Rebreather Informer

PADI TecRec

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Introduction

The Rebreather Informer is a document that provides an informational orientation to recreational rebreather diving. It is intended for divers interested in learning more about rebreathers. It also provides information that may be useful if an open-circuit diver decides to buddy with a certified rebreather diver.

This document is not a substitute for training and certification as a PADI Rebreather Diver or any other level of rebreather/CCR diver. The information provided with respect to being an open-circuit buddy to a diver using a rebreather is not a substitute for an orientation to the specific rebreather by that diver, or a PADI Rebreather Instructor.

This document provides rebreather information in three sections:

1. Overview: Rebreathers and Open-Circuit Scuba
2. Basic Function of CCRs and SCRs
3. Diving with a Rebreather Diver

To help guide your learning, this document provides learning objectives similar to those found in other PADI printed and online learning media.

Overview: Rebreathers and Open-Circuit Scuba

Learning Objectives
Look for the answers to these questions as you read:
1. What is the primary difference between a rebreather and open-circuit scuba?
2. What are the two basic types of rebreathers, and how do they differ?
3. What are the differences, advantages and disadvantages between rebreathers and open-circuit scuba with respect to:
- *noise*
- *buoyancy control*
- *breathing gas humidity and temperature*
- *duration*
- *no stop time*
- *predive setup and post-dive care*
- *differences between makes and models*
- *breathing effort*
- *reliability?*

Open-Circuit and Rebreathers
When you started diving as a PADI Open Water Diver, you learned to dive using *open-circuit* scuba. When you inhale, air (or EANx) flows from the cylinder into your lungs via the regulator. When you exhale, your breath vents into the water and rises to the surface as bubbles. The circuit is "open" because you breathe the gas only once.
Open-circuit scuba has been around since the 1940s. It's popular and well suited to recreational diving because it is mechanically simple and reliable. But, because you only use a small fraction of the oxygen available in each breath you take, you exhale most of the oxygen you inhale. This means that it is wasted with respect to how much air or EANx you have to carry with you.
Rebreathers are a type of scuba that reuse some or all of the gas you exhale. There are two basic types: closed-circuit rebreathers (CCRs) and semi-closed rebreathers (SCRs). Both use a chemical process to remove waste carbon dioxide from the recycled gas, and both replenish the oxygen consumed from the recycled gas.
Closed-circuit rebreathers (CCRs) recycle *all* the gas that you exhale. Few bubbles escape, (some do, such as during ascents to release expanding gas). CCRs require two gas supplies, a *diluent* (usually air) and 100 percent oxygen. CCRs suited to recreational divers are electronically controlled, as discussed in more detail in the next subsection.
Semi-closed rebreathers (SCRs) recycle *some* of the gas that you exhale. Bubbles escape in a stream or small bursts, but significantly less than open-circuit. SCRs only need one gas supply, but it must be enriched air – typically EANx36 or higher, but it must be breathable to the maximum dive depth. In the past, mechanical SCRs were used by recreational divers, but modern ones are electronically controlled, as discussed in the next subsection.

Unit-Specific Certification
Another difference between open-circuit scuba and rebreathers (note that "rebreather" means both CCRs and SCRs) is that you must qualify and be certified on *each model* of rebreather separately. Although the underlying operational principles are the same, rebreathers may differ substantially from each other in how you set them up, where their controls are and how you perform certain procedures. Each level of rebreather certification lists both the diver's training level, and the rebreather. After qualifying at a given level with one rebreather, the PADI Rebreather/Tec CCR Qualifier program allows a diver to qualify to dive a different model rebreather at the same level without having to retake the entire course.

Differences Between Rebreathers and Open-Circuit Scuba

Because rebreathers recycle exhaled gas, there are some distinct differences between diving with them and with open-circuit scuba.

Noise. Rebreathers are substantially quieter than open-circuit scuba. One of the first things rebreather divers notice is that they can get closer to fish and other aquatic organisms – it's not unusual, after a dive, for rebreather divers to discover they saw things that their open-circuit counterparts didn't even know were there. With a rebreather, divers may be able to talk to their buddy to some degree, and hear things that open-circuit divers normally don't hear.

