosis for sensitive people).

b/ use of a few standard diluents mixes according to main depth zones to gain experience and avoid making several and different mixes. This simplifies logistics and may reduce the risk of error and decompression differences inside a dive team.

c/Make use of breathable quality gases for the composition of your blends and avoid industrial quality mixes. EN12021 norm exists for air/gas quality and must be strictly followed.

d/ Do not delegate the verification of your mixes (diluent & bailout) to anybody else. Every diver MUST verify him(her)self the gas composition of all cylinder used before signing the blender book and analysis tags on tanks. Never rely only on a check made by another person (e.g. Blender)

-Gas density

Very often today CCR divers are not taking enough care of the gas density of their breathing mixture. This parameter is essential for CCR diving. The maximum gas density that must be used is 6,3 g L^{-1} with a recommended value at 5,2 g L^{-1} (6,7 g L^{-1} and 5,7 g L^{-1} for Norro 2016)

-Decompression strategy & decompression procedure and dive computers

Most of the time, occupational diving national legislation relies only on the dive table and based on the rules accepted for a sector of activity. Dive tables to be used for CCR diving are scarce or utterly lacking availability. However, USNavy developed some dive tables for Heliox mixes (Johnson & Gerth, 1999, Johnson *et al.* 2000 and Gerth & Johnson 2002) but in the sector of occupational scientific diving, diver using CCR generally accept that 'decompression software' and dive computers are used instead. Reliable and 'validated only' software must be used. Several plans must be computed, and total decompression time must be challenged against existing decompression tables and/or experience of the sector. The software includes adjustable conservatism, and that should not be seen as added safety, nor as an exact science; it is just a smart, or not, way to increase decompression at the given stage or for the complete decompression plan. Conservatism is used during the challenging/comparison phase introduced earlier. Several plans must be computed for a deeper excursion or longer bottom time as well as for bailout purposes. Multi-level diving may be planned as well. ***But always plan the dive and dive the plan!***

-Embarked back up decompression procedure or computer

It is advisable to have a backup decompression procedure when diving. The simplest is a printed copy of the decompression plan(s) agreed during planning, but most of the time, it is a dive computer. Almost every CCR includes a decompression computer that is linked to the online PpO_2 measurement system. The backup computer capable of managing constant PpO_2 diving should be used unlinked to the CCR. It is advisable to set up that backup computer to a lower setpoint than the CCR to build a safety margin. Use of dive computer must be authorised by National/ regional laws or sector rules. As soon as CCR diving is foreseen backup plan must include 'normal' CCR plan(s) as well as bailout plan(s)

Note: - we carry a backup computer with harsher GFs, a lower safety margin, still higher than Bühlmann's original idea but it allows quicker deco if you need to get out of the water. If you have to bailout, you bailed out for a valid reason and doing extra deco doesn't make sense. You can always add deco safety if you have the gas available and there are no other risks.

-Bailout strategies

Diving in complete autonomy seen as diving alone or another strategy like sharing bailout gases within the team / or even a riskier strategy that is to ensure sufficient gas autonomy to reach the shot line where other gas cylinders are stored. The three solutions could be part of the plan and will be discussed at the time of establishing the risk analysis for the dive. e.g. what if the diver cannot find the line or in case of gas loss etc…? or is stopped by the decompression ceiling before reaching the gases. Consideration on standard gases within the groups or for the complete expedition must be discussed and taken into account when completing the risk analysis.

-Man-Machine Interface (MMI)

MMI is a critically important component of any CCR. The CCR diver must completely and deeply understand it before any dive is conducted. Maintenance of this knowledge is to be verified as often as possible during drill exercise that can be integrated on any dive. Suppose logging information is included with the possibilities of download by the MMI. In that case, it must be used during the debriefing phase of the dive, helping to review the dive together with the log file of the dive computer if available. It is advisable to keep track of those data in respect with GRDP.

-Mouthpiece strap

This strap is seen by French Navy as a very important part of the rebreather equipment. Its increase the safety of the activity. It is therefore advisable to use one for occupational scientific diving.

-OCBailout valve

This piece of equipment is available today on the market. Some divers consider this device as increasing their safety; others see this as an unnecessary complication of their rig and therefore as an additional failure point that is better not to have. In any way, it is advisable in case the diver has one OCBailout valve that this equipment fulfill the existing EU norm (EN250) by itself but also when used inside the loop of the CCR (EN14143).

