

# HAZARD AND OPERABILITY STUDY (HAZOP) REPORT

## CONCLUSIONS AND ACTIONS

<b>Subject:</b>	<b>O-rings</b>
Project:	O.R. Rebreathers, including provision of diver rebreather (RB) and monitoring system NR0006357.
Site:	St.