Buoyancy control. With open-circuit scuba, when you inhale and exhale, your volume changes as your lungs expand and contract, which is what allows you to fine-tune your buoyancy with your breathing. With a rebreather, the counterlung expands on exhalation and contracts on inhalation, so there's no change in volume. This means that unlike with open-circuit, breathing doesn't affect a diver's buoyancy with a rebreather. All buoyancy adjustment are made with a BCD and/or dry suit. Because a diver doesn't use a significant gas volume with a rebreather, a diver does not become significantly lighter over the course of the dive. There's some change with an SCR and little or no change with a CCR.
Relearning buoyancy control is one of the skills divers learn in the PADI Rebreather Diver course. Although breath control doesn't affect buoyancy, once buoyancy's set at a given depth, it won't have to be adjusted much. Rebreather divers learn new habits, like swimming around objects instead of over them, to avoid buoyancy changes (and some other issues).

Breathing gas humidity and temperature. Open-circuit gas is cool (due to expansion when delivered from the regulator) and dry (compression removes the moisture). Rebreathers supply warm, moist gas because the chemical process that removes carbon dioxide generates heat and moisture. In addition, the diver's own breath moisture tends to stay in the system.
All else being equal, most rebreather divers find the warm, moist gas more comfortable to breathe. It helps keep them warm for a given depth and duration, even when the same dive could feel cooler when made using open-circuit.

Duration. For a given gas supply, rebreathers offer far more underwater time, and the difference is substantial. It is not unusual for a CCR dive to last two or more hours. SCRs aren't quite as efficient, but they are still much more gas efficient than open-circuit diving, all else being equal. Within recreational depth limits, depth does not affect the duration of a rebreather. No stop time, the scrubber (chemical that removes carbon dioxide) or comfort usually limit a dive – not gas supply.

No stop (no decompression) time –Rebreathers provide more no stop time than does open-circuit. This is because modern rebreathers electronically measure and vary the oxygen-nitrogen ratio in the breathing gas as the depth changes, so that a diver is always breathing the lowest possible amount of nitrogen. With open-circuit scuba, the nitrogen-oxygen ratio is fixed.
(Note: older SCRs that are not electronically controlled, such as the Draeger SCRs, differ from this. With manual SCRs the exact EANx mix breathed does vary slightly with the diver's exertion rate. However, they deliver the same EANx mix throughout the dive and do not have any no stop advantage over open-circuit EANx.)
Predive setup and post-dive care. A disadvantage of rebreathers is that they require more time and effort to prepare and to maintain compared to open-circuit. As divers gain experience and practice, proper setup and post-dive care become less time-consuming, but it nonetheless takes more time.

Breathing effort. Rebreathers breathe *differently* from open-circuit scuba. It wouldn't be accurate to say it is easier or harder, but it isn't the same. The diver's breathing provides the

energy to move gas through the rebreather. Open-circuit seems to "push" gas with each breath. Many divers say that rebreathers feel more natural with respect to breathing.

Differences between models. As mentioned previously, rebreather models differ, sometimes significantly. This is why each PADI Rebreather Diver (and all other rebreather level) certification is specific to a rebreather for which you've qualified. It is also why **rebreather divers *must* read the manufacturer's literature entirely and completely. *Rebreather divers have a responsibility to stay up to date with changes in recommendations and procedures that the manufacturer may make***.

Reliability. Rebreathers are more complex than open-circuit scuba and have more potential failure points. Without proper predive setup and checks, and post-dive care – *which are very important with rebreathers* – malfunctions are more common, though most are not catastrophic. It is more common for rebreather divers to have to postpone or cancel a dive, or make it using open-circuit, due to technical issues that can't be resolved on site.
With respect to reliability, another major difference with open-circuit is that rebreathers have a potential for problems that can't be detected except by the warning systems in the unit. Rebeather divers must monitor displays frequently and diligently, and *never* disregard warnings.

Check your learning.
1. The primary difference between a rebreather and open-circuit scuba is
[] a. a rebreather recycles exhaled gas.
[] b. open-circuit scuba recycles inhaled gas.
[] c. rebreathers exhaust exhaled gas as bubbles.
[] d. open-circuit scuba recycles some gas but rebreathers recycle all gas.
2. The two basic types of rebreathers are _____.
[] a. open-circuit and CCRs
[] b. CCRs and SCRs
[] c. open-circuit and SCRs
3. A(n) _____ rebreather recycles *some* of your exhaled gas.
[] a. SCR
[] b. CCR
[] c. open-circuit
4. Which of the following characteristics apply to rebreathers? (Choose all that apply.)
[] a. quiet
[] b. breathing affects buoyancy
[] c. warm, moist gas
[] d. shorter no stop time
[] e. shorter, simpler predive setup and post-dive care
[] f. makes and models differ significantly
[] g. breathing feels "more natural" to some divers

How did you do?
1. a. 2. b. 3. a. 4. a, c, f, g.

