SUBMATiX

SERIES

REBREATHER

CCR 100 SMS

USER MANUAL

Guarantee

The first owner of the unit must send the completed guarantee back to SUBMATIX within 14 days.

All dives must be planned using the enclosed dive schedule and signed by the user and his/her dive partner. The owner is obliged to service the unit annually using a Submatix Approved service centre. In case of missed service periods or a non completed service book, Submatix is not liable for any damages. SUBMATIX accepts no liability for damages before receiving the guarantee and/or because of an incorrectly planned dive schedule.

Serial number: .....
Purchase date: .....
Name: .....
Address: .....
City, Postcode: .....
Country: .....
Telephone: .....
Email: .....

I accept the conditions of use.

Signature:

I accept that if no other place is written in this manual, the legal home address and the place of fulfilment is Erfurt/Germany.

Signature:

SUBMATIX
REBREATHERTECHNOLOGY

CCR Dive Schedule

Name, Surname		
Dive Site		
Date/time (start of the dive)		
Buddy		
Data of the last dive		
Have you dived within the last 24hrs? If yes, what is your current tissue code (current nitrogen load)	Current Tissue Code: ___	
Current CNS Loading	___	
	Gas Planning	
Gas mixture diluent	___ % O_2 ___ % H_e ___ % N_2	
Allowed partial pressure of O_2	ppO_{2max} = 1.4bar max. 180 min (24hr exposure, 150min single exposure)	
Maximum operation depth of diluent	MOD = ___ m	
Constant dosage (f) O_2 Flow Rate	___ l/min	
Gas Supply Duration	Fill Pressure x Cylinder Size / Flow Rate	
Effort	☐ low ☐ normal ☐ high	
Duration of the scrubber	☐ normal 180 min ☐ high 120 min	
Maximum dive time (based on scrubber duration and deco obligation)		
Dive	**Planned Dive**	**Actual Dive**
Max Dive depth	D = ___ m	D = ___ m
Equivalent air depth → EAD (table)	EAD = ___ m	EAD = ___ m
No decompression time → determined with EAD and deco table	No Stop Time = min	No Stop Time = min
Dive time	BASICtime = ___ min	DIVEtime = ___ min
Tissue Code → after the dive		
CNS % accumulated	___ % O_2	
OTU Accumulated	___	___
Scrubber Time	=__Min	=__Min

_____ _____

Signature diver Signature buddy

Table of content

For your safety, please pay attention to the following directions of use!

The SUBMATIX CCR 100 SMS is a mixed gas rebreather, which was designed and built for recreational diving only. As a rebreather the Submatix CCR has certain typical characteristics, which can lead to serious injury or death in the case of incorrect use. Therefore, it is absolutely essential you do not attempt to use the CCR 100 SMS without first successfully attending and passing an approved Submatix CCR training course from an approved training agency , recognised by Submatix.

This user manual is designed to be a guideline to the proper use of your CCR 100 SMS. It is not a substitute for thorough, appropriate training and certification in the use of this rebreather.

This manual does not contain all the information needed for the safe use of the unit but it provides the general background information, which are necessary to successfully pass the CCR training.

This manual will also provide you with the necessary manufacturer's guidelines for maintenance and service. These instructions must be followed strictly to avoid serious injury or death.

Use of the Submatix CCR requires close observance of these guidelines. The unit is only meant for the prescribed use as a recreational rebreather. Also observe the safety data sheet and product information of Spherasorb or any other CO_2-absorbent used with the Submatix CCR.

1 Hazard Indicators

The warnings, and the hazard they describe in this manual, are as follows:

Danger! This indicates an immediately hazardous situation, which, if not avoided, will result in death or serious injury.

Warning! This indicates a potentially hazardous situation, which, if not avoided, could result in death or serious injury.

Caution! This indicates a potentially hazardous situation, which, if not avoided, can result in minor or moderate injury. It may also be used to warn of unsafe practices.

You must carefully follow all of these warnings to safely enjoy your SUBMATIX CCR 100 SMS.

Warning! You must have your SUBMATIX CCR 100 SMS inspected and serviced according to the guidelines contained in this owner's manual, and by an authorised service and repair facility. USE ONLY authentic SUBMATIX parts. When you do not do this it may lead to a malfunction of the SUBMATIX CCR 100 SMS resulting in serious injury or death.

The maintenance of your SUBMATIX CCR 100 SMS, must be carried out by an authorised SUBMATIX CCR 100 SMS repair facility at regular intervals. Both, you and the service facility must keep complete records of all service and repair visits. Pay careful attention to the sections of this owner's manual, which describes the maintenance intervals and procedures. Only SUBMATIX trained repair technicians are permitted to carry out service and repair of the SUBMATIX CCR 100 SMS. Use only authentic SUBMATIX parts in the maintenance and repair of the SUBMATIX CCR 100 SMS.

2 Liability Statement

The owner or user of the unit is liable for the function of the unit and/or damages if the unit is not maintained or repaired correctly by persons, who belong to Submatix or who were trained by Submatix.

As far as notes to laws, decrees and standards are given, they are based on the legal rules of Germany. Submatix is not liable for damages, which arise from incorrect use or from the use of components by other dive equipment producers.

Guarantee and liability conditions of the conditions for sales and delivery cannot be extended through the above-mentioned comments.

The Submatix CCR 100 SMS is a mixed gas rebreather for sport divers and it was not designed for commercial use. It is built as a constant flow closed circuit rebreather with an oxygen manual override. The constant flow of oxygen is crucial to the operation of the unit and must be determined for each individual using it. The users metabolic oxygen consumption must be determinded individually and the correct constant flow must be set on the adjustable flow nozzle (Pro Booster). This is typically between 0.7lpm and 1.5lpm and is determind as the amount of oxygen consumed by a diver while at rest in the water. This is indicated by a static PPO2 on the Oxyscan Pro A PPO2 monitors without the diver having to manually inject any extra oxygen. Once the diver starts to metabolise more oxygen, such as when swimming, the PPO2 should drop and the diver will have to manually inject more oxygen to maintain a constant PPO2. As the diver descends, the increasing hydrostatic pressure will cause the Auto Diluent Valve to operate injecting diluent into the breathing loop. The diluent will be air, trimix or heliox. The injection of the diluent causes the PPO2 to drop thereby allowing the diver to maintain a PPO2 not exceeding 1.4 bar.

To avoid a hypoxia or a hyperoxia, the unit must be used with at least 2 independent oxygen monitors. These monitoring systems must have an acoustic and/or visible low and high ppO_2-warning. The absolute maximum set points are: low 0.20 bar and high 1.4 bar.

All PPO2 monitoring systems used must be certified by the producer for use in closed circuit rebreathers.

Submatix insists on the use of at least 2 independent redundant systems.

You are only allowed to dive with the CCR after successfully passing a training course specifically for the Submatix CCR rebreather, that has been approved by Submatix.

3 Intended purpose of Use

The Submatix CCR 100 SMS is a recreational sport diving unit, designed for the use of 2 gas mixtures, oxygen and a diluent (air or Trimix). It is intended for use in standard diving practices and not designed for use as a bailout system or any other function other than recreational diving. The system was designed for recreational diving only and it is not permitted for use as a commercial diving rebreather.

The CCR was developed for sport dives to a maximum depth of 40 metres with nitrox or for technical dives to a maximum depth of 100 metres with trimix.

Attention: Submatix delivers the CCR configured for a depth of 80 meters. For depths deeper than 80m the unit must be adjusted by an authorised service technician.

The diver must be trained and certified by an authorised diver training organization approved by Submatix. While using the Submatix CCR 100 SMS, the training guidelines set out by the qualifying agency must be closely observed.

NEVER breathe from the unit when the cylinders are closed or empty! Hypoxia will be the result leading to unconciousness and possibly death.

Before diving the Submatix all points of the pre-dive-checklist must be carried out and the unit must be fully functional. If anything is not working correctly, do not dive the unit until the problem is rectified or the unit has been sent to an approved service technician for repair.

The unit is designed to be worn on the back. Any other configuration is not validated for use by Submatix.
The diver must carry an appropriate bailout system which corresponds to the planned dive depth and time.

4 Glossary of common rebreather terms

Bailout: Redundant Gas supply for emergency bail out

Bar: One atmosphere of pressure, i.e. 14.7 psi.

Gas mix: The gas used for the maximum planned depth.

BCD: Buoyancy Control Device. The inflatable vest is used to trim buoyancy while diving and provide buoyancy on the surface. These are sold separately by Submatix.

ADV: The Auto Diluent valve or bypass valve, similar to a scuba second stage, which provides gas to the breathing loop when the diver descends or needs to flush the loop with diluent.

Caustic cocktail: The caustic, soapy mix, which occurs, if water is allowed to flood the scrubber. Caused when water mixes with the carbon dioxide absorbent.

Counter lung: A bag into which the diver's breath flows. It inflates as your lungs deflate, i.e. counter to your lung. Submatix counter lungs are coaxial, i.e. one inside the other or available as separate counter lungs for easier cleaning. The Submatix counter lungs are made from a clear poly vinyl and are back mounted.

Mouthpiece: The mouthpiece assembly, which has an 'off/on' switch. The SUBMATIX mouthpiece can be operated with one hand.

Flowmeter: A device to measure the amount of fresh gas flowing into the counter lung during pre-dive checks.

Loop: The hose assembly, scrubber canister and counter lungs, which cycle the breathing gas in a 'loop'. The diver is also part of the loop once the mouthpiece is open and being used by the diver.

Overpressure valve: A valve, which allows excessive pressure in the counter lung to exit. Very similar to an auto dump on a drysuit. This is set to a level the user is comfortable with and allows expanding gas to escape on the ascent.

ppO$_2$: Partial pressure of oxygen. Maintained between 0.2 and 1.4 bar. SUBMATIX offers the Oxyscan 100 Pro A series of monitors to measure PPO2 in the loop. You must ALWAYS know your PPO2.

Octopus: An open circuit scuba second stage used for bail out.

Pressure gauge: Shows current pressure in the cylinders. One is provided for each cylinder.

Purge: Cleansing of the loop of one gas mixture when changing to another.

1st Stage: A valve, which reduces the gas pressure in the cylinder to 10bar above ambient pressure on the diluent 1st stage and to a fixed 10bar on the O2 1st stage.

Scrubber: A refillable canister, which holds a carbon dioxide absorbing chemical in a course granular form.

Scrubber material: A caustic white granular material, which absorbs carbon dioxide exhaled by the diver.

5 Maximum operating depth

The maximum operating depth of the Submatix is governed by three elements. The type of diluent used, the amount of bailout required to ascend from the max depth and the depth the unit has been officially proved to operate at.

Attention: A maximum partial pressure of oxygen of 1.4 bar should not be exceeded.

Maximum operation depths with air diluent/trimix diluent	
Diluent	Maximum Depth
Air	40m
Trimix	100m

Table 1

Attention: Reading of this manual does not exclude the user from participating in an approved Submatix CCR 100 SMS training course. Diving the unit BEFORE successfully passing the course is NOT PERMITTED. Using the Submatix CCR 100 SMS without appropriate training can lead to serious injuries or death!

