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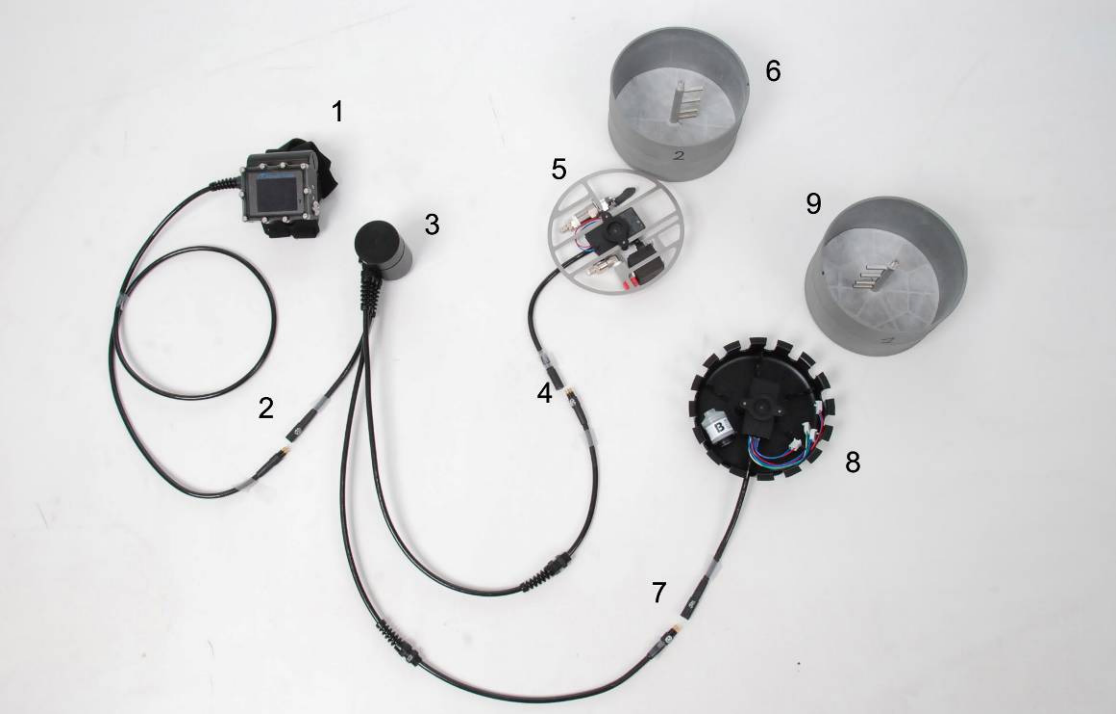
A: General information on the rMS: rEvo monitoring system

1How is the rMS configured?



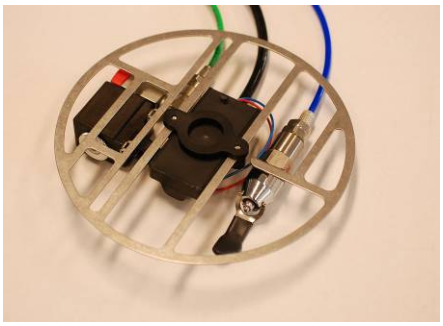
rMS full starts with a Predator DiveCAN™ wrist unit (1), connected to an external battery pack (3), over a cable with a wet mateable connector (2). Unlike the classic Predator, this unit does not have any analog signal lines going in and out. It communicates over a digital bus. In this case the CAN bus.

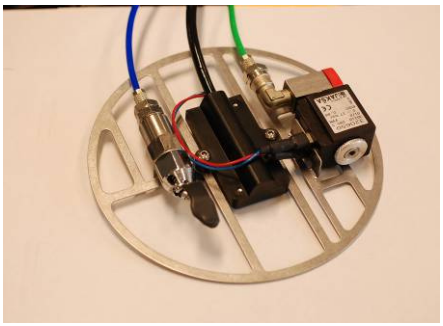
The use of digital communication guarantees that any cable problem that causes errors in the communication, is immediately detected. (This is unlike analog signal lines, where you just get a lower or higher signal).