Basic Function of CCRs and SCRs

Learning Objectives
Look for the answers to the following questions as you read:
1. What are the basic parts and functions of CCRs and SCRs?
2. What are the different types of rebreather?

3. What are the characteristics of Type R rebreathers and Type T rebreathers, and who are they intended for?

All rebreathers function by recirculating gas, but CCRs and SCRs differ in some respects as to how they process the gas for reuse. Let's go over the general operational theory behind CCR and SCR operation. As you read the descriptions, you'll learn some new terms that apply to CCRs and/or SCRs, but keep in mind that different manufacturers sometimes use different names. Another important point is that rebreathers are a technology still in development. By the time you read this, some of the description may not apply directly to newer rebreathers.

CCR Function and Operation

Let's start by taking a look at the circular path gas takes through a rebreather (CCR or SCR) which is called the *loop*. (Note: Sometimes divers loosely refer to the mouthpiece and breathing hose assembly as the *loop*.) The easiest way to describe the way rebreathers function is to follow gas as it flows through the loop, starting at the *counterlung*. The counterlung is a collapsible bladder (or bladders) that contracts when divers inhale and expands when they exhale.

Some rebreathers have a single or double *rear mounted* (a.k.a. *back mounted*) counterlung typically contained over the upper back. Others have dual *over-the-shoulder counterlungs* that come down over the upper chest on both sides. (There are also front mounted counterlungs, but they're not common in sport rebreathers.)

When the diver inhales, fresh gas from the counterlung flows through the *inhalation hose* to the mouthpiece and into the diver's lungs. This is usually the hose on the left as worn. When the diver exhales, one way *mushroom valves* (also called *nonreturn or check valves*) in the mouthpiece assembly channel the gas down the *exhalation hose*, which is usually on the right. These valves, plus the diver's breathing, circulate gas through the loop properly. Gas flows from the exhalation hose either into another counterlung and then into the *scrubber canister*, or directly into the scrubber. The scrubber is a cartridge of porous *absorbent* that, through a chemical reaction, removes waste carbon dioxide (CO_2) as the gas passes through it.

After passing through the scrubber, the gas flows to where the *oxygen sensors* or *cells* are typically located (although placement may vary). This area is sometimes called the *head* or the *electronics module*. The sensors measure the oxygen and send the information to the computer. Based on information from the sensors, the rebreather maintains an oxygen partial pressure setting call the *setpoint* – commonly about 1.2 or 1.3 bar/ata. Some computers have a *floating setpoint* (also called a *dynamic setpoint*) , which is setpoint that automatically changes based on a computer program, to optimize gas use, no stop time and other calculated variables.

If based on the oxygen sensor data the computer determines the oxygen partial pressure is below *setpoint*, it triggers a *solenoid* (electromechanical valve) to release oxygen from the *oxygen supply* cylinder in a CCR, or to increase the flow of EANx from the *supply gas cylinder* in an SCR. The computer also uses the oxygen content data to update the diver's no stop time and oxygen exposure in your dive computer. With the carbon dioxide removed and the oxygen replenished (as needed), the gas flows to the counterlung and/or directly to the inhalation hose to begin another cycle through the loop.

As the diver descends, the gas in the loop compresses, just as it does in a BCD. This makes it necessary to add gas to maintain a breathable volume. When the diver inhales and the counterlung collapses completely (or to a minimum volume with some models), the pressure activated *automatic diluent valve (ADV)* releases gas from the diluent cylinder (CCR) or supply gas cylinder (SCR) to restore the volume. On some rebreathers, the diver can also add gas manually with the *manual diluent valve*.