Due to the design of the Submatix CCR 100 SMS rebreather, it is possible that the breathing mix in the loop can become hypoxic or hyperoxic. This is owing to the fact that the unit works on a small constant flow of oxygen with the ability to override and add more if required. The constant flow needs to be set using the needle valve on the Pro Booster to a flow rate just below the metabolic rate of the user. ‘Mr Average’ diver has a metabolic rate of around 1litre per minute – ‘Mrs Average’ diver slightly less. So, the flow rate is best set at 0.8-0.9lpm. This allows the PPO2 to remain steady if the diver is not moving ie. taking photographs, on a deco stop, pausing on the bottom etc.

Once metabolism increases, such as while swimming, manual addition is required to maintain the PPO2 at a constant value.

As a rule of thumb, an individuals 02 consumption can be worked out at 0.044 x RMV (Respiratory Minute Volume).

For example, a diver with a RMV of 20lpm will consume (metabolise) approximately 0.88lpm (0.9lpm) of oxygen.

Should the constant flow be set too high, the oxygen will not be metabolised, the PPO2 will increase and could reach hyperoxic levels.

It is also possible for the inverse to occur. If the constant flow is set too low, the oxygen will be metabolised quicker than it can be replaced and if not rectified, a hypoxic breathing mixture will be created in the breathing loop.

Both scenarios are easily rectified and are thoroughly covered in the approved training courses.

The problems discussed above will have serious effects on the diver. An elevated PPO2 (above 1.6bar) can cause serious oxygen toxicity of the Central Nervous System, which will lead to convulsions and drowning. A PPO2 of 0.16 or less will lead to hypoxia, unconsciousness and drowning. Therefore, diving the Submatix CCR 100 SMS with less than two redundant ppO_2-monitors with high and low setpoint alarms is not permitted or recommended.

Considerations when using diluent other than air

Any dives on the Submatix CCR 100 SMS unit deeper than 40m must use a diluent such as trimix or heliox.

Although the unit can use a variable PPO2 (the user dictates what level to run the unit at, not exceeding 1.4bar PPO2) it is recommended that a PPO2 of 1.3 bar is not exceeded on dives deeper than 40m.

Due to the increased density of gas at depth, more oxygen molecules are injected when the Pro Booster is used. If the unit is running at its maximum 1.4 bar PPO2 setting, it would be very easy to spike the PPO2 above safe levels when injecting oxygen at depth thereby potentially endangering the user.

Secondly, running such a high PPO2 (1.4bar) at depth will have minimal decompression advantages while running the ‘bottom’ phase of the dive however will accumulate significant CNS loading which may lead to oxygen toxicity issues.

It is recommended that an END (Equivalent Narcotic Depth) of 30m is used as a maximum up to 70m reducing to an END of 24m at 100m.

The PPN2 of the diluent effects the narcotic effect and density of the gas in the loop. Increased density of gas also increases the Work of Breathing (WOB) and effects the duration of the scrubber (reducing it significantly).
Increased work of breathing also increases the level of retained carbon dioxide which in turn increases the effect of narcosis! As you can see, a viscious cycle.
The simple solution to this is to reduce the PPN2 in the breathing loop by using 'PPN2 reduced' diluents such as trimix or heliox. See the table below for examples of suitable diluent for use at depths exceeding 50m.

Depth (m)	END	Max PPN2	PPO2	Trimix O2/He *
50	30	3.16	1.3	21/26
60	30	3.16	1.3	18/36
70	30	3.16	1.3	16/44
80	28	3.00	1.3	14/52
90	26	2.84	1.3	13/59
100	24	2.68	1.3	11/64

***** - These are 'Ideal Gases' and are only shown as an illustration

Attention: The diver must have a clear understanding of the dangers of hypoxia and hyperoxia. It is not advisable or permitted to dive the unit without having an understanding of these 2 risks and of their avoidance.

Danger: The Submatix CCR 100 SMS should never be dived with the cylinders turned off or empty. Disregarding this comment can lead to serious injuries or death.

Attention: Due to the way in which the Submatix CCR 100 SMS operates, accurate PPO2 maintenance while diving is critical to correctly plan your decompression if using constant PPO2 decompression tables.
Precise calculation of your decompression obligation is only possible with a dive computer with a loop integrated oxygen cell.

Attention: If using a dive computer to calculate your decompression while using the Submatix CCR 100 SMS, it is recommended that only computers designed specifically for use with CCR units are used. Dive computers using an optional

integrated oxygen cell are also highly recommended. The Submatix Oxyscan A is only a PPO_2-monitor and will only display the PPO2 in the breathing loop. The accuracy of the reading can also be affected by humidity and moisture.

Attention: The CCR should only be used with at least 2 redundant PPO_2-monitors with audible and visible warnings. Systems with several sensors on a connected PPO_2-monitor and/or a connected dive computer are not considered to be redundant.

6 Knowledge Review 1

1) What is the maximum operating depth of the Submatix unit for a) air b) trimix?

2) What is the factory depth setting?

3) Can the depth setting be altered by the user? If not, who can change any of the factory settings?

4) Can the Submatix rebreather be dived safely without training? If not, what training should be undertaken?

5) The Submatix is a manually driven, constant flow closed circuit rebreather. It relies on a constant addition of oxygen to the breathing loop just below the metabolic rate of the user. What is the 'average' metabolic rate and how can you work out your own?

6) What is the metabolic rate of a diver with a RMV of 25lpm?

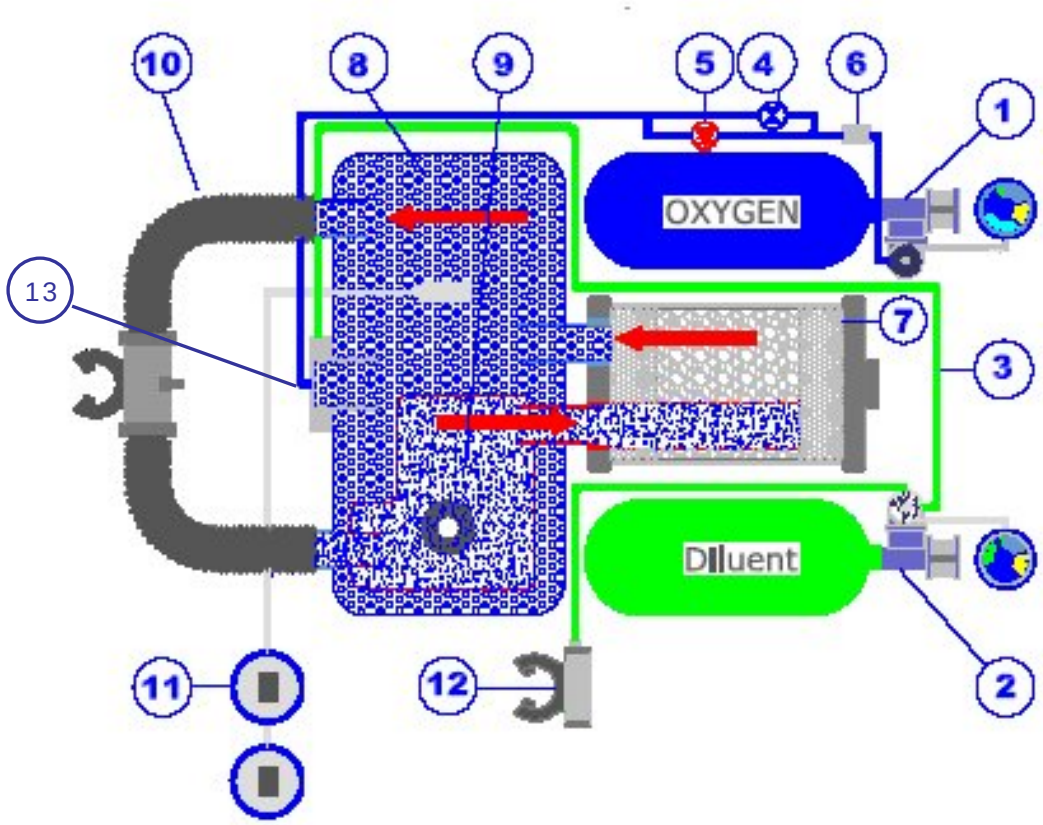
7) What is the maximum and minimum operational PPO2 setpoints recommended by Submatix?

8) How many independent PPO2 monitors do Submatix recommend? Why?

9) At what depth should a diluent other than air be used?

10) What is the recommended END (Equivalent Narcoitic Depth) at 50m, 70m and 100m?

7 Assembly of the unit



1 Oxygen 1st stage with pressure gauge
2 Diluent 1st stage with pressure gauge
3 Diluent supply to ADV
4 Adjustable needle valve
5 Pro Booster oxygen manual addition unit
6 Filter
7 Scrubber canister
8 Inhalation Counterlung
9 Exhalation Counterlung with Over Pressure Valve (OPV)
10 Breathing hose with ‘closeable’ mouthpiece
11 PPO_2-monitors
12 Octopus
13 Auto Diluent Valve (ADV)

8 Description

Breathing Loop

The Submatix CCR 100 SMS is a manually driven mixed gas rebreather. The diver breathes gas from the loop via the mouthpiece (10). The exhaled gas flows through the breathing hose into the exhalation counterlung (9). From the exhalation counterlung the gas flows through to the scrubber canister (7). Surplus gas is expelled via the adjustable overpressure valve.

While passing through the scrubber canister (7) Spherasorb removes the CO_2 from the gas. From the scrubber canister the gas flows to the inhalation counter lung (8). The design of the counterlungs is called coaxial, that means that the exhale lung (9) is in the inhale lung (8). Through this design the breathing resistance is significantly improved. Separate counter lungs are also available and allow much easier cleaning of the lungs – either can be specified for the Submatix.

It is vital that the gas in the breathing loop flows in one direction, right to left. This is achieved with the unidirectional flow valves in the mouthpiece (10) The mouthpiece also needs to be able to be isolated. The lever at the front of the mouthpiece enables the diver to open or close the mouthpiece to prevent water ingress if the mouthpiece is removed while underwater.

Cylinders and 1st Stages

The onboard gas is provided by 2 x 2ltr, 232 bar cylinders wth DIN valves. The cylinders are held in place with Velcro straps. The cylinder pressure is reduced to ambient pressure in the diluent cylinder 1st stage and to a fixed interstage pressure of 10bar (use up to 80m) or 12bar (use up to 100m) on the oxygen 1st stage. (1, 2). The left cylinder contains the diluent gas and the right cylinder contains oxygen. The 1st stage of the diluent cylinder is depth compensated and the 1st stage of the oxygen cylinder is fixed and does not compensate for depth. This allows the oxygen 1st stage to deliver a constant flow of gas independent of depth up to its operational depth limit.

Oxygen Delivery

The oxygen is dosed through an adjustable needle valve (4) set to deliver oxygen at a rate just below the metabolic requirement of the diver. As the oxygen is metabolised by the diver and the PPO2 drops, addidional oxygen can be fed to the system by the Pro Booster manual oxygen addition unit (5). The PPO2 in the breathing loop is monitored by the Oxyscan Pro A which is plugged into the inhalation counter lung via a S-Con connector system. Dual sensor head units are recommended. These allow two separate oxygen cells to occupy one port in the breathing bag. They feed separate Oxyscan units and are truly independent. The constant flow must always be set for the individual metabolic rate of the diver using the unit. The settings MUST be checked and verified before EVERY dive. As the metabolic rate (therefore oxygen consumption) varies with workrate, it must be permanently monitored using a PPO2-monitoring system. The PPO_2 should not be allowed to drop lower than 0.2 bar or allowed to rise above 1.4 bar. Therefore it is recommended to operate within setpoints of 0.3bar and 1.3bar which allows the diver time to react to any adverse fluctuations.