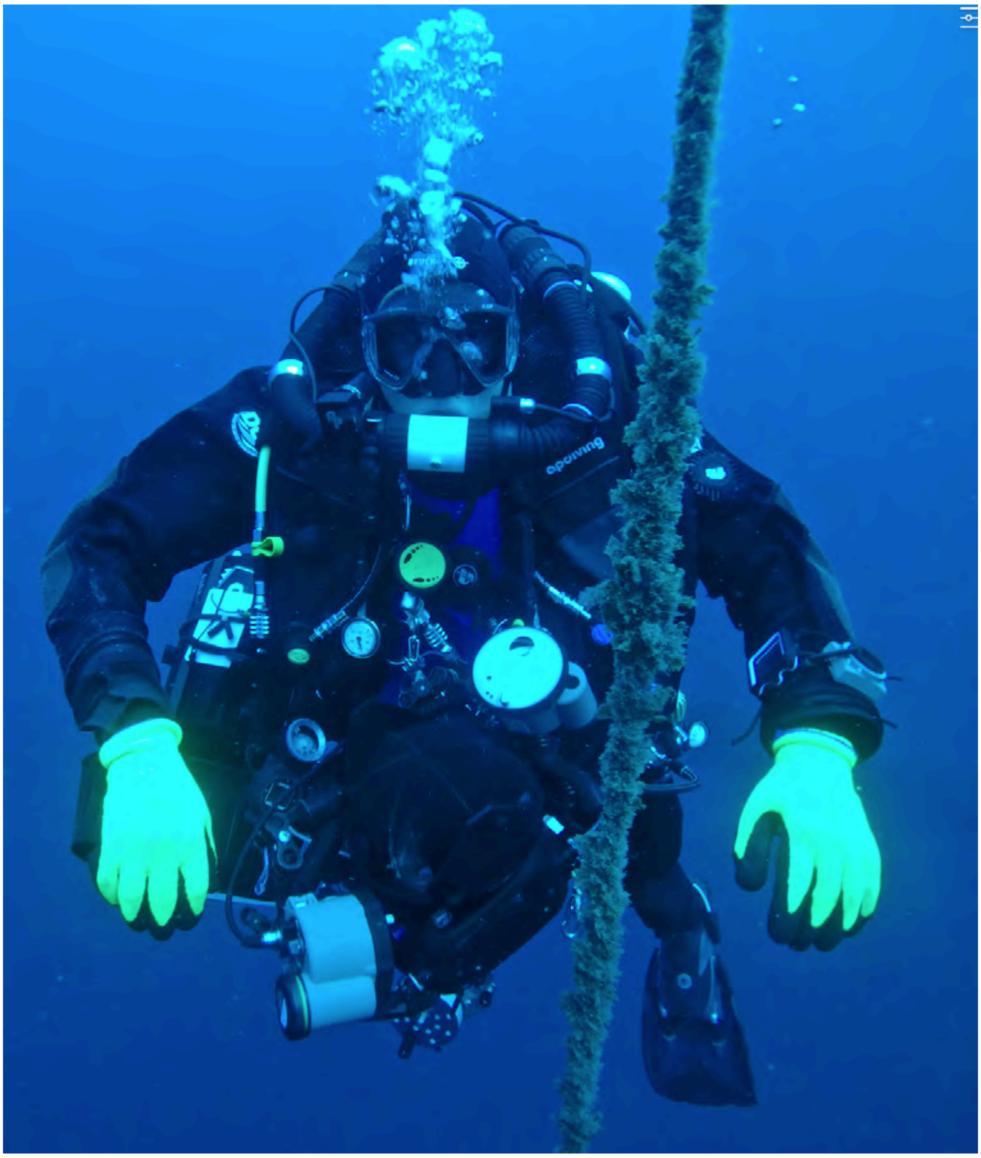
-Wired or wireless underwater communication systems