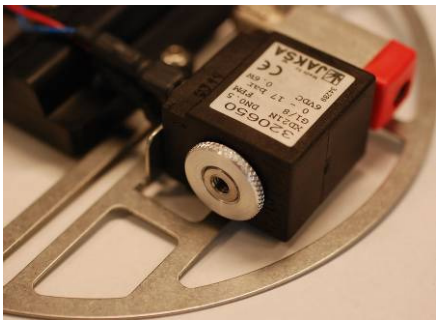
The Predator DiveCAN™ unit is connected with an electronics board in the external battery package (3). This package contains a 9V battery that is used to fire the solenoid, and to give main power to the scrubber electronic systems. The electronics board in the battery pack takes care of power distribution between all systems, and is connected with an electronics board in both the exhale lung (5) and the inhale lung (8), over a digital line. (All electronics boards are completely potted and can be completely immersed without any damage).

The electronics board in the exhale lung takes care of the solenoid firing using the 9V battery power. At the same time, the board communicates wirelessly with the electronics inside the central axis of the exhale scrubber(6). These electronics are also completely potted and contain no battery. The board in the exhale lung takes care of both wireless power transmission to the 'temperature sensing board' inside the scrubber and data communication

(read-out of the different fast response temperature sensors). When requested, it will send the temperature info to the Predator DiveCAN™ unit.







Note that the rMS uses the new type of solenoid, with incorporated orifice and one-way valve: both are inside the solenoid now, and a small plug is supplied with each unit if the user would want to close off the CMF. The rMS also uses the smaller orifice (0.0030), the IP of the oxygen is set at 12 bar overpressure, and in this configuration the recommended maximum operating depth for the rEvo rMS hCCR is now 100m, even in hybrid mode!

The electronics board in the inhale lung (8) takes care of the read-out of the oxygen sensors in the inhale lung. At the same time, in the same way as in the exhale lung, the board communicates wirelessly with the temperature sensing electronics in the inhale scrubber (9).

Both electronics boards in the lungs are also connected to the external battery pack with a wet mateable connector (4) and (7) so that, if needed, easy exchange of parts can be done. Wet mateable connectors are very robust and nearly indestructible. They easily withstand pressures over 100 bars!

In summary, the Predator DiveCAN™ unit takes care of displaying the PPO2, executing the decompression calculation, and communicating with all the other electronics in the system. At the same time, it will run the scrubber prediction algorithm using the information from the different temperature sensors in both scrubbers.

2. How does rMS predict remaining scrubber time?

The rMS algorithm to calculate remaining scrubber time is a 'prediction', similar to the TTS, or time to surface prediction.

When calculating a prediction, the system makes assumptions of what will happen in the near future; between the time now, and a certain time in the future.

To predict a TTS, the system assumes that you will do certain things in the near future. The system assumes that you will ascend at a certain speed, that you will make stops at certain depths, that you will (or will not) change gasses during the ascent, or keep a certain PPO2. If you do exactly what is assumed, the prediction will match closely to what happens in reality. If not, the predicted time will be longer or shorter, depending on what is done differently than the assumptions made before.

Prediction of the remaining scrubber time is similar. It is based on the assumption of a certain oxygen consumption and associated CO2 production, at a specific depth, and is related to the water temperature.

Because prediction of remaining scrubber time is more critical than prediction of TTS, the assumptions to calculate the predictions are set conservatively. For example, the system will assume that the diver will have a relatively high CO2 production all the time; higher than what an average diver would normally produce. Also, the time of breakthrough of the scrubber is set conservatively, even far lower than the values in the CE standard.

This also means, that for most divers, the remaining scrubber time will decrease less than one minute, per minute of dive time… and it must be that way!

3. Can I upgrade my current Shearwater to rMS?

Unfortunately this is not possible. rMS contains so many technological innovations that the current Shearwater units, with analog data exchange, cannot be upgraded to complete digital communication systems. To accommodate those clients who want to keep their current analog Shearwater hybrid system, we have developed the rMS light that can be added to all existing units. rMS light works similar to a back-up computer, except that it can also read oxygen sensors, and give a prediction of optimized cycling times.

4. Why does temperature based scrubber life prediction work better on a dual scrubber system then on a single scrubber system?