When the diver ascends, gas in the loop expands. The *overpressure valve* (OPV) releases excess gas from the loop. The OPV is similar to the overpressure valves found on BCDs and dry suits. The diver may also release gas from the loop by exhaling through the nose. On SCRs the OPV

bubbles more frequently and when the diver is at a steady depth, hence the term Semi-closed Rebreather.
It's important to keep water out of a rebreather's loop, so unlike an open-circuit regulator, it has a *mouthpiece* that the diver opens and closes. The diver must close the mouthpiece before removing the mouthpiece from the mouth (whether at the surface or underwater), or the loop will flood and render the rebreather unuseable. The mouthpiece is usually closed with a lever or knob on the mouthpiece.
The *bailout valve (BOV*) is an open-circuit regulator integrated into the mouthpiece assembly. When the loop is closed, the BOV activates, supplying open-circuit gas directly from the diluent (CCR) or supply gas (SCR) cylinder. In an emergency related to rebreather function, this allows the diver to close the loop and begin breathing a known open-circuit gas with a single motion, and without removing the mouthpiece. This is why the diluent/supply gas must always be a gas that can be breathed at the deepest depth of the dive.
Rebreathers also have a way of monitoring gas supplies. Some rebreathers use SPGs similar to those used in open-circuit diving, whereas others use electronic sensing that integrates the supply information with the computer and the rebreather's display.
All rebreathers suitable for recreational diving have a means for determining scrubber absorbent use. A growing number of rebreathers also have a *carbon dioxide monitor* that warns you if the scrubber has failed and carbon dioxide is accumulating in the system.

Types of Rebreathers
There are different types of CCRs and SCRs, as well as different models. They even differ in the types of diving for which they're suited. Here's a summary and their differences.
eCCR. This is an electronic CCR, with electronics controlling the setpoint throughout the dive by adding oxygen as needed. Electronics also provide warnings if there are any problems. All CCRs suited to recreational diving are eCCRs.
mCCR. The manual CCR (also called dcCCR, or diver controlled CCR) has electronics that tell the diver the PO_2 and may provide warnings, but the diver must monitor and manually inject oxygen as needed to maintain the setpoint. mCCRs are used in tec diving, but are not suited to recreational diving.
eSCR. As you just read, electronic SCRs have electronics that control a floating setpoint to optimize gas use and to adjust for changing exertion (oxygen consumption) rates. All SCRs suited to the PADI Rebreather Diver and Advanced Rebreather Diver courses are eSCRs.
Electronically monitored mSCR. This is a mechanical SCR with electronic monitoring. Gas flow is mechanical, but electronics update the computer and alert the diver to the oxygen content in the loop and provide warnings.

Type R and Type T
Besides the previous divisions, rebreathers are also categorized as *Type R* (suited to recreational divers) and *Type T* (suited to technical divers). A Type R rebreather is an eCCR or eSCR specifically suited to recreational, no stop (no decompression) diving. Among other characteristics, the units use pre-packed scrubber canisters, have a system for estimating scrubber duration and provide electronic prompts for the predive check. They provide automatic setpoint control, have status warnings to indicate problems, HUD (heads up display) warning systems and a BOV
A Type T CCR is an eCCR or mCCR suited to technical deep diving, decompression diving and cave diving. These units have differing technical requirements and the divers using them need substantially more training and experience in using them. Type T characteristics include that they may have user-packed scrubbers, that they must have manual controls for the diluent and oxygen supply, and they must be rated and functional to 100 metres/330 feet. Type T CCRs need at least one backup display for use during manual oxygen control, and they must have manual setpoint

control capability. Type T CCRs are intended for tec divers. To learn to dive with a Type T CCR, enroll in the Tec 40 CCR Diver course.

Check your learning.
1. The _____ expand and contracts when the diver exhales and inhales.
[] a. loop
[] b. mushroom valve(s)
[] c. counterlung(s)
[] d. BOV
[] e. OPV
2. In the event of an emergency, the diver would activate the _____ and, depending upon the type rebreather, breathe diluent or supply gas.
[] a. loop
[] b. mushroom valve(s)
[] c. counterlung(s)
[] d. BOV
[] e. OPV
3. The _____ and the diver's breathing circulate gas in one direction properly though the loop.
[] a. inhalation hose
[] b. mushroom valve(s)
[] c. counterlung(s)
[] d. ADV
[] e. floating setpoint
4. The purpose of the scrubber is to remove carbon dioxide from the breathing gas.
[] True
[] False
5. One difference between a rebreather mouthpiece and an open-circuit mouthpiece is that a rebreather mouthpiece
[] a. is much smaller.
[] b. opens and closes.
[] c. encloses your nose.
6. Rebreathers suited to recreational diving are designated as
[] a. mCCRs.
[] b. Type T.
[] c. Type R.
[] d. mSCR.
How did you do?
1. c. 2. d. 3. b. 4. True. 5. b. 6. c.

Open-Circuit/Rebreather Buddy Teams

Learning Objectives
Look for the answer to the following questions as you read:
1. What five things does an open-circuit diver need to consider when deciding whether to buddy with a rebreather diver?
2. How can a rebreather's quietness affect maintaining buddy contact with an open-circuit buddy?
It is becoming increasingly common for rebreather divers and open-circuit divers to buddy together. There's nothing unreasonable about this, provided all buddies agree to do so and feel they have the knowledge and skills to adequately be able to do so. A diver does *not* need to be a

rebreather diver to be an effective buddy for a rebreather diver. However, there are five things a potential open-circuit/rebreather buddy team needs to consider.

1. Dive limits. Open-circuit and closed-circuit divers will have different limits – no stop time, gas duration, maximum depths, etc. Buddies need to agree that the shortest, most conservative limits apply. Usually – but not always – open-circuit limits apply.

2. How to share gas. Rebreather divers share gas with an open-circuit second stage, just as open-circuit divers do, so this is a skill the open-circuit diver already knows. The main differences are knowing where to find the second stage, and that a rebreather diver has a much smaller gas supply, so ascents must begin *immediately* in an emergency. There may not be enough gas for a safety stop – something to consider.

3. Visible/audible warnings. Provided buddies maintain good, close contact (as they should), it not essential for the open-circuit buddy to know all of a rebreather's warnings, but it can be useful. Briefing the open-circuit diver on the rebeather's alarms allows the diver to get close and be ready to provide support and ascend quickly – before the rebreather diver signals – should an alarm activate.

4. How to close the mouthpiece and activate the BOV. In the event of most rebreather problems, the rebreather diver closes the loop and activates the BOV. If a rebreather diver becomes unresponsive for some reason, however, the open-circuit diver provides help just as for any other unresponsive diver, with the added step of closing the mouthpiece/activating the BOV. The open-circuit diver should do this whether at the surface or underwater, and whether the mouthpiece is in the mouth or not (if it is, the rescuer holds it in, but closes the loop and activates the BOV).
Beyond this, the only other difference in assisting an unresponsive rebreather diver versus a open-circuit diver is gas expanding in the loop during ascent. Much of it will vent from the OPV, and it is possible to manually trigger the OPV with many CCRs, much as with similar valves on BCDs and dry suits. It may help to squeeze the counterlungs to force gas from the OPV. As when helping any unresponsive diver, if the victim becomes too buoyant to control, the rescuer should let the victim go, ascend at a safe rate, and resume the rescue at the surface. At the surface, the priorities for an unresponsive diver are the same for a rebreather diver as any other: establish buoyancy for the rescuer and victim, call for help, check for breathing, provide rescue breathing as appropriate and tow the victim to safety and help. The PADI Rescue Diver course is recommended for hands-on practice in these skills.
5. How to work the BCD and harness. Assisting a rebreather diver (responsive or unresponsive) may mean inflating the BCD and at some point, releasing the scuba unit (at the surface). Rebreather BCDs and harnesses function identically to those used in open-circuit. The primary consideration is for the open-circuit diver to know where the BCD inflator is (usually obvious), and the appropriate harness releases (may be covered by counterlungs).

Buddy Contact
Open-circuit divers buddying with rebreather divers for the first time sometimes discover they have more trouble maintaining buddy contact. This is because many divers unconsciously monitor their buddies by listening for their bubbles. Rebreathers are so quiet that such divers may find it harder to stay close and not realize why you keep "getting away" from them. It may help for rebreather divers to stay *slightly* in front of open-circuit buddies, at least until they get used to this.

Check your learning.
1. When open-circuit and rebreather divers buddy, the time limits that apply are

[] a. the shortest/most conservative limits of any buddy.
[] b. a compromise between the longest and shortest limits.
[] c. not an issue – no limits apply.
2. If a rebreather diver becomes unresponsive underwater, the buddy would need to know how to
[] a. close the loop/activate the BOV.
[] b. change the scrubber canister.
[] c. use the alternate second stage.
3. An open-circuit buddy has an out-of-air emergency and secures and begins breathing from a rebreather diver's alternate second stage. The team
[] a. can share the loop if necessary.
[] b. must ascend immediately.
[] c. will make a very long safety stop.
4. Some divers learn to maintain buddy contact by hearing, so it may help buddy contact if rebreather divers stay a bit in front of an open-circuit buddy. [] True
[] False

How did you do?
1. a. 2. a. 3. b. 4. True.

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