Bailout

Dependent on the planned dive, the diver MUST carry sufficient open circuit bailout gas in order to make a safe and controlled ascent from the deepest section of the dive allowing for the maximum amount of decompression that may have been accumulated. Remember that when planning open circuit bailout gas requirements that your decompression obligations could be different to your planned CCR dive. The bailout gas should also take into consideration total gas loss on the rebreather so should also allow for enough gas to drive buoyancy devices such as BCD and drysuit. A separate bailout system is not included as part of the standard Submatix package.

Diluent Addition

The unit is supplied with fresh diluent gas through the ADV (Auto Diluent Valve) (13). The ADV is supplied with fresh gas from the 1st stage as pressure in the inhale lung drops (through purging the loop of gas via nose or mouth) or as ambient pressure increases during descent.

Carbon Dioxide Removal – Scrubber Operation

We recommend the use of Sofnolime as a carbon dioxide absorbent. While the use of other scrubber types is acceptable (Divesorb, Sofnolime, Spherasorb, Soda Lime) it is insisted that the datasheets for use etc given by the producer are closely observed. Spherasorb has a colour indicator. This is an approximate indicator of used absorbent and it must be checked immediately after the dive as it is only temporary. Exhausted absorbent must be removed and disposed of.

Do not attempt to use again, no trick in the book can 'rejuvenate' exhausted absorbent!

The Submatix scrubber canister has a maximum volume of 1.8 kg scrubber. Under the following conditions the duration times are as follows:

Example illustrated used Spherasorb:

- water temperature: 4 °C
- breathing rate: 40 l/min
- Metabolic rate (O2 consumption): 1.78 l/min
- 'Break Through' indicator: 0.5 Vol % carbon dioxide in inhale gas
- absorption of carbon dioxide: 1.6 l/min

determined life time: 135 min

- water temperature: 4 °C
- breathing rate: 30 l/min
- Metabolic rate (O2 Consumption): 1.33 l/min
- 'Break Through' indicator: 0.5 Vol % carbon dioxide in inhale gas
- absorption of carbon dioxide: 1.2 l/min

determined life time: 180 min

Absorption of carbon dioxide SPHERASORB/SOFNOLIME			
CO_2 absorption of 1 kg	CO_2 production	Duration of scrubber 1.8 kg capacity	Water temperature
Sofnolime 2.5/5.0mm 100 l/min	1.2 l/min	150 min	4°C
	1.6 l/min	112 min	4°C
Spherasorb 120 l/min	1.2 l/min	180 min	4°C
	1.6 l/min	135 min	4°C
Sofnolime 797 140 l/min	1.2 l/min	210 min	4°C
	1.6 l/min	158 min	4°C

Table 2

According to the US Navy Manual (revision 4: 20th January 1999) an oxygen consumption of 1.7 l/min is considered high work rate and an oxygen consumption of 2.5 l/min is considered extremely high work rate. An average work rate corresponds to oxygen consumptions between 0.8 l/min and 1.4 l/min.

Carbon Dioxide Production Rates

Carbon Dioxide production by the body for a given oxygen consumption rate (metabolic rate) can be worked out at 0.9 x O2 metabolic rate.
For example, a diver with a metabolic rate of 1lpm will produce 0.9 lpm of carbon dioxide.

If you reduce the test conditions to an oxygen consumption of 1.33 l/min, you will simulate an average work rate which a diver could realistically maintain underwater. Using Spherasorb Submatix recommends a maximum scrubber duration of 180mins.

Attention: At the moment the manufacturer of Spherasorb has not approved its use for diving. As such its use in the Submatix rebreather is at the users own risk.
The values, given in this manual, are the result of US Navy tests.

Scrubber Duration at Depth

At depth, the scrubber duration is drastically affected and as such this should be considered when planning your dive.

i) At diving depths up to 20m, the full duration of the scrubber can be enjoyed. Using Spherasorb as our example absorbent and a CO2 rate of 1.2lpm, this means a scrubber duration of 180mins.

ii) Dives deeper than 20m and up to 50m should reduce the cumulative dive time to a maximum of 140mins – so the diver should be leaving bottom once total elapsed time has reached 140mins - approximately 25% reduction in scrubber duration.

iii) For dives of 50m and more – cumulative dive time should be kept to a maximum of 100mins – so the diver should be leaving bottom once total elapsed time has reached 100mins - approximately a 45% reduction in scrubber duration.

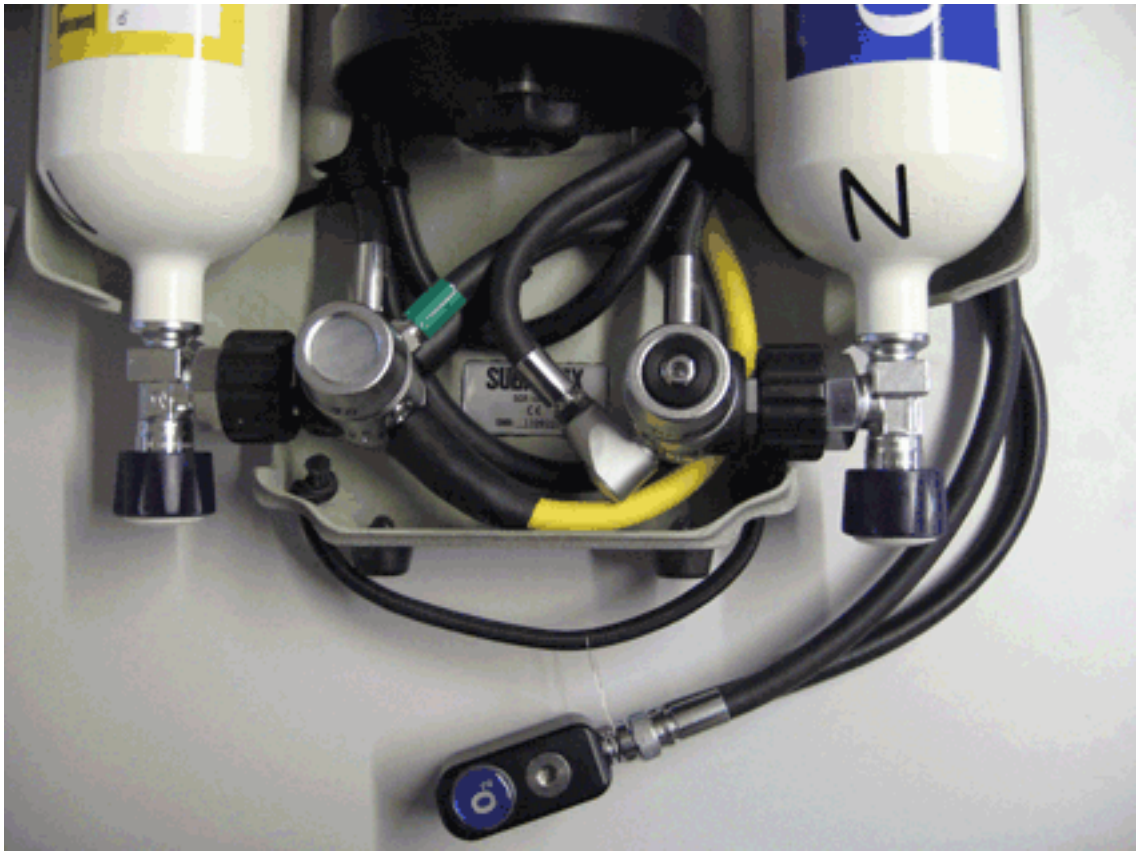
9 Technical data

Weight (ready for use):	approx 15 kg
Dimensions of case (exc. hoses):	620 x 390 x 170 mm
Volume:	9 litres (breathing loop with filled scrubber tank)
'Tidal' volume:	7 litres
Gas supply:	1 x 2 litres, 232bar diluent 1 x 2 litres , 232bar oxygen breathing gases must correspond to the guidelines for medical oxygen (DIN 3188, EN 132)
Operating temperature:	+4°C to +34°C
Operating pressures:	232 to 20 bar
Volume scrubber tank:	approx 1.8 kg
Positive buoyancy:	2.5 kg (with full counterlungs)

10 Knowledge Review 2

1) What direction does the gas flow in the Submatix? Why is it important for gas to flow in one direction in the breathing loop?
2) What is the IP (interstage pressure) of the Diluent and Oxygen 1st stages? Why is the oxygen 1st stage fixed?
3) How is oxygen delivered into the breathing loop? What would make the PPO2 drop in the breathing loop? What action is required to maintain a constant PPO2?
4) What bailout should a diver carry? How much bailout would a dive to 35m need assuming a SAC (surface air consumption) rate of 25lpm, an ascent rate of 15mtr per minute and a deco schedule of 3 mins at 9m and 6mins at 6m? Allowing for extra gas for buoyancy devices etc?
5) What would cause diluent to be added to the breathing loop? What effect would this have on the loop PPO2?
6) What is the scrubber duration using Spherasorb at a 1.2l/min CO2 production rate?
7) At depths exceeding 50m, how should you adjust your dive plan?
8) How can you work out your CO2 production rate? What would be the CO2 production rate for a diver with a metabolic rate of 0.9lpm?
9) You have completed a dive for 45mins @ 42m a second dive for 50 mins @ 35m and a third dive for 60 mins@ 20m. You plan to dive you next dive in the morning to 50m for 35mins – will your scrubber duration permit this?
10) What is the weight of the Submatix in the water? How can this be counteracted?

11 Component parts and assembling



Gas supply: right: oxygen cylinder with fixed Interstage Pressure first stage of 10bar (MOD 80m) or 12 bar (MOD 100m), left: diluent tank with environmentally sealed and depth compensated first stage, below: Pro Booster manual oxygen addition unit with adjustable needle valve and quick-release coupling. (Note: European Oxygen cylinders used in example above.)

Oxygen 1st Stage with the Interstage Pressure kit fitted to fix the IP at a predetermined level of 10bar (80m MOD) or 12bar (100m MOD)

Right side: diluent cylinder with depth compensated first stage and environment kit fitted

Auto Diluent Valve (ADV)

Pro Gas Booster manual oxygen addition unit showing needle valve and manual override button (in blue) and quick disconnect coupling

Octopus attached to diluent for emergency bailout – sufficient bail out gas should be carried in addition to this. Optional rail mounted bailout or side mounted cylinders should also be considered if the depth and duration of the dive warran it.

Breathing loop showing separate counter lungs

Separate counter lungs – Left: Exhale bag with over pressure valve and water trap.

Right: inhale bag with ‘anti-collapse’ spiral inside

Scrubber Canister with spring loaded spacer plates inside

Breathing hose showing colour coded Pro Con connectors, RED exhale, GREEN inhale

The Pro cons are also a different shape as well as being colour coded to prevent accidentally assembling the breathing loop back to front.

Easy to operate mouthpiece with rotating slide valve.

Breathing hoses with one way flow valves (disassembly and maintenance should only be carried out by Submatix approved service technicians or while under strict supervison)

Attention: Disassembly and maintenance of the breathing hose and mouthpiece should only be carried out by Submatix approved service technicians or while under strict supervison.