As explained before, the most critical phase in scrubber use is when the scrubber comes close to saturation, so that with a sudden small increase in CO2 production, the diver could get breakthrough. That is the reason why you have to add extra safety margins when trying to use the scrubber until you have to dump it completely. At that moment, however, you will still have a large percentage of your absorbent that is still unused, and the colder the water, the larger that amount of non-saturated absorbent.

In a dual scrubber system however, with accurate fast response temperature based prediction, you can safely extend the time until you have to do a cycle (replacing only one canister; the one that is almost saturated 100%) to almost the same time that you would have if you had to completely exchange a scrubber of the same volume in a single canister system! As in both cases, single or dual canister systems, you change when you still have a large amount of unused absorbent in your system. (Depending on the water temperature, the time to cycle using rMS will be 80 to 90% of the time to exchange the complete scrubber system)

Now, why can you safely extend the time until you have to do a cycle, to more than 66% of the total scrubber time? (As recommended when doing cycling without rMS; cold water cycling every2 hours or dumping the whole scrubber every 3 hours, warm water 3 hours /4.5 hours).

The reason is clear. When using rMS, it matters much less if the second scrubber is already partially saturated because of delayed cycling. The rMS will notice that the scrubber is already partially used and will take that into account when calculating the remaining scrubber time.

5. Why does the temperature sensing probe in the canister have such a peculiar shape?

To achieve correct prediction of remaining scrubber life, rMS needs both *accurate* and *fast* temperature information.

Accurate, because the algorithm must recognize temperature differences of less than **0.3°C** in the different areas in the scrubbers.

Fast, so that the algorithm allows the first prediction of remaining cycling time in less than **3 minutes** after the start of the pre-breathing.

Both accurate and fast are not possible with the 'classic' system where the sensors are located inside a central 'rod' in the middle of the canister. This system is not fast, as the thermal mass of the central axis will decrease the temperature gradients around the sensors. This system is also not accurate enough, as there is always heat-flow between the different

sensors inside the rod and from the inside to the outside of the canisters at the top and the bottom of the canister.
Therefore, the temperature sensors must actually be located inside and be surrounded by the absorbent to get as much as possible contact with the gas-flow through the absorbent. This sensor configuration is technically more difficult to manufacture, but is the only way to get the most correct prediction.

B: How to use the scrubber monitoring system on the rMS

Version 0.4 13.06. 2012 not final yet: updates will follow

Includes new updates of Predator DiveCan software V44

1 Definitions:

RCT: Remaining Cycle Time: the time you have left until you must do a scrubber cycle.

RST: Remaining Scrubber Time: the time you have left until you will have break-trough over the scrubber

2 New Shearwater DiveCAN™ displays:

The Shearwater DiveCAN™ rMS starts up with the following screen:

If you don't see the C ??, then the scrubber monitoring system is not activated.
To activate the system, go to System Setup+, where you will find a new page 'rMS Setup'

The rMS setup screen allows you to turn on and off the temperature probes, so switching on and off the scrubber monitoring system.
The same screen also allows you to put biometric parameters into your computer: this is new in the world of diving, but for scrubber monitoring systems quite logic: as we know that CO2 production is different for man and women, and also depending on body weight (amongst other parameters..), entering these data in your computer, allows the algorithm to give a better, real-time prediction of remaining scrubber time. You can already enter the data here.

When you scrolled towards the System Setup+ menu, you probably saw the screen:

This is also a new menu for the scrubber monitoring system, that gives you information on the remaining scrubber times, and on the temperatures inside the scrubber
A right pushes give you:

The information under Scrubber Times will be used for dive planning, and the information under Temperatures allows you easier troubleshooting is something is not clear. See further in this text.

After the System Setup+ screen, there is another screen added, typical for the DiveCAN unit:

A right push on Bus Devices+ will show you all the devices connected to the CAN bus, and the software version they are using. This screen allows you to easy identify if one of the devices is missing, and if you are using the correct software in each device.