Wireless communication system with or without a full-face masks (FFM) may be used in some situation to maintain a link between the diving team and the diving supervisor at the surface or underwater. Adding devices into the loop of the CCR may alter the EU Norm and that should be verified.
Some models exist that can be used to a depth of 100m and a horizontal range of a few hundred meters. They can use a waterproof microphone positioned on the CCR mouthpiece and require no modification to the CCR loop. (no risk of losing CE norm of the rebreather)
Drop camera or ROV can also be used to ensure communication and/or to verify the work/safety of the occupational scientific diver. Hand or light signals can be used in front of the ROV video camera.
Traditional line signal to the surface or wired communication are probably not possible for deep, fully autonomous, diving using CCR.
Communication diver to diver and diver to surface strategies or diver recall procedures are part of the risk analysis.
If FFM is used, the divers must have completed specific training for the FFM to be used prior to the first dive of the expedition. Verification of the CE norm is also needed to find out if the norm for CCR remains valid.
The diver can also be tracked by an Ultra Short BaseLine (USBL) acoustic system. In this case, the occupational scientific diver will have a transponder attached to the side of the CCR. In any case, completing the risk analysis must include review of the communication systems options

-The concept of task loading

The occupational scientific diver is not only diving, but (s)he is 'working’ underwater. In addition to the ‘normal’ tasks relevant to rebreather diving, the scientific working tasks may be unique or multiple, repetitive or sequential with a simple sequence or even including conditional links. The tasks should be discussed within the diving team at the time of making the risk analysis and further during the dive briefing. In the event that too many tasks pop up simultaneously, the diver may become 'over-task loaded' with experience difficulties in completing the dive safely with the possibility of shortcutting some vital actions. Hence correct gas choice is essential to reduce the chance of narcosis which may increase task loading causing earlier “over-task loading”.

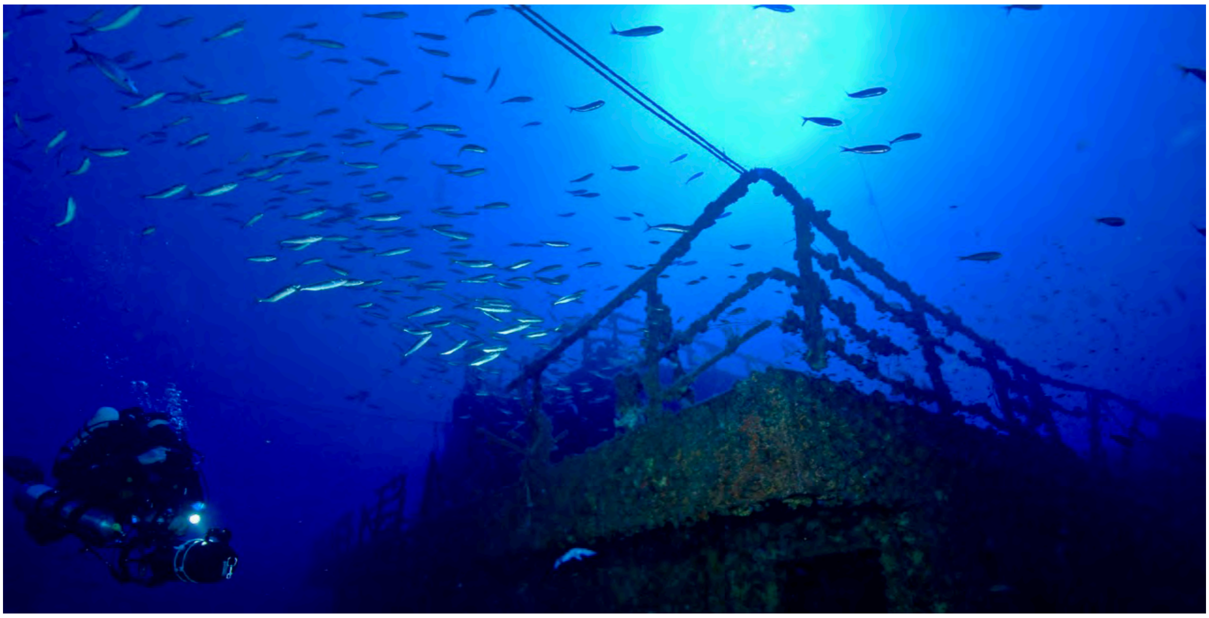
As a general point when developing an experiment that must be conducted underwater, the task load of the diver must be considered. Most often, one task or one combined task must be planned per dive. Trying to do more than that is often producing no data at the end of the dive due to the diver's brain being over task loaded; furthermore, that may induce new risks. One may remember that diving CCR is already generating numerous tasks by itself. For instance, during initial decent, the CCR diver is busy checking the unit. When complex tasks may be undertaken, it is advisable to include into the dive team one extra diver hose responsibility is only managing the dive safety and who will strictly respect the dive plan and decompression procedure.