Submatix ULLI TEC BCD (Standard Supply)

Submatix Weight Harness will match up to virtually any standard wing system

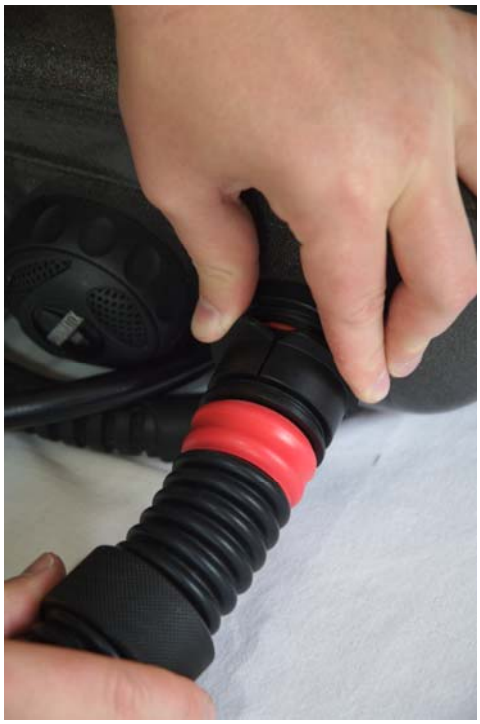
PPO_2-monitoring system (Oxyscan)

All component parts must be assembled in accordance with the instructions in this manual. With all plug-in connectors, such as Pro-Con and S-Con, particular attention must be paid to ensure that they are not damaged, they are free of any contaminating debris such as sand or grit and they are the correct size for the particular connector. All sealing O rings must be regularly lubricated with the appropriate lubricant (Submatix General Use and Extra Thick O2 compatible grease).

When assembling the Pro-Con connectors, ensure that the locking ring is properly ‘clicked’ shut to ensure that it has locked into position. The integrity of the connection can be checked by pulling on it, it should not pull apart unless the locking ring is eased apart. All connections in the breathing loop are colour coded (green - fresh gas, red - exhaled gas). Note that all connections must be assembled correctly in accordance to the colours.

When assembling the unit, be careful to connect the breathing loop in the correct direction, noting that the colour coded connectors all match up. The breathing hose Pro cons are also shaped differently so actually fitting the loop in the wrong direction is virtually imposible.

The hoses will naturally try and twist to their own shape, this can make the position of the mouthpiece uncomfortable. When fitting the hoses, make sure that they are twisted to a position that suits you as the diver. The hoses should route neatly over the shoulder and into the case without twists and kinks yet remain comfortable in the mouth.



Optional hose weights are available. These counteract the buoyancy of the hoses while in the water. 2 or 4 of these can be added as an option should you decide they are required.

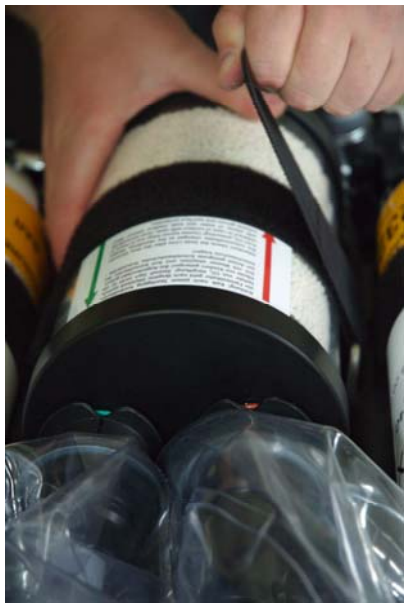
The breathing hoses are connected to the breathing bags with colour coded and shaped connectors. The locking ring holds the connection together and this is further secured with a secondary locking ring that slides down over the whole assembly keeping it tightly held together.

When installing the exhale counter lung, be careful to ensure that the Over Pressure Valve is correctly ‘snapped’ into place in the OPV holding ring. If not correctly fitted, the OPV is help open evey time you exhale. Not only does this mean an unnecessary loss of gas, it will also allow water back into the counter lung, eventually flooding the scrubber. This is easily detected in the water as you will feel and hear a lot of bubbles being expelled from the unit, very similar to breathing open circuit. Should ths occur, abort the dive and refit the OPV into its locking ring.

The connections for the inhale and exhale counter lungs are held in place on the case by 1 ½" threaded locking rings. Pass the threaded connectors through the correct opening on the case and use the threaded locking rings to hold securely in place.

While installing the Inhale counter lung, it is easier to connect the ADV (Auto Diluent Valve) first, making sure that the connector is securely locked in place, listen out for the 'click' as it locks together. Once both counter lungs are connected, exhale lung making sure the OPV is correctly fitted, inhale lung with securely fitted ADV connection then connect the scrubber canister, again, listening out for the 'click' as the Pro-Cons lock into place. For ease, make sure that the open side of the locking ring is facing towards you, this allows you to see if it has closed properly.

When installing the scrubber canister, it is imperative that it is fitted correctly to maintain the correct gas flow direction. The canister is clearly maked with coloured direction arrows (red down, green up) and the Pro-Cons themselves are also colour coded. Incorrect installation will lead to an increased work of breathing (WOB) and carbon dioxide build up as it will not be scrubbed properly. Once fitted, hold in place with the Velcro strap.



The diluent and oxygen cylinders should be analysed before installation to verify their content. Once analysed, mark them up with their contents and install them to the unit, ensuring that they line up correctly with the DIN 1st stage connections.

The cylinders are also held in place using Velcro straps which should be fastened as tight as possible to prevent the cylinders moving around while the unit is being transported. This prevents the possibility of the cylinders working loose on the 1st stages.

The unit is held shut on four points around the case. The top 'lip' has a locating slot cut out of it, this also helps to prevent the lid popping open after entering the water via a backward roll. Down the sides of the unit are two metal slots resembling a 3 bar slide. The extended cylinder straps thread through these to hold the lid onto the case. At the bottom of the case is the main securing point. This is a thick bungee loop that locates into a moulded groove on the bottom of the lid. This was designed to be 'field replaceable' should it break while you are out diving. Make sure that all securing points are tightly shut without trapping or kinking any of the hoses or leads required to run the unit.

The Submatix S-Con connector is locked in place by turning a small pin on the sensor head, 180 degress in a groove on the S-Con socket. Once in place, it is important that the sensor head is not allowed to turn in the socket while the unit is in use. If this happens, it would be possible for the sensor head to come out of the socket and the breathing loop to flood. When installing any of the PPO2 monitoring equipment, be careful to route the cables in such a way that while in use, they are pulling the sensor into the locked position. If no sensor is being used, the socket must be sealed with an S-Con blanking plug.

Line up the locking pin with the groove in the socket and push the sensor head into position.

Turn the entire sensor head assembly 180 degrees to lock into position. The cable to the PPO2 monitor display must be routed in this directon to ensure the device stays locked while in use.

The Patented Pro-Con connectors are colour and shape coded so that it is impossible to connect the breathing loop the wrong way round. Before diving the unit, make sure the Pro-Con securing ring is pushed down over the connector.

Attention: The Pro-Con connector rings must be snapped in so that you can hear the ‘click’ as they lock in. The securing ring must then be pushed down over the connection before diving.

12 Handling and use

12.1 General instructions

To safely use the Submatix you should:

- check the unit and all of its equipment before every dive.
- check and maintain / clean the unit and all of its equipment after every dive.
- protect the unit from exposure to direct sunlight.
- assemble the unit in strict accordance to the instructions in this manual.
- check if the cylinders are filled with the appropriate gases.
- analyse the gas before use.
- check the oxygen dosage rate using a flow meter. Adjust to your personal metabolic rate.
- check operation of the oxygen manual addition valve. Does it return to normal flow rate after it has been activated?
- calibrate the Oxyscan PPO_2-monitor in ambient air before every dive.

You should never

- have poor buoyancy control especially through diving the unit with too little or too much weight.
- expose the 1^{st} stages or any part of the rebreather to oils and greases that are non oxygen compatible.
- leave the scrubber in direct sun or excessive heat.
- use the scrubber beyond the manufactuers recommended duration limits
- use unanalysed gas mixtures.
- breathe the unit on the surface for long periods.
- Dive the unit without adjusting the constant flow of oxygen to match your personal metabolic rate
- dive without a bailout system, which is properly calculated and matched for the planned dive.
- use components by other manufacturers, which are not approved for use in the Submatix.

12.2 PreDive Preparation

12.2.1 Filling the Scrubber Canister

Packing and filling the scrubber canister is one of THE most important aspects of pre dive preparation of any rebreather system. If packed incorrectly, channelling can occur which will allow gas laden with carbon dioxide to bypass the CO2 absorbent leading to hypercapnia. One of the key design features of the Submatix rebreather is the clear material used in the scrubber canister, this makes packing much easier as you can see if the material has packed correctly.

Follow these steps to correctly fill the canister.

1) Place the spring loaded plate into the scrubber can. Be sure to use the correct plate with the conical spacers, these must be facing the top of the scrubber. Make sure the plate is clean and seated properly.
2) Pour approximately 50-75mm of CO2 absorbent into the canister, this is best done with a light breeze blowing so that any dust is blown out of the material as it is poured.
3) Tap and rotate the canister. This settles the absorbent into place. Continue this for a minute or so. Hold the canister up and check that the absorbent has settled evenly.
4) Repeat this step until you reach the red filling mark on the outside of the canister. You may find it easier filling to the mark if the grey tube in the canister is bunged using a rubber blanking plug, this prevents unnecessary spillage of absorbent.
5) Once the scrubber is fully packed, place the second plate in place with the flat spacers facing to the top.
6) Push on the scrubber lid, checking that the sealing o-ring on the canister is in position and free of debris. A light coating of suitable lubricant may be useful.
7) Using the tightening nut, tighten the whole canister up until you are unable to twist the nut any more.
8) Check the seal of the canister by attaching the breathing hose to the red and green connectors on top. You will now be able to carry out a positive and negative test on the canister. Any reduction in the pressure of either the positive or negative tests indicates a leak. DO NOT dive the Submatix until this has been rectified. Flooded scrubbers can lead to a caustic solution in the breathing loop. This is very dangerous for the user.

Attention: While filling the scrubber it is advisable to wear protective gloves and goggles as the dust is caustic and will burn if it comes in contact with wet skin or your eyes. See Handling Sheet for the absorbent used for further medical advice.



12.2.2

1. Partially Fill	2. Tap and rotate to ‘bed in’ the absorbent.	3.Carry on this process until the red filling mark is reached.

Pre dive checks: Positive Pressure and Negative Pressure

12.2.2.1 Positive pressure test - exhale counter lung

For this test the overpressure valve (OPV) must be fully shut and the outlet of the scrubber canister must be sealed with the breathing hose. Once connected up in this way, fully inflate the exhale lung using the mouthpiece until the OPV vents gas. Once inflated, place a small weight on the counter lung. The lung should be able to remain firm for several minutes. Should the counter lung start to deflate, check the connections and all components to isolate the leak. If the leak is not detected, DO NOT dive the Submatix until it is rectified.

Sealing the scrubber canister with the breathing hose (seperate counter lungs shown)

The same test MUST be carried out with the co-axial breathing bags. This ensures that the integrity of the exhale counter lung is good and that a CO2 bypass will not occur while diving.

12.2.2.2 Negative pressure test – exhale counter lung

In the same way that we tested the exhale counterlung with a positive pressure test, the same needs to be done with a negative pressure test. This is because some forms of damage or failure of the material or the construction of the lung may be hidden by one type of test but obvious with the other and vice versa.

With the breathing hose still connected to the exhale lung and to the inhale port of the scrubber canister, suck all of the air out of the loop via the mouthpiece. As you are sucking the air out, crush the breathing hoses with your hands. Once a good vacuum has been created, shut the mouthpiece. The crimps in the hoses should remain in that state, if they start to pop back into shape, this indicates a leak in the system. Thorough checking of all conections, o-rings and seals need to be carried out. Be sure to also check the mouthpiece, it is possible that air is getting back in via the seal on the inner mouthpiece barrel if it has become contaminated with sand or grit or the lubrication has been allowed to dry out. DO NOT dive the Submatix if any form of leak in the breathing loop cannot be rectified.

12.2.2.3 Positive pressure test - breathing loop

Once we have individually tested the exhale counter lung, the same needs to be done with the entire breathing loop assembly. Once fully connected, close the OPV and fully inflate the breathing loop using the mouthpiece. Once the OPV starts to vent as, the loop is full, shut the mouthpiece. Place a 1kg weight on the counter lungs and leave for a minimum of 3 mins. The lungs should not deflate at all. If they start to deflate, this indicates a leak.

Should this happen, all connections, O-rings and PPO2 sensor sockets must be checked. If the leak is very difficult to find, reassemble the breathing loop in its entirety outside of the case. This allows the diver to submerge the entire loop in water to detect the leak. If the leak sill persists and is not fixed, the unit MUST NOT be dived and MUST be returned to a Submatix Approved Service centre for repair.

Positive Pressure Test (separate counterlungs shown)

12.2.2.4 Negative pressure test – Breathing Loop

Testing the entire breathing loop prior to a dive is essential. Any leaks in the system will allow valuable gas out and water in. Neither of which are desireable in a closed circuit rebreather. As already stated, some leaks that are hidden on a positive pressure test are obvious on a negative test so both must be carried out prior to diving.

With the entire loop assembled, suck all of the air out of the loop, crushing the breathing hoses as you do so. Once a vacuum is created, shut the mouthpiece and leave the loop in this state for a min of 3-5 minutes. No change should be noted. If the loop starts to slowly reform its shape, a leak can be assumed. This must be located and removed before diving the unit. DO NOT dive the Submatix if the leak cannot be removed.

Negative Pressure test of the breathing loop (separate breathing bags)

12.2.3 Checking Cylinder Pressure and Analysing the mix

Prior to diving, it is essential that the contents of the gas supply cylinders are checked. Using a simple oxygen analyser, or the Submatix Oxyscan Pro 100 A with a special adapter, the contents of BOTH cylinders must be checked. If using air as a diluent, the contents of the diluent cylinder must show 20.9% O2 content and the contents of your oxygen cylinder must be 100% O2 content. If using diluent other than air, the gas must be analysed using an appropriate mixed gas analyser. If the diluent mix is not breathable at the surface (i.e PPO2 less than 0.16 bar) then suitable breathable gas must also be carried. Once analysed, mark up each cylinder accordingly and fit to the rebreather.

The Submatix is supplied with 2 x Pressure gauges. To check cylinder pressure, turn on each cylinder slowly and read off the pressure from the gauges. The Submatix must not be used unless both cylinders are full. After checking, remember to turn the cylinder valves off as the the oxygen will continue to flow and will be wasted.

12.2.4 Checking the auto diluent valve (ADV)

Another vital pre dive check is checking the operation of the ADV. The ADV delivers diluent into the breathing loop as the diver descends allowing a full breath to be taken and diluting the breathing mixture so that it can be breathed at depth. To check its operation, turn the diluent cylinder valve on, inhale though the mouthpiece and out through your nose until the breathing loop is empty. As the breathing loop reaches its minimum volume, the ADV will activate injecting diluent. Continuing to breathe against the ADV will continue to deliver gas, similar to breathing on an open circuit regulator. Should the ADV not function in this way, the Submatix must not be dived and must be returned to an authorised Submatix service centre.

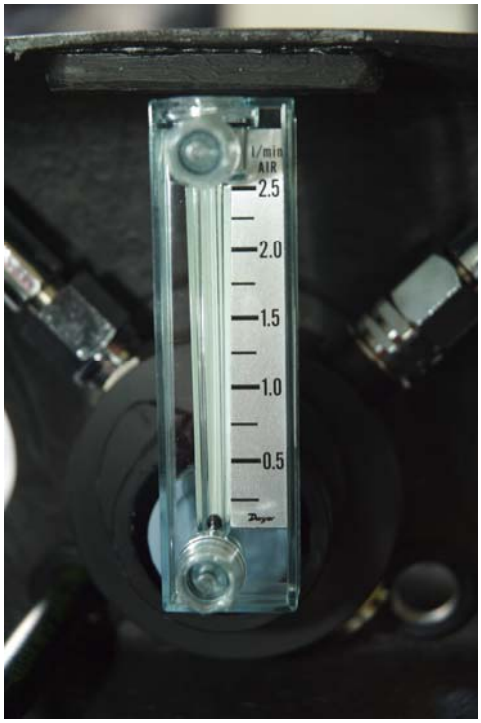
Attention: If the Submatix rebreather fails ANY of these tests and cannot be rectified, it must be returned to a Submatix approved service centre for repair.

12.2.5 Flow meter

The flow meters which Submatix supply are in the following scales:

- MMA-21 0-2.5 l/min
- MMA-23 0-10 l/min
- MMA-24 2.5-25 l/min

The Submatix 100 ST SMS CCR uses flow meter MMA-21 with a range of 0lpm to 2.5lpm.
Before using for the first time, the flow meter must be assembled according to the instructions supplied with it. In order to test the flow of the constant flow needle valve, the flow meter needs to be fitted with a rubber bung. This allows the flow meter to be inserted into the ADV orifice with a tight fit.



Once inserted into the ADV orifice, the flow being delivered from the Pro Gas Booster can be measured.

The ‘ball’ in the flow meter may occelate at first, this can be stopped by rotating the meter horizontally onto its side, then slowly rotating back to the vertical. The ball in the meter must be static in order to give an accurate reading.

12.2.6 Adjusting the flow from the Pro Gas Booster

The correct constant flow is a very important aspect of a manual closed circuit rebreather. It is this contant flow which provides a life sustaining amount of oxygen into the breathing loop. Too much oxygen flowing in and the breathing mixture in the loop will become hyperoxic with the associated fits, convulsions, blackout and ultimately death, while too little will create a hypoxic breathing mixture with a similar outcome! The Pro Booster's operation is very simple. An adjustable needle valve controls the constant flow of oxygen into the breathing loop. The large blue button on the Pro Booster operates a simple valve and allows the user to 'boost' oxygen into the loop should it be required. Provided the flow rate is set correctly for the users metabolic rate, the blue Booster button will only be used when the divers metabolic rate increases, such as when swimming. While stationary or while inactive, the PPO2 in the breathing loop should remain static.

The Booster should only be used to inject oxygen as the diver is exhaling. This drives gas through the breathing loop, mixing with the freshly injected oxygen and gives the PPO2 monitors time to react to the gas mixture helping to prevent oxygen 'spiking' in the breathing loop.

In the unlikely event of an oxygen 1st stage failure, it is important that the gas flow can be isolated quickly, preventing dangerously high PPO2 levels in the breathing bag. On the Submatix, this is achieved using a quick disconnect similar to a drysuit feed. Pulling the collar of the connector back will release the hose and isolate the oxygen. The unit can still be used in SCR (semi closed rebreather) mode to end the dive and surface safely. This technique is covered in your training.

The constant flow needs to be set using the needle valve on the Pro Booster to a flow rate just below the metabolic rate of the user. 'Mr Average' diver has a metabolic rate of around 1litre per minute – 'Mrs Average' diver slightly less. So, the flow rate is best set at 0.8-0.9lpm. This allows the PPO2 to remain steady if the diver is not moving ie. taking photographs, on a deco stop, pausing on the bottom etc.
Once metabolism increases, such as while swimming, manual addition is required to maintain the PPO2 at a constant value.

As a rule of thumb, an individuals 02 consumption can be worked out at 0.044 x RMV (Respiratory Minute Volume).

Once diving the unit, if the PPO2 in the breathing loop is constantly drifting up, the flow rate is too high. If the user is constantly manually adding oxygen, the flow rate is too low.

To set the flow, insert or connect the flow meter to the ADV or the hose delivering to the ADV from the Pro Booster. Turn the oxygen cylinder on. The flow meter will indicate the current flow. From the factory, the flow rate is set at 0lpm. Using a small screwdriver, turn the needle valve until the desired flow rate is set. To check the Pro Booster, remove the flow meter, and press the booser button a few times. You will hear the oxyen injection. Now replace the flow meter to check the flow rate has returned to the level it was set at. Any fluctuation on this indicates a problem with the Pro Booster unit. DO NOT dive the Submatix until this problem has been rectified. Failure to attend to this problem will lead to serious injury or death.

Pro Gas booster with adjustable needle valve and quick disconnect fitting.

12.2.7 PPO_2-monitoring

Due to the nature of how the Submatix CCR (or any manually driven CCR) works, it is possible for the PPO2 in the breathing loop to fluctuate. The PPO2 levels need to be monitored closely throughout the dive as it is this information that prompts the diver to react in a specific way. Low PPO2 would prompt the diver to inject more oxygen, while a high reading will prompt a diluent flush. As this information is vital for the well being of the diver and for the operation of the unit it is imperative that a level of redundancy is built into the PPO2 monitoring systems. Submatix specify that a minimum of 2 totally independent PPO2 monitors are used. These units must be CE certified and approved for use by Submatix. They must also feature both acoustic and visual alarms for high and low PPO2 setpoints. Systems which use 2 or 3 cells in one housing providing output to a single hand set are NOT redundant, should the cable be compromised, all PPO2 information will be lost.

The prescribed maximum PPO_2-set points of the alarms must be:

- low: 0.2 bar
- high: 1.4 bar

The recommended set points for the warning are the following:

- low: 0.3 bar
- high: 1.3 bar

With the help of these conservative warning set points the diver will have enough time to react to the alarms. Too low and the diver can add oxygen, too high and the diver can flush the loop with diluent.

12.2.8 Checking the flow direction valves

Close off the exhale end of the breathing hose by holding the end of the hose against your left cheek and blow into the mouthpiece. No air should escape from the breathing hose. Now close the inhale end of the breathing hose by holding the end of the hose against your right cheek. While inhaling your cheek should be sucked in and no air should come in through the exhale side. If it is possible to pull air in from either end, the valves are worn or the hose damaged and must be replaced by an authorised service centre.

12.3

Diving with the SUBMATIX CCR 100 ST

12.4 Positioning of the Unit

The unit is designed to be worn on the back. The back mounted counterlungs keep the unit neat and compact with minimal ‘clutter’ at the front of the diver. The hydrostatic work of breathing (WOB) can be drastically altered with back mounted counterlngs by simply moving the unit up or down on your back. The aim is to try and position the counterlungs as close to your back and closely matching the position of your own lungs. When adjusting your harness or BCD try and imagine that the centre of the counterlungs should be within +/- 10cm of the tip of your breastbone or sternum to give an optimum breathing performance. While the harness must be comfortable it should not be loose. Also remember that the unit will sit differently on land compared to when you are in the water. A crotch strap may help to hold the unit in position better.

12.5 Setting the OPV – Final checks and Prebreathe

The overpressure valve must adjusted to your personal preference. The setting is different from diver to diver and should be tried in a swimming pool or sheltered open water before the first open water dive with the unit. As an initial setting we suggest fully closing the OPV and opening between 5 and 10 clicks. This can be adjusted to suit on subsequent dives. Aim to set it so that it takes a fairly hard ‘blow’ from the diver to vent gas.

Attention: Before entering the water, ensure that both cylinder valves are fully open.

Danger: Only open the cylinders just before diving. The oxygen cylinder will deliver oxygen in a constant flow once the valve is turned on. Running out of gas on the dive is dangerous and can lead to unconsciousness and drowning.
Attention: Ensure that your bouyancy devices (wing / BCD, drysuit) are supplied with gas from two separate gas supplies. This provides redundancy should one of the gas supplies fail.

Once both cylinders are open, check pressures in both the diluent and oxygen cylinders. Do not dive the unit with less than 100bar in either cylinder. Preferably, only dive the unit with full cylinders.

Before entering the water, put the mouthpiece in your mouth and open it. **Important:** When the mouthpiece is not in your mouth, it must be closed. This prevents accidental flooding of the breathing loop.

Important: Before entering the water is important that the unit is ‘breathed in’. Prebreathing the unit achieves a number of important functions. Firstly, it starts the scrubber reaction in the scrubber canister. The absorbent needs ‘warming’ up prior to diving, ESPECIALLY in water colder than 10^{o}C. It is possible for the scrubber reaction to fail to start if not prebreathed immediately before diving in cold water. Secondly, your oxygen addition, both constant flow and manual add functions can be tested while on the surface, boosting the PPO2 up to 0.70bar and seeing that it stays there tests both elements of the oxygen addition system. Also, your PPO2 monitoring system is also checked while prebreathing the unit, seeing that all of the displays track accurately as oxygen is added and breathed around the loop. Your prebreathe cycle should be no less than 3 mins and MUST be carried out prior to EVERY dive.

12.6 Descending with the SUBMATIX CCR 100 ST

Before starting the dive the breathing loop must be flushed to raise the PPO2 to 0.70 bar. To flush the breathing loop, exhale 3 or 4 times through your nose and inject oxygen into the unit using the Pro Gas Booster. You will see the PPO2 rise quickly to the desired level. Once this is reached, breathe the unit normally. Not only does this produce a suitable gas mixture to start your dive, it also encourages the unit to be used with a 'minimum loop volume' starting the dive with just enough gas in the loop to breathe comfortably.

After flushing the unit, the diver should no longer breathe from atmospheric air. The flushing removes the ambient air (21% oxygen) from the loop and the divers lungs and replaces it with a 70% Nitrox mixture (0.70 bar PPO2 at surface). As the diver descends, diluent is automatically injected 'weakening' the gas mixture as the ambient pressure increases. This maintains the PPO2 at a safe level through the descent. The diver must closely monitor the PPO2 on the descent, maintaining it at a safe level throughout. Once the 'bottom' of the dive is reached, the PPO2 can be 'boosted' up to the desired setpoint, usually 1.2 – 1.3 bar PPO2. Provided the constant flow rate has been set correctly, the setpoint will be maintained with the occasional 'boost' of oxygen should it be required.

12.6.1 During the Dive

KNOW YOUR PPO2!!!! *THE* most important aspect of rebreather diving. The PPO_2 must be checked every 3 minutes using your PPO2 monitoring system. If the values displayed vary by more than 0.05 bar, remedial action must be taken. Firstly, flush the breathing loop with diluent. Prior to diving, create a 'sanity slate' with the PO2 of your diluent at 10m increments *AND* your planned Maximum Operating Depth. For example, using air as a diluent your expected PPO2 at 10m will be 0.42 bar, at 20m 0.63 bar and so on with a planned dive depth of 35m. See table below:

	Air Diluent
Depth (M)	**Expected PPO2 (bar)**
10	0.42
20	0.63
30	0.84
40	1.05
PLAN	
35	0.95

By flushing with diluent and knowing what PPO2 you should see, you will know which of your PPO2 cells is defective as those working correctly will display a PPO2 that closely matches the values on your slate. Based on this information, if the displays still vary more than 0.05bar the dive must be aborted. Move onto your open circuit bail out and ascend. For safety, the dive should not be continued with only one operational oxygen monitoring system. A new oxygen cell should be fitted or the damaged PPO_2-monitor must be checked and repaired by an authorised Submatix Service Centre.

Throughout the dive, it is recommended that the chosen set point (max 1.4bar PPO2) is maintained as accurately as possible. If using constant PPO2 decompression tables, it is imperative that the planned maximum PPO2 is adhered to as closely so that your decompression obligation is also correct. Integrated decompression computers can have advantages here as they are adjusting your decompression based on 'real time' data collected from the oxygen cell in the breathing loop. It is highly recommended that a back up timing and depth device and hard copy tables are also carried as a precaution even if using an integrated dive computer.

12.7 Ascents with the SUBMATIX CCR 100 ST

Before starting your ascent, check your current PPO2 and monitor this closely throughout the ascent. As the ambient pressure decreases on the ascent, the PPO2 of the breathing mix will drop. Your decompression tables assume a constant PPO2 value and as such it is important that this is followed closely. Maintenance of a contant PPO2 takes some practice but is simpler with a manually driven closed circuit rebreather than with other systems. This will be taught thoroughly on your training course and should be adhered to throughout your diving.

Fast ascents on the Submatix 100 ST CCR SMS should be avoided. Unlike diving with open circuit SCUBA, you now have four sources of buoyancy to control - lungs, counterlungs, BCD and drysuit. As such, a fast ascent can lead to loss of control. Uncontrolled ascents are dangerous and can lead to decompression injuries.

Attention: Pay particular attention to your PPO2 on or near the surface. It is here that the PPO2 is likely to fluctuate the most and may become hypoxic. Try to avoid long surface swims, if left on the surface for long periods, closely monitor your PPO2, or shut the mouthpiece, and breathe from your open circuit bailout.

Attention: Drive gas for your drysuit and BCD can be provided by the onboard diluent cylinder or preferably from a separate offboard source. If using your offboard bailout, ensure that the oxygen content is less than 40% - higher oxygen concentrations may lead to degradation of the material and maybe even fire as the BCD and drysuit components will not be oxygen compatible.

12.8 Post Dive Procedures for the Submatix CCR 100 SMS

Once on the surface, if not breathing from the unit, the mouthpiece must be closed. This prevents accidental flooding of the unit. The breathing loop has a volume of 9 litres, if full of water this adds a further 9kg of weight to the system. If you have not chosen a Submatix BCD or wing system, ensure that your BCD system has sufficient buoyancy to support you, the unit, bailout cylinders AND a fully flooded loop. On the surface, closely monitor your PPO2, be prepared to regularly inject oxygen to maintain a breathable gas mix. After leaving the water, the gas cylinders must be closed.

Immediately on exiting the water, check the breathing loop for any water ingress and check the saturation of the scrubber. The scrubber (Spherasorb) has a colour indicator, changing from white to violet. The colour change indication is only temporary and should ONLY be used as a ready reckoner of scrubber usage. The absorbent will start to change back to white within 10-15mins of completing your dive. Accurate time records of usage should be the ONLY method of monitoring scrubber usage. Always adhere to the manufacturers recommendation for scrubber duration. If you are close to the end of the scrubber duration, or plan to carry out a second dive that will take you over the maximum allowed duration, dispose of the absorbent and repack the canister.

Attention: Moist absorbent material is caustic – be very careful when disposing of this. Avoid contact with your skin or eyes and keep away from clothing. Safety goggles and gloves should be worn.

12.9 Cleaning the Submatix CCR 100 SMS

If you have not planned further diving, you must rinse and dismantle the unit and disinfect all component parts of the breathing loop.

Equally, if the unit is to be used by a second user, it is recommended that the entire breathing loop is thoroughly disinfected, dried and reassembled and the scrubber repacked before use. This prevents any contamination from one user to another.

If possible rinse the complete unit with clean water at the dive site. While washing the unit, it is advisable to keep the mouthpiece closed. Keep the cylinders pressurised while washing the unit to prevent any water getting into the 1st stages or hoses. Pay particular attention to the ADV, OPV, Pro Gas Booster, 1st stages, sensor heads and PPO2 displays make sure all are kept free of salt, sand and debris.

Once at home, thorough disinfecting of the breathing loop is required. This includes all components of the breathing loop – hoses, mouthpiece, counter lungs, scrubber canister and sensor head. The scrubber tank must be empty and all components of the scrubber also stripped out ready for cleaning. Trigene is the recommended disinfectant. It is a very effective Bactericidal, Fungicidal, Virucidal, Mycobactericidal and Sporicidal solution that is safe for use within the breathing loop. Spray all items needing disinfecting and leave for 5-10mins. After disinfecting, all items must be thoughly rinsed in clean water and dried before using again.

Avoid exposing the components to direct sunlight. The ADV must be also be inspected for scrubber dust and, if necessary, rinsed with clean water.

12.10 Transporting the Submatix CCR 100 SMS

While in transit, it is recommended that the unit is secured upright if possible. This keeps any moisture build up after use, or dust in the absorbent before use working into the loop.

Transporting the unit overseas required some forward planning. Make sure that the dive centre you plan to use has access to the correct gas, cylinders and absorbent. If you plan to take all of this with you, may allowance for the extra weight. Included in this manual is letters of certification from the manufacturers of the absorbent to confirm it is safe for transit.

molecular

TO WHOM IT MAY CONCERN

We hereby certify that the Soda Lime (Sofnolime) manufactured by

Molecular Products Ltd contains less than 4% (Four Per Cent) Caustic Soda (NaOH)

is classified as non-hazardous and that it is not restricted for transport.

The label showing the corrosive symbol is a label for use of the product – not for transport.

Signed

A Harding, Despatch Co-ordinator
For Molecular Products Ltd

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E-mail: sales@molprod.com

Registered office as above
Reg No. 02731125 England.
A member of Molecular Products Group plc

13 General comments for handling and safety

- check the rebreather and all ancillary equipment before and between every dive
- clean and maintain the unit at the end of every dive
- check the connections between the rebreather and the gas cylinders
- regularly practise all life support skills
- protect the unit against exposure to direct sun
- thoroughly rinse the BCD after every use and test it before every dive

When cleaning the unit you should:

- rinse all component parts with fresh water after every dive
- dry all component parts out away from a direct heat source before the assembling
- keep the 1st stages connected and pressurised to prevent water getting into them

The unit should not be stored with a filled scrubber canister. The unit should be stored in a dry, shady and well ventilated area. If diving in the winter, where possible do not leave the unit in a car overnight where it may be exposed to temperatures close to or lower than freezing. Avoid unnecessary exposure to UV-radiation. If the unit is to be stored for a longer period of time all component parts of the breathing loop should be disinfected and dried thoroughly prior to storing.

14 Safety Procedures

The following safety procedures will be taught thoroughly during your training course and form the basis to safe rebreather diving. Like all skills learned while diving, these should be practised regularly in order to develop an automatic response. A well practised, vigilant rebreather diver is a safe diver. We strongly recommend that at least one skill is practised on every dive, this keeps your safety skills well honed.

15 Loop Bailout

This basic skill is the foundation point of all other rebreather skills.

1) Close mouthpiece valve – be sure the valve is fully shut before removing from your mouth.
2) Shut off oxygen cylinder.
3) Let the hose and mouthpiece float up above your head
4) Place open circuit bailout regulator in mouth and breathe (we recommend wearing the bailout regulator on a neck tie where it is easily found)
5) If required, ascend safely following any decompression obligation you have. Be aware that the counterlungs will also be expanding as you ascend.

16 Loop Recovery

If possible, stay on the loop wherever possible. It could be that after a bailout it is possible to resume breathing from the loop once the problem has been rectified.

1) Lean backwards, the breathing loop will naturally float above you and wil rotate forward, reach up and grab the loop.
2) Remove open circuit regulator and replace rebreather mouthpiece.
3) Before opening the mouthpiece valve, blow hard to remove any water in the mouthpiece through the drain valve.
4) Before opening the mouthpiece, check the PPO2 of the loop, make sure it is still safe to breathe before opening the mouthpiece.
5) If all values check out, open mouthpiece and breathe as normal.

17 Flooded Loop

This skill is useful for general rebreather diving. Due to the moisture build up, a small amount of gurgling' will be heard in the exhale side of the breathing hose while diving. This drill clears the water and moisture into the water trap.

1) Fully close the mouthpiece valve
2) Remove from mouth and stretch the hose as far forward and up as you can push it – this straightens out the corrugations in the hose that traps the moisture.
3) At the same time roll backwards to your left, dipping your left shoulder backwards. This helps to move the moisture into the water trap in the exhale counter lung.
4) Replace mouthpiece, clearing the mouthpiece before opening. Remember to check the PPO2 before opening the mouthpiece.

18 Hypoxic Loop

This situation is indicated by a very LOW PPO2 and could be the result of the oxygen addition stopping or being inadequate for the user or the task.

1) Bailout to open circuit regulator.
2) Manually add oxygen. If this has no effect, check Oxygen cylinder contents gauge.
3) If cylinder showing full but no oxygen being added, check the cylinder valve. Turn on if it is off. Return to loop if problem rectified.
4) If cylinder empty, remain on open circuit regulator and ascend safely adhering to any decompression obligation you may have.

19 Hyperoxic Loop

This situation is indicated by a very HIGH PPO2 and could be the result of the oxygen addition increasing or the diver being beyond the Maximum Operating depth of the diluent or adding to much oxygen when manually boosting oxygen.

1) Bailout to open circuit regulator
2) Check depth, if deeper than plan, ascend, if PPO2 drops back into safe limits, resume breathing from the loop.
3) If oxygen can be heard to be constantly added, disconnect oxygen addition on the Pro Booster and shut oxygen cylinder valve. Remain on open circuit bailout and start ascent. Once shallow, resume breathing from the loop. Turning the oxygen cylinder valve on momentarily (1 second at a time) to boost PPO2 then turn off. Repeat this action to maintain PPO2 content in the loop.

20 Hypercapnia Drill

This is indicated by a variety of symptoms including headache, nausea, narrowing of vision, slowing of reactions etc etc.

1) Immdiately bailout to open circuit.
2) Shut off oxygen valve
3) Start ascent adhering to any decompression obligations and compensating for the expansion of the counter lungs as well.

21 NOAA Oxygen Toxicity Table

PPO2	Maximum Single Exposure in Minutes	Maximm Daily Exposure in Minutes
1.6	45	150
1.5	120	180
1.4	150	180
1.3	180	180
1.2	210	240
1.1	240	270
1.0	300	300

22 Constant PPO2 Tables

23 Service intervals

Attention: The components of the breathing loop should only be greased with SUBMATIX O2 Compatible grease and the low-pressure parts should only be greased with HALOCARBON 25-5S. All high pressure leading parts should not be exposed to any lubricant unless approved for use within oxygen environments. Danger of explosion!!!

Service intervals				
Component part	**Work Requirement**	**Before every dive**	**After every dive**	**Annually**
Complete unit	Check Overall function and positive / negative pressure tests	x		
	Cleaning		x	
Breathing loop	Disinfection		x	
	Grease mouthpiece slide valve			x [1]
	O-rings ADV, O-rings scrubber Canister			x [1,2]
	O-rings breathing hoses			x [1,2]
	Pro-Con connections, overhaul of scrubber canister			x [1,2,x2]
Cylinders	Filling	x		
	Pressure check	x		
Pressure Gauge	Check operation	x		
Pro Booster	Adjust and check constant flow and boost function	x		
PPO_2-monitors	Calibration	x		

1 More often if used regularly (ie lubrication of mouthpiece should be done monthly if diving 4-6 times a month)

2 only by Submatix authorised service centre

24 Maintenance intervals

After servicing or changing any other components, the function of all other corresponding components must be checked. Only Submatix parts are permitted.

Component part	Action Required	After every dive	Every year	Every 2 years	Every 4 years
CCR 100 SMS	Cleaning (all components)	o			
	Complete overhaul		o[x)]		
	Check low-pressure hoses		o[x)]		
	Change O-rings at low-pressure connections			o[x)]	
	Change of low-pressure hoses				o[x)]
Cylinders	Visual or Hydrostatic Test			o[x) xx)]	
Oxygen Cylinder	Oxygen Service		o [xx)]		
Pro Booster	Check function			o[x)]	
	Change of O-rings			o[x)]	
	Change inline filter		o[x)]		
1st Stages	Check low-pressure setting		o[x)]		
	General maintenance		o[x)]		
Oxygen 1st Stage	Interstage Pressure test		o [x)]		
Breathing loop	Change O-rings on all Pro-Con connections		o		
Breathing hose	Change diaphragm in direction valves		o[x)]		
	Change valve seat in direction valves			o[x)]	
	Maintenance of mouthpiece slide valve		o[x)]		
	Change mouthpiece slide valve			o[x)]	
	Change breahting hoses				o
Scrubber tank	Change O-ring cover screw			o	
	Change O-ring cover			o	
ADV/bypass valve	Change diaphragm			o	
	Change valve seat			o[x)]	
	Check pressure setting for activation		o[x)]		
Counter Lungs	Check positive pressure / negative pressure	o			
	Check condition and replace if neccessary				o[x)]

x) If used heavily, replace, check or service more regularly

xx) carried out by authorised persons and in accordance to the stamp on the cylinder

Corresponding to the frequency of the use, all component parts of the unit should be serviced periodically. The diver should check the functions of the unit before and after every dive. At least once a year the unit should be checked by a Submatix Authorised Service Centre. We recommend you keep a record of all repairs, services and replacement parts. Only genuine Submatix parts are permitted for use in the unit.

Troubleshooting		
Problem	Reason	Help
No reading on the pressure gauge after opening the cylinder	Empty cylinder	Fill cylinder
	Damaged pressure gauge, blocked hose	Replace Pressure gauge
Leaking cylinder valve, high pressure connection, 1st stages or ADV	Damaged or incorrectly installed O-ring	Close cylinder, purge pressure from system, check connections, if necessary check and repair by authorised service centre
1st stage doesn't supply gas despite cylinders being full	Damaged 1st stage	Service or replace 1st stage by authorised service centre
ADV supplies no gas	Blocked connection, damaged ADV	Change connections, hoses or ADV only by authorised service centre
ADV fires constantly or delivers too much gas	Wrongly adjusted or damaged ADV	ADV service or replacement of ADV by authorised service centre
Oxygen constant flow is higher or lower than preset values	Oxygen 1st stage interstage pressure higher or lower than 10bar or damaged Pro Booster	Check and change interstage pressure if required and Pro Booster by authorised service centre
Exhale Flow valves do not open	Damaged or sticking valve	Change valve by authorised service centre
Inhale Flow valves no not open	Damaged or sticking valve	Change valve by authorised service centre
Mouthpiece slide valve difficult to open	Dirty slide valve or needing lubrication	Disassembly, greasing and installation of slide valve
Leaking breathing loop	Damaged or dirty / unlubricated seals	Change or clean and lubricate

25 Mouthpiece Maintenance

1 Prize apart the locking rings either side of the mouthpiece

2 Use a Posidrive screwdriver to undo the lever on the mouthpiece valve

3 Strip out the components onto a cleansurface ready for cleaning and regreasing

4 Thoroughly coat the internal barrel With Submatix Extra Thick Oxygen grease. When inserting, make sure the purge channel lines up

5 Once the barrel is in place, screw the lever back in, ensure the O ring is greased and replaced

6 With the assembled mouthpiece, grease the O rings that seal the breathing hose

7 Offer up the breathing hose with the locking ring pulled up on the hose

8 Making sure the O ring is not trapped, snap the locking rin into place.

26 Record card

Service	Date	Signature

27 Diving with Open Circuit Buddies

Your regular buddy may be in awe of your new found diving tool… your rebreather. To help them understand how your diving has changed, it is good practice to talk them through the operation of the unit and the pre dive checks that will differ to diving on open circuit SCUBA.

John Liddiard of Diver Magazine has kindly allowed us to reproduce a feature he published in a 2006 issue of Diver magazine that clearly outlines the facts of rebreather diving and the immediate pre dive checks you need to be carrying out. We hope you find this feature a useful tool in helping your open circuit dive buddies understand your new diving style.

So Your Dive Buddy has a Rebreather

For many divers and boat skippers, seeing a rebreather on the boat, or even worse, being worn by a previously unknown buddy, is a very scary thought. After all, people die on rebreathers, don't they? They are dangerous things. Everyone knows it. Rebreather divers don't help matters. With typical divers' black humour, Inspiration owners often refer to their rebreathers as YBOD for "Yellow Box of Death" and other rebreathers have similarly macabre nicknames.

A natural respect for the unknown coupled with some well publicised accidents has created the common misconception that a diver with a rebreather is just an accident waiting to happen. While most divers have some idea in general about how a rebreather works, they don't really know much about rebreather diving.

To put this in context, to many of the non-diving public, any "deep sea diving" is just an accident waiting to happen. How many non-divers have asked you "isn't it dangerous?" At least with rebreathers they can get the bit about oxygen cylinders right.

Most diving safety is about procedures. Procedures for planning a dive. Procedures for setting up equipment. Procedures for when things go wrong. Good procedures don't necessarily make a good diver, but they go a long way towards it. On the other hand, sloppy procedures are much more likely to be a sign of a sloppy diver.

Back when I first started playing with rebreathers, Richard Bull made the comment that most rebreather accidents have already occurred before the diver gets in the water. It's just that they have not realised it yet. Pre-dive procedures are a critical part of rebreather safety and much more extensive than for open circuit equipment. Knowing something about the procedures that rebreather divers go through before the dive can go a long way to putting a buddy's mind at rest.

The details differ between rebreathers, the owner's kit configuration, and the personal preferences of owner, but the essential elements of the procedures are pretty similar whatever the flavour of rebreather is. So for all of those wondering what a diver with a rebreather is actually doing with their kit on the way to the dive site, here are some of the essentials.

27.1 Positive and Negative Pressure Tests

One of the things that a rebreather diver definitely doesn't want to happen during a dive is a flooded breathing loop. Water in the loop gets in the way of breathing, and worse still, reacts with the scrubber chemicals to create an alkaline solution that is not at all nice to ingest or inhale.

Positive and negative pressure tests are ways of checking that there are no leaks in the breathing loop before a dive. A positive pressure test involves inflating the breathing loop of the rebreather until it is tight and then waiting to see if it deflates. A negative pressure test is the opposite, sucking all the air out of the breathing loop until it crushes down, then waiting to see if any air leaks in.

A rebreather diver will have performed both of these tests when assembling the rebreather from scratch, so you are unlikely to see both on the boat. What you are likely to see as a matter of good procedure is for the a rebreather diver to put a rebreather into a positive or negative pressure test while kitting up, as a final check before diving that nothing has worked loose while the boat bounces about.

As to which test it is that is used for a final check, it all depends on the rebreather and the owner. Rebreathers with counter lungs inside the casing are easiest to check with a negative pressure test. Rebreathers with counter lungs outside the casing have a choice. A positive pressure test can be performed quickly by screwing down the dump valve and pressing the diluent button. On the other hand, a negative pressure tests is less likely to get in the way of putting the rebreather on while it is left in the test state. An added advantage is that less oxygen is needed to flush the loop and bring the ppO2 up when the rebreather is turned on.

27.2 Sensor Calibration

Nearly all rebreathers have oxygen sensors in the breathing loop to tell the diver (and any controlling electronics) what the oxygen level is during the dive. An exception is that some semi-closed rebreathers can be used without any sensors, because the constant flow of gas through the loop ensures oxygen levels.

The sensors are like weak oxygen powered batteries. The more oxygen they face, the higher the output voltage. The associated displays are really just volt-meters that are calibrated to read ppO2 instead of volts.

As with any battery, the sensors age and the output degrades with use. To make sure they are showing an accurate ppO2 during the dive, the calibration has to be checked and adjusted before use.

Some rebreathers allow the oxygen sensors to be calibrated in the breathing loop while the rebreather is fully assembled. Others need to be calibrated before being inserted into the breathing loop. So as with the positive and negative pressure tests, you may not see the full procedure immediately before diving.

Nevertheless, any rebreather that depends on oxygen sensors to function will have at least 2 displays. They may be identical, they may be a master and a slave, they may be a comprehensive primary and a simpler secondary. Whatever the configuration, one of the things a rebreather diver will do more than once during the process of kitting up and getting in the water is to look at all the displays, check that they are switched on, and that they all show the same ppO2 within the loop. It won't be a perfect match, because no two sensors are identical, but it will be within a close margin.

27.3 Warming up the Scrubber

The chemical reaction in a rebreather's scrubber takes a while to get warmed up and going at full efficiency. As a consequence, either during the process of kitting up, or after kitting up but before getting in the water, a rebreather diver will begin breathing off the rebreather for a few minutes before starting the dive.
As part of this process they will turn the gas on, check cylinder pressures, and check the O2 displays several times, to make sure that the sensors and hence displays track the oxygen level as it comes up to the operating level. They may also make adjustments by pushing buttons or twiddling knobs, depending on what type of rebreather they are using. Its all part of making sure a rebreather is working properly while still safely on the boat. A sign of good procedure.
As a buddy, what you need to be concerned about is a rebreather diver who just puts the mouthpiece in and rolls off the boat, missing all this procedure.

27.4 How does the Mouthpiece Close?

If the mouthpiece comes out of a rebreather diver's mouth, it has to be closed. Normally the rebreather diver will take care of this, its part of their procedures. But if you have to rescue them, closing the mouthpiece becomes part of the rescue procedure.
Leaving it open will result in the loop flooding and a big loss of buoyancy. Whilst they should have a big enough wing to cope with this, keeping the buoyancy inside the rebreather loop is always preferable.
The technical term for the entire assembly is DSV, for "Dive-Surface Valve". To be accurate, the mouthpiece is just the bit the diver chews on.
Most DSVs are a barrel design, where the inner barrel rotates inside the outer barrel to bring and inner hole in line with an outer hole that the mouthpiece is connected to. To close it, the inner barrel is rotated through 90 degrees so that the holes no longer line up and are sealed from each other.
It could be done with a lever that sticks out the front, or by rotating a ring at the end of the barrel. In either case, you may need to use both hands to close the DSV. If needed, you can hang on to them by the crinkly hose. Part of the CE test for rebreathers is that the crinkly hoses are strong enough to hang on to it by.

27.5 Where is the AAS?

As a diver who is buddied up with someone wearing a rebreather, a concern more to do with your personal safety is "Where is the alternate air source?"
You may be surprised to learn that while rebreathers all look complete straight from the manufacturer, many come with a minimal bailout that is configured more for the benefit of the rebreather diver than for their buddy. As a rebreather diver, I am all in favour of bailout that is configured for me, but it shouldn't be at the expense of not being able to assist my buddy should it be required.
The one thing that you can't do with a rebreather diver is to grab the mouthpiece they are breathing from. That would flood the loop and endanger both of you.
As a consequence, nearly all rebreather divers will have a conventional second stage regulator connected up and placed ready for their own or their buddy's use. But it is very unlikely to be standard. There aren't any.
It could be connected to the diluent cylinder's first stage, it may be connected to a dedicated first stage sharing an H valve with the diluent, or it could be connected to a separate pony cylinder or side mount cylinder dedicated to bailout.
There may also be a second stage connected to the oxygen cylinder's first stage, something you definitely do not want to mistakenly grab at depth.
You need to know where the AAS is that you can use, how to get to it, what gas it is connected to and how much gas is available.

27.6 We're on Different Gasses

Whatever gas mixes you are breathing, from air to nitrox to trimix, if you are on open circuit and your buddy is on a rebreather, you will be breathing different gas mixes, except for a few points in the dive where they coincide. Different gas mixes mean a different decompression schedule, most likely that the rebreather diver will have considerably less decompression than you do.
So what happens when you run out of no-stop time? What happens during the ascent? Will the rebreather diver shorten their dive to stay with you? Will they make longer decompression stops than they need to stay with you?
There is no right and wrong answer. But if you are going to be ascending separately, you need to be prepared for it as you would for any solo dive, and the boat skipper needs to be prepared to look out for 2 separate divers.

27.7 This Buddy Check's Getting Complicated

Lets look at a couple of the common mnemonics for buddy checks. BAR for Buoyancy, Air and Releases. BWRAF for Buoyancy, Weights, Releases, Air and Final Check. The only bit that differs with a rebreather is Air. The rest means the same as it always did. Once the mouthpiece is in, a rebreather diver will be reluctant to interrupt pre-breathing to take it out and talk. So any talking about kit needs to be done before the pre-breathing starts. After that, most of a buddy check can be done by gestures and showing gauges. What you don't want at this stage of preparing for a dive is a lecture on how rebreathers work. So what is the minimum you need to know under the Air part of a buddy check?
I suggest just keeping it simple and looking at the cylinder pressure for whatever cylinder the AAS is connected to. That's the only part of their "Air" you could ever get to use.

27.8 Pause and Check for Bubbles

As a rebreather diver descends the shot line, part of the descent procedure is to pause a few metres down and check for bubbles. This isn't a procedure unique to rebreather divers, some open circuit divers also like to do a bubble check before they get too far down the line. If you are buddies with a rebreather diver, they may do this as a self-check, or they may ask you to help with the check.
The trick is to know which bubbles are supposed to be there and which are not. At the start of a dive, there will be little bubbles of air trapped under all sorts of bits of equipment that slowly work their way out and bubble up as a diver moves in the water. Is that just air trapped under the rebreather shell escaping, or is it a genuine leak? Or maybe it's a semi-closed rebreather and is supposed to trickle bubbles out through the exhaust valve.
Even with no knowledge of rebreathers, there are some parts that we can all agree should not emit bubbles. The crinkly hoses and mouthpiece, the DIN threads on the first stages, and any of the HP or IP hoses.

27.9 What is a Rebreather?

Under normal conditions a diver will metabolise between 0.7 litres and 1 litre of oxygen per minute.

Suppose we are breathing air open-circuit at a Respiratory Minute Volume (RMV) of 20 litres per minute. At the surface this air will contain approximately 4 litres of oxygen and 16 litres of nitrogen. Out of all this gas, we metabolise just 1 litre of the oxygen, and the remaining 19 litres are breathed out unused and effectively wasted. At 30 metres down we breathe 80 litres of air per minute, with 79 litres being wasted. At 50 metres we breathe 120 litres per minute with 119 litres being wasted.

That's an awful lot of gas that we carry just to bubble it away.

The principle of a rebreather is to keep the gas a diver breaths out, remove the carbon dioxide, add a little bit of oxygen, and feed it round again in a closed circuit, hence the term Closed Circuit Rebreather or CCR.

The part of a rebreather that does this is the breathing loop. Exhaled gas is stored in bags called counter-lungs. The exhale counter-lung and inhale counter-lung are connected by the scrubber canister. The scrubber canister contains chemical pellets that remove carbon dioxide. The counter lungs are connected to the mouthpiece by wide-bore crinkly hoses, much wider than normal LP hoses or a BC crinkly hose so that breathing resistance is minimised.

Somewhere in all this will be oxygen sensors to monitor the ppO2, a means of injecting oxygen to make up for what is breathed and a means of injecting air (often referred to as diluent) to fill the loop as the diver descends.

With all this capability, there is no reason to just breathe air. With an air diluent, a CCR can mix nitrox as it goes, giving the diver the ideal nitrox for the current depth. With a heli-air diluent (part fill a pony with helium and top up with air), a CCR can mix trimix as it goes.

A semi-closed rebreather (SCR) is a less perfect, but much simpler solution. Suppose we are breathing nitrox 40 open circuit. Over a single minute there will be 8 litres of oxygen and 12 litres of nitrogen. We metabolise 1 litre of oxygen to leave 7 litres of oxygen and 12 litres of nitrogen, which is nitrox 37. If we save this in a breathing loop and breathe it again, there will be 6 litres of oxygen and 12 litres of nitrogen, or nitrox 33. We could continue re-circulating this weakening nitrox mix until the oxygen dropped below 21%, but that would give us such a rich mix with nitrogen that it wouldn't give any decompression advantage.

So in an SCR, just part of the exhaled gas is leaked out into the water and replaced with fresh nitrox on each breath, so that some of the weaker nitrox that has been breathed is constantly replaced by fresh nitrox. There are many ways of achieving this with a completely mechanical systems and no electronics, ranging from precision gas-flow jets to variously sized bellows linked by levers.

An equilibrium is reached where the diver ends up breathing a nitrox mix a bit below that in the supply cylinder. For example, by leaking out and replacing 10 litres per minute, our nitrox 40 example reaches an equilibrium at about nitrox 33 in the breathing loop. At the surface, 10 litres is half of what an open circuit diver would breathe. But this 10 litres can be independent of depth, because a diver's metabolism is independent of depth, so at 30 metres this SCR would use just 12.5% of the gas an open circuit diver would use.

28 Unit Information

This manual applies only to the SUBMATIX CCR 100 ST with the serial number:	
1st stage Oxygen with serial number:	
1st stage Diluent with serial number:	
Scrubber canister with serial number:	
Bailout octopus with serial number:	
Oxygen Cylinder 1	
Diluent Cylinder 2	
If the serial number has not been filled in by Submatix, these instructions for use are provided for general information and are not intended for use with any specific unit or device. After repair or change of registered components, it is necessary to replace the corresponding numbers.	

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