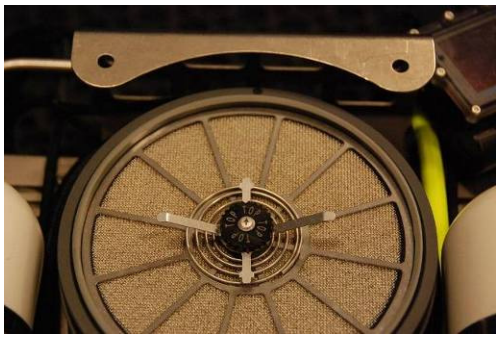
Before we explain how to use the scrubber monitoring system, let's correctly prepare and setup the rebreather:

3 Preparation of the rebreater unit

Besides all the normal preparation, this highlights the typical rMS features

- fill both scrubbers as normally
- put the spring locking screws on the units, and tighten them gently till the end of the thread
- if some grains of sorb come out of the mesh, poor them away
- put the 'top-marker' on one of the canisters

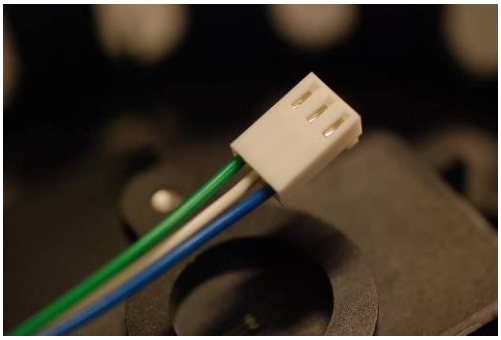
- put the canister with the 'top marker' on top of the exhale lung, in the upper place of the rebreather, **and make sure the arrow on the central ax points to the top of the unit**



- put the other canister in the lower position, and make sure the arrow also points to the top of the unit
- close the unit and do the normal checks / calibration as usual using the checklist. (closed check)

ATTENTION:

When you have installed the oxygen sensors on the sensor tray of your rMS, you will have noticed that there is now a 4th molex connector, with 3 wires, green, white and blue, unlike the normal molex connectors for oxygen sensors, that have only 2 wires, red and blue.



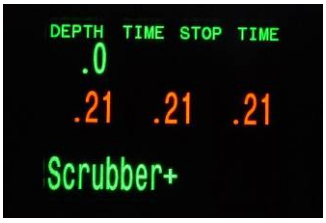
In the rMS, this new extra connector is for future applications: we already added this connector, so that when in the future new types of sensors come on the market, you don't have to change anything on the unit.
Later, when we want to, we can activate and use this connector, by just a software upgrade, just like the current software upgrades from Shearwater.

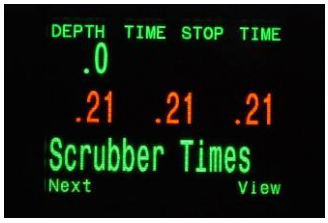
So at this moment, don't do anything with that connector, and surely do not connect it to an oxygen sensor.

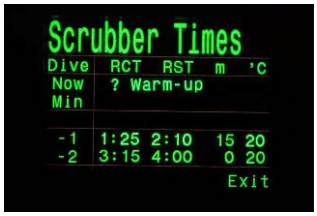
4 Dive planning

Before diving, always check the remaining cycle time of the scrubber: make sure you never start a dive unless your remaining cycle time after the previous dive is more then the planned dive time: the idea is that you never use your scrubber till you have zero remaining scrubber time: as at that moment you are really near the end of the scrubber, so it is never a good idea to plan a dive so that at the end of that dive, you will come close to scrubber break-trough!

To make dive planning easy, there is a log of the remaining cycle and scrubber times at the end of the previous dives: you find this in the menu by pressing left until you see:







The 'Scrubber Times' screen shows you the Remaining Cycle Time (RCT) and the Remaining Scrubber Time (RST) of the actual dive, and of the 2 previous dives.

Do notice that during any dive, there are 2 different 'remaining cycle (RCT) / remaining scrubber times (RST)': the 'actual' (now) , and the 'minimum' during that specific dive

In surface mode, and while the scrubber is cold, there is no prediction of remaining times, so the screen just shows '? Warm-up'

Once the scrubber is warming up, and the dive starts, remaining times are calculated and displayed in the line 'Now'

Once the scrubber is fully ready (fully warm), the minimum cycle/scrubber time is recorded/updated all the time during the dive, together with the associated depth and temperature when the minimums were recorded: this is needed for future dive planning.

At that moment both the actual 'Now' and the minimum 'Min' remaining times are displayed.