CCR Scientific diver at deco: photo Michel Lafontaine

Advice on general planning for a CCR based scientific diving expedition/ Element of risk analysis

Besides the basic information required for the organisation of a scientific diving expedition[2], we highlight items specific to planned use of CCR by a group of occupational scientific divers.
Gas planning regarding the scientific objective of the expedition is paramount.
Moreover, for CCR-based scientific diving expeditions, there is a need to rely on experienced personnel with a good CCR diving experience. The diver selection is a critical task for the expedition leader.
The complete team must have dived, preferably together, for a minimum of YY dives before the expedition (know the equipment and procedures used during the expedition).
In terms of equipment, sufficient planning for spares should be done taking into consideration the possible variety of breathing apparatus used during the expedition.
Strategies to reduce risk during the scientific diving expedition are part of the general and specific risk analysis planning of every project, including the scientific diving activities to be undertaken. Again, it is not the purpose of this document to be extensive on that aspect but rather to include a specific point of attention regarding CCR diving aspects. Therefore, the next points must be addressed (not limited to these points because they are 'expedition dependent').



CCR diver exploring a deep wreck Photo Alain Norro

[2] Not the purpose of this document

Among others *and not ranked:*

- Certification of the diver, national/international recognition of certification as well as local rules considering CCR diving.
  This includes verification of medical clearance/ insurance in respect to national, international and local law/rules/considerations for the use of CCR

- Authorisation to dive on the given site cultural/natural heritage, etc…

- Gas filling: Specific consideration when diving CCR is the use of a gas booster. Specific training is required for the operator, and increased fire risk must be considered, and other strategies developed to mitigate the risk.

- Availability of gases. When using a CCR, smaller quantities of gases are used than for an equivalent expedition using OC Scuba. Nevertheless, gases of suitable quality must be available, their quantity carefully planned, and quality assessed. It is good to verify prior to arrival on site the type of valves or cylinders sizes and pressure available/ordered.

- Wrong gas situation (diluent and/or bailout) for the planned dive. Here, it is advised to have a double verification strategy, including at least a gas verification made by the diver himself before assembling the CCR bailout.

- A bailout plan must be discussed and assessed before any dive. Having to bail out in the worst-case scenario during the dive (end of the bottom time) must be planned for. A realistic RMV of the concerned diver must be taken into account. Every team diver must assess dive team bailout or 'solo' bailout strategy before any dive starts. If team bailout is used, the worst-case RMV must be considered for the entire concerned group.

- Failure of equipment: failure of any system of the CCR is unacceptable before the dive. In case of failure before the dive, back up equipment must be used or the dive must be cancelled. If the dive team is reduced in numbers the Bailout strategy must be reviewed, particularly when the bailout plan was for "team bailout".

- In case of failure underwater, the dive must be terminated quickly according to the foreseen plan and/or according to the 'what if' situation planning.

- 'What-if' planning. Series of questions to reply about any exception that may occur before, during and after the dive.

- CCR equipment consideration in the group

- Use of DPV

- Vessels/speedboat/surface support/platform used including CCR support like bailout gases, agreed signal with SMB (colors, sign/etc…), communication, ROV, etc…

- Getting lost underwater may increase due to the absence of bubble and risk analysis must provide strategy(ies) to mitigate that risk.

- Identification of "high risk" situations for scientific diving using CCR and the strategies applied to mitigate the level of risk. e.g. deployment of a heavy or cumbersome instrument (risk of breathlessness) or working in areas with strong currents must be addressed in the specific risk analysis.

- Evacuation of injured diver/team must be planned according to local/national/international standards.