The main screen of the predator shows you the **actual** remaining cycle/scrubber time for the actual dive: because the actual time can vary during a dive: going deeper will decrease the time, going shallow will increase the remaining time etc.

Example: you do a 60m dive with 1 hour bottom time, and all the rest deco. At the end of your 1 hour bottom time, your remaining cycle time is X. (usually the minimum remaining time will be identical to the actual remaining time at that moment.)
Now when you start to ascent, the temperature profiles will change in the scrubber, and when coming close to surface for the long deco, the actual remaining cycle time will have increased again, (as you can stay much longer on the scrubber at deco depth then at bottom depth). This actual remaining time is also the reality: it will give you the time you have left on your unit from that moment on.
The minimum remaining time at the end of the bottom time however is logged. This is usefull for planning the next dive: as from that data, you know what the minimum remaining cycle time will be when you will be at the same (or lesser) depth in the next dive.

In the screen you see that in the previous dive, the minimum recorded RCT was 1h25 and that happened at a depth of 15 meters while the water was 20°. So if you plan another dive at a depth of around 15m, for one hour, there is no need to change the scrubber.

Now what happens if you want to do a much deeper dive?
How to plan, and what is the correct relation between remaining time at 15m and remaining time at 45m?

At this moment, **the safe approach** is using the following rule of thumb:

A: if the minimum RCT of the previous dive is recorded at a depth of >20m depth, then

always consider that remaining time is inverse lineair with depth of the future dive if you go for a deeper dive, and is equal to the remaining time of the previous dive if you go for a more shallow dive. Example:

1 At the end of your previous dive, your minimum RCT was 2 hours at 40m depth.
Your next dive is to 30m: you can consider that you have a RCT of 2 hours at 30m depth.

2 At the end of you previous dive, your minimum RCT was 3 hours at 20m depth.
Your next dive is to 40m: you can consider that you have a RCT of 1.5 hours at 40m depth.

B: if the minimum RCT of the previous dive is recorded at a depth between 0 and 20m, assume it was recorded at 20m depth: now follow the rule of thumb A: Example:

At the end of your previous dive, your minimum RCT was 3 hours at 0m (surface): you can assume that you have 3 hours at 20m depth. My next dive is to 40m depth: you can consider that you have a RCT of 1.5 hour at 40m depth.

We know that this is a conservative approach, and that it does not take into account the temperature: but till further notice it is a safe approach!

Do remember that the scrubber prediction is only working with rEvo approved scrubber material!

Anyway: the basic rule will always stay:

- never plan a dive where you assume that you RCT will become zero
- diving with an RCT below zero should be seen as an emergency mode

So:

- always Cycle one canister before your planned remaining cycle time becomes zero,

And

- after every dive: write down the time you used the scrubber, even if the rMS logs the remaining times after the previous dives

5 Starting a dive

When you have installed the rMS canisters in the rEvo and closed the cover, you can switch on your Shearwater

Normally you will see:

If you don't see 'C ??' this means that your temperature probes are switched off in the 'rMS Setup'. Go to the setup menu and change the setting of the temp probes to 'on'.
Switching 'off' the temperature probes can be done when diving on the dual radial scrubbers, or when using classic non-rMS axial scrubbers.

When the ?? after the C (Cycle time) is yellow, this indicates that the system is asking for temperature data from both canisters, but has not received any info.

Each ? stands for one scrubber: the first ? for the top scrubber, on top of the exhale lung, the second ? for the bottom scrubber, on the inhale lung.

As soon as the ?? becomes green, communication is established, and temperature data is communicated. However, the ?? indicates that the temperature data does not allow to make any prediction of cycle/scrubber. (mostly because the scrubber is still cold, as you have not yet started pre-breathing)

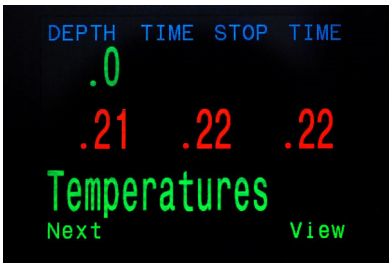
You can always check the activity of the scrubber by pushing on the right button till you see:

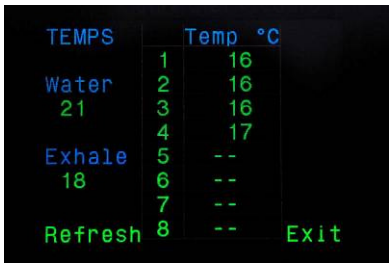
This screen shows that the unit is ready for warm up, but none of the 7 zone's in the scrubber have started to become active (they are all grey) so no prediction can be made for RCT or RST

If a red X shows after the C, this means that the attempt to communicate was unsuccessful, and the unit will try again later (for example when the canisters are not installed, or not touching the solenoid/oxygen board).

The two red XX show you that there is no communication with either of the temp probes.
If communication with one of the temperature probes is successful, you see:

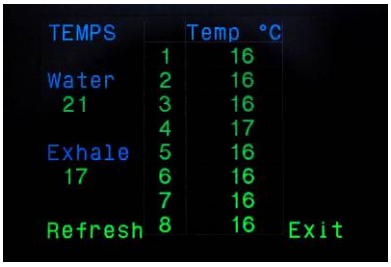
This tells you that the exhale scrubber communicates with the system, but there is no communication with the temp probe of the inhale scrubber.
At this moment, you can even check the temperatures in the scrubbers: at the Scrubber+ screen, pushing the correct right buttons gives you:





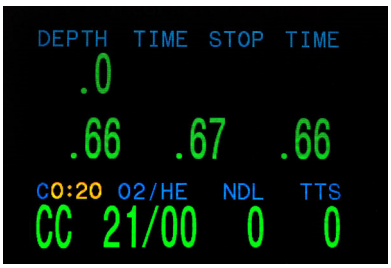
You notice that the temperatures of the first scrubber, the top scrubber, are indicated (temp 1 to 4), but that there is no indication of temperature 5 to 8: the sensors of the temperature probe in the inhale scrubber.

Only when all temperature probes are read correctly, the main display will indicate 2 green ??, and going to the Temperatures screen will show:



If all ok, and the display shows the green ??, you can start pre-breathing your unit. (as part of the pre-jump check: see checklist)

When you start pre-breathing your unit, the first zone's in your scrubber will start to warm up, due to the absorption of CO2, and as soon as enough warmth is produced, the green ?? will change into a number:

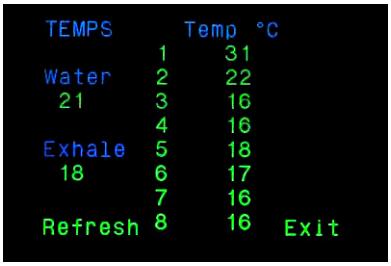


and a bit later

With only the temperature info at the inlet of the scrubber, the system has already received enough data to predict a minimum remaining time. You can see on the info screen that the warming up of the first zone in the scrubber has started: the color changed to yellow.

However, only when that zone is fully warm, the color will become green.

You can even notice in the temperature screen that the temperature has increased at the inlet of the exhale scrubber:



Do know that the temperature screen is only available in surface mode.

IMPORTANT:
Once you start to pre-breath your unit, and the scrubber starts warming up, do NOT switch off your computer anymore: if you do this, then part of the information for the algorithm is missing, some zone's in the scrubber will not be able to reach 'ready' status or even 'warm-up' status, so the monitoring system will never show full working conditions

When you continue to pre-breath, you will notice that when the remaining cycle time reaches 45 minutes or more, the color of the numbers changes into green:

So this will become a new rule when using the scrubber monitoring system: always pre-breath until you have at least 45 minutes CYCLE time (green): this means that the scrubber is

working, and that during further warm-up of the scrubber, the remaining cycle time will increase until the complete scrubber is warmed up:

Now, this warming up of the scrubber can take between 20 to 40 minutes in real diving situations, and you don't want to wait for diving until your complete scrubber is warmed up: this is not needed! : if the logged remaining cycle time after the previous dive is sufficient for the next dive, you know that it will reach that time once the scrubber is fully warmed. So as soon as you know that your scrubber is active and has sufficient capacity (C > 0:45) you can start your dive. (when you finished the other pre-jump checks)

(do notice that the screen shots show depth and time in surface mode, in normal diving you will of course see depth, time stops etc)

During diving you can follow the warming up of the scrubber on the info page. Once the scrubber is fully warm, you have reached the maximum remaining times for that given depth.