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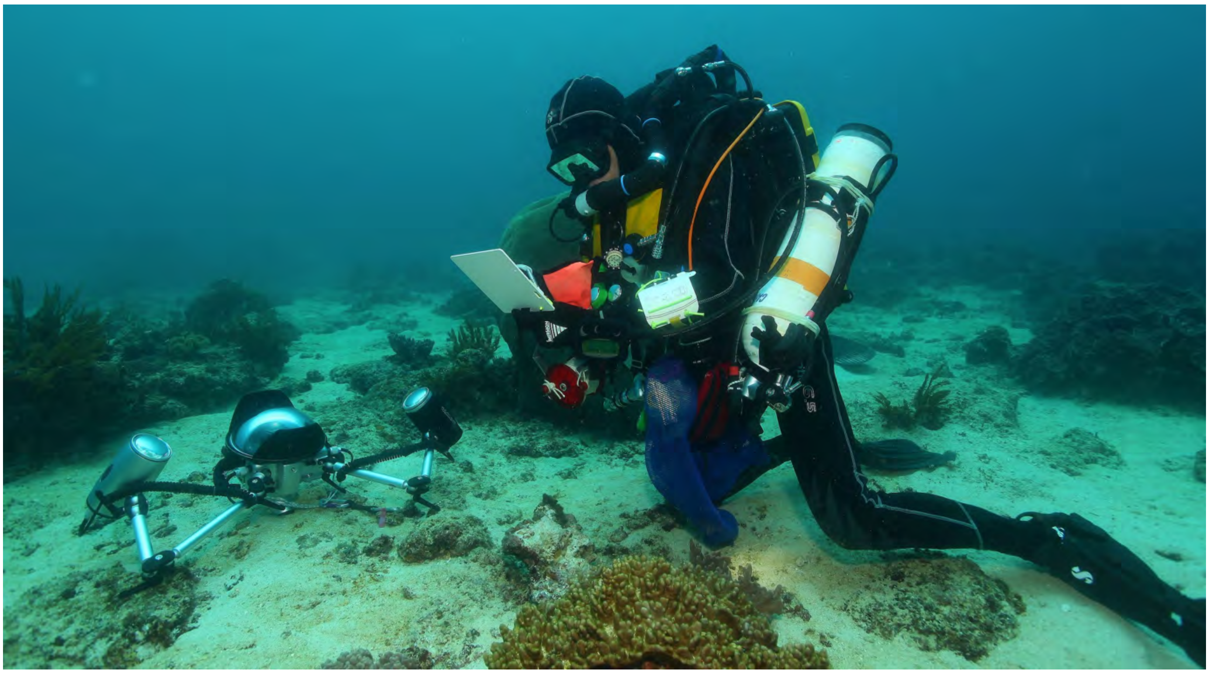
- TO BE CONTINUED



CCR scientific diver at work: photo provided by Régis Hocdé

Bibliography

AAUS, 2019 The American Academy of Underwater Sciences: Standards for Scientific diving manual. 77 pp

Dardeau M., Pollock N., Mc Donald C. & Lang. M:2012. The incidence of decompression illness in 10 years of scientific diving. DHM 42(4):195-200

EN 14143, CEN 1/5/2013. Respiratory equipment - Self-contained re-breathing diving apparatus, 60pp

ESDP, 2017. Common practices for the recognition of European competency levels for scientific diving at work. European Scientific Diver (ESD) Advanced European Scientific Diver (AESD) updated edition 2017 European Marine Board.

Anonymous. 2015. Avis et rapport révisés de l'ANSES relatif aux « Effets sanitaires liés aux expositions professionnelles à des mélanges gazeux respiratoires autres que l'air dans le cadre des activités hyperbares » (annule et remplace l'avis et le rapport révisés du 1er octobre 2014) . Mai 2015, France. https://www.anses.fr/fr/system/files/AIR2013sa0030Ra.pdf

Fox A.W. 2013. Analysis of recreational closed-circuit rebreather deaths, 1998-2010 DHM Vol.43 (2): 78-85

Hocdé R. 2015. L'usage du CCR par la science : vers de nouvelles perspectives. In : Brun F., Bernabé P. Le guide de la plongée en recycleur. Challes-les-Eaux : Gap, 2015, p. 58-61. ISBN 978-2-7417-0567-3 fdi:010067365 hal.ird.fr/ird-01394153

Hocdé R., Menou J.-L., Pouyaud L., Suruwaky A. M., Vimono I. B. 2017. At the heart of the coral triangle in West Papua: an Indonesian-french scientific exploration of a white area with closed-circuit rebreathers (eCCR). [Poster] IIIrd European Conference on Scientific Diving (ECSD), 22-23 March 2017, Funchal, Madeira, Portugal. fdi:010069727 ird-01512559, version 1

ISO, 2020: Draft Recreational diving services TC228_WP1/Requirements for rebreather diver training. Under development. ISO TC 228 WG1

Johnson T.M, Gerth W.A and Southerland D.G. 2000 1.3 ATA PO2 N2-O2 Decompression table validation. NEDU, Report TR 9-00 Panama city USA

Johnson T.M & Gerth W.A, 2001 1.3 ATA PO2 in He Decompression tables for MK16 MOD1 diving: Summary report and operational guidance. NEDU Report TR 14-01, Panama city USA

Gerth W.A. & Johnson T.M. 2002. Development and validation of 1.3 ATA PO2 in He Decompression tables for the MK16 MOD 1UBA. NEDU, Report TR02-10 Panama city USA.

L107, 2014, Scientific and archaeological diving projects Diving at Work Regulations 1997, HSE Book, www.hse.gov.uk/pubns/books/l107.htm.

Lobel P. 2009. Underwater Acoustic ecology, Boat Noises and fish behaviour. In Pollock NW ed. Diving for science 2009 Proceedings of the American Academia of Underwater Sciences, 28th Symposium Dauphin Island, AL:AAUS; 2009 pp 31-42

Norro A., 2016. The closed-circuit rebreather (CCR): is it the safest device for deep scientific diving? doi:10.3723/ut.34.031 Underwater Technology, Vol. 34, No. 1, pp. 31–38, 2016

Norro A., Hocdé R. 2017. A European competency level applied to the use of the closed-circuit rebreather in scientific diving at work. First step. Highlighting the best practice. IIIrd European Conference on Scientific Diving (ECSD), 22-23 March 2017, Funchal, Madeira, Portugal.

Pollock NW, Sellers SH, Godfrey JM, eds. Rebreathers and Scientific Diving. Proceedings of NPS/NOAA/DAN/AAUS June 16-19, 2015 Workshop. Wrigley Marine Science Center, Catalina Island, CA; 2016; 272 pp.

Pyle R.L. 1999. Mixed-gas, closed-circuit rebreather use for identification of new reef fish species from 200-500fsw. In Hamilton, Pence and Kesling (Eds): Technical diving forum, AAUS, November 1999. Pp 53-65

Sellers S. (2016). An Overview of Rebreathers in Scientific Diving 1998–2013. In: Pollock NW, Sellers SH and Godfrey JM. (eds). Rebreathers and Scientific Diving. Proceedings of NPS/NOAA/DAN/AAUS Workshop, 16–19 February, Catalina Island, California, 5–39.

Thouzeau, G., R. Hocdé R., J.-P. Beurier, M. Coulange, A. Couté, G. Eldin, J.-P. Féral, E. Folcher, S. Jacquet, P. Le Bras, S. Legrand, P. Lenfant, M. Lepage, L. Lévêque, S. Nicolas, V. Parravicini, C. Play and G. Saragoni, 'The French National Committee on Scientific Diving (CNPS): a key actor for developing scientific diving in France', presented at the 5th European Conference on Scientific Diving (ECSD), Institute of Oceanology, Polish Academy of Sciences, Sopot, Poland, 24-Apr-2019. hal-02123970

Terminology

CCR : Closed Circuit Rebreather

ESDP: European Scientific Diving Panel, under the umbrella of Mars

MARS: The European Network of Marine Stations

MCE: Mesophotic zone

MMI: man-machine interface

RBINS: Royal Belgian Institute of Natural Sciences, 29 rue Vautier, B-1000 Brussels

RMV: Respiratory minute volume

…/…

Annexe 1

Composition of the ESDP working group on occupational scientific diving using CCR

Sweden
Dr Brandon Foley Lund Univeristy, Sweden

France
Ing. Régis Hocdé is research engineer working in the 'MARine Biodiversity, Exploitation and Conservation' research unit (MARBEC Univ Montpellier, CNRS, Ifremer, IRD, Montpellier, France). His expertise lies in marine biodiversity, observatory systems and data science. He is currently involved as PI or co-PI in different international programs. He is also a scientific diver and a deep diver expert with a closed-circuit-rebreather. For scientific diving, he is a national expert for his institute (IRD - French National Research Institute for Sustainable Development) and French authorities (Ministry of Research/MESRI, Ministry of Labour/DGT). He is the secretary of the French National Scientific Diving Committee (CNPS). He also teaches diving and scientific diving methods.

United Kingdom
Martin Parker is a diving equipment manufacturer specializing in CCR. A diver since 1974, a technical diver since 1993, and the first diver to use the Inspiration CCR on Trimix (1996). He has been a member of BSI and CEN creating European standards for diving equipment for 30 years and is currently part of the ISO Committee creating rebreather training standards.

Finland
Dr Juha Flinkman is a marine scientist and a scientific diver currently working at Finnish Environment Institute (SYKE), Marine Research Center. He was involved in the development of the ESC standards and the Finnish national scientific diving system. Flinkman has been diving since 1982, and a IANTD technical diver OC Full Trimix since 1997, and JJ-CCR Full Trimix since 2015. Flinkman has undertaken historic wreck research for over 30 years with his team Badewanne (www.badewanne.fi)

Italy
Dr Lorenzo Bramanti is a marine ecologist working as a senior researcher at CNRS (France) on conservation, ecology and restoration of Mediterranean and tropical corals. He practices scientific diving since his master Thesis at University of Pisa (Italy) in 1997 working at on the Mediterranean red coral (*Corallium rubrum*). Lorenzo Bramanti is certified in Italy as Advanced European Scientific Diving since 2006. He started diving with CCR in 2010. Since 2020 he is class IIIB professional French diver.

Belgium
Dr Alain Norro, the organiser of the working group, is a physicist working at the Natural Sciences Museum in Brussels in oceanography, underwater acoustic and mathematical modelling. He is also in charge of the sector of scientific diving in Belgium (managing & training responsible) and founding member of the ESDP; he is diving from 1975 and an

occupational diver using and teaching the CCR diving technique (all levels) for more than 15 years, including use in the occupational scientific diving sector in Belgium

Meetings composition

At the first meeting of the 16th September 2020 were present Régis Hocdé(FR), Juha Flinkman(FI), Lorenzo Bramanti (IT), Brandon Foley (SE) Martin Parker (UK) and Alain Norro (BE)
At the second meeting of the 17th December 2020 were present Juha Flikmann(FI), Lorenzo Bramanti (IT), Brandon Foley (SE) Martin Parker (UK) and Alain Norro (BE)
Apologies: Régis Hocdé(FR)

Annex 2

Situation of using CCR for occupational scientific diving in Europe

Finland: Finland: There is no law existing in Finland that may restrict the use of CCR for scientific diving. In addition to national occupational scientific diving certification, the ESDP recognised certifications ESD & AESD are used. National certification is compatible with AESD. There is no limitation to diving methodology or equipment. Surface supplied, mixed gas, CCR, etc. can be utilised by a scientific diver, provided a proper and recognised training and adequate experience has been received. Recognised training agencies may be professional or recreational, but they must be internationally recognised and accepted. Under development is an academy of scientific diving.

Sweden: OC and no deco were the base of scientific diving prior technical diving emerged. In Sweden ESD& AESD are recognised. Employer can propose any kind of diving equipment and will be responsible for its use permitting to use for instance CCR at work. However, any part of common legislation(rules) may help on the evolution of Sweden rules.

Italy: Apparently no one is using CCR at work for scientific activities in Italy, some, of course, use it aside of working activities but for research linked to their professional activities. More information should be gained from the Italian National committee (Massimo Ponti)

United Kingdom: Some code of practice exists (L107,2014) and CCR can be used

Belgium: There is no limitation on the CCR use in Belgian rules/legislation. The use of CCR is encouraged in Belgium as soon as there is an advantage for the diver or the scientific purpose of the dive. It was used and it is used in Belgium inside that framework.

France: In France, legislations exist including CCR, for science and archaeology, recreational activities and other sectors. More and more research programs are dedicated today to the exploration of the mesophotic zone where the use of CCR take advantage on any other scuba diving technique and often over other exploration methods (ROV, AUV, dredges...). Since 2019, many academic scientists are currently training to be able to work in diving beyond 50 m and use CCR.