Also on the main screen there is an indication if the scrubber if fully ready or not: as long as the warming up is not yet finished, the colon between the C and the number is yellow, and only when the scrubber is fully warmed and ready, the colon becomes green, and full information of the total scrubber can be used to predict the cycle and scrubber times.

From this point on, and in dive mode, the minimum remaining cycle and scrubber time of the dive is logged, while at the same time the actual RCT/RST is shown on the main screen and the extra info screen.

You will notice that the actual remaining RCT and RST can vary during the dive, depending on the water temperature, the depth, the effort you do etc. Only make sure you stop the dive before the RCT decreases to zero, as the RST is your safety margin for diving!
(color changing on the C numbers will indicate that you come close to zero RCT)

So you should never see the following screens during diving! :

When after a dive, you want to exchange one scrubber, (cycle), follow exactly this procedure: If you make it a habit to immediately empty a canister when you have removed the 'TOP-MARKER', you will not make a mistake when exchanging/filling/replacing canisters. So:

1 take the top canister, with the 'TOP-MARKER' out of your rebreather
2 unscrew the 'TOP-MARKER' from the canister and immediately empty that canister. (you are now sure you emptied the exhausted canister)
3 screw the 'TOP-MARKER' on the remaining (full) canister, and either put that canister in the upper position of the unit, or if you are finished diving, in a sealed container or plastic bag.
4 fill up the empty canister, and put it in the lower position of the rebreather, or in a sealed container if you finished diving
5 mark separately which canister is in top position, and that you refilled the bottom canister with fresh sorb

So the rule of thumb will always be: if you remover the 'Top-Marker', empty the canister!

6. *Starting a second dive after a short surface interval: the scrubber is still warm!*

As we have seen, the RCT on the main screen can be different (and usually is different) from the RCT in the log: the RCT on the main screen is always the actual for the current dive, or the current surface interval, and the current state of the scrubber. The RCT in the log is the lowest encountered RCT during the previous dive, after the scrubber got fully warmed up.

Now during the surface time in between 2 dives, the RCT on the main screen can still vary, as the temperature profile in the scrubber changes slowly due to cooling down, but nobody is breathing on the unit. The longer the surface time after a dive, the more the scrubber will be cooled down, until the temperature profile does not give any more data. BUT the RCT you see on the main screen after say 1 hour surface time, has no real value, because this is not a result of the temperature profile when someone was breathing on the unit.

For correct functioning and showing a normal profile, the scrubber should cool down till there is no more 'profile' detectable in the scrubbers, and you see ?? on the main screen; starting from there, it is again like a first dive of the day.

Now when doing short surface interval, the scrubber temperature profile is 'deformed' due to cooling down, but there is still some profile detected, and when you start pre-breathing, only after a few minutes, a' breathing' profile is created, and a correct RCT can be calculated.

For this reason you can see a sudden drop in RCT a few minutes into pre-breathing for the second dive, and then an increase in RCT again.

All this together means, that when doing a short surface interval, and your main screen RCT had not yet returned to ??, you use the RCT in the log for planning your next dive, (as you always do) and you pre-breath until you see a clear change in the RCT on the main screen, and after this change, you can start your second dive when you have > 45 minutes RCT on the main screen

Do notice that pre-breathing for a second dive can take longer, as the sorb near the entrance of the first scrubber is already partially saturated

7.Warnings

- do not breath on the rebreather when the shearwater is off: scrubber monitoring is also based on temperature variations over a given time period: if you breath on the unit, and the rMS has not been able to detect the temperature changes due to breathing, it will not be able to detect a correct warming up of the scrubber, and so might never get to full ready/working status
- wait with breathing on the unit until you have C ?? (?:green!!) : as long as the '??' is orange, there is not yet communication with the temperature sensing probes
- do not touch, try to bend, force the temperature sensing probe
- the maximum allowed temperature on the sensing probe is 70°C: so do not rinse the canister with hot/boiling water!
- never disassemble the probe from the canister: you need a tool for this, and if you try, the sensing probe will be damaged

- do not use the following functions in the Scrubber+ menu, unless you were asked to do by rEvo or your instructor, and only for trouble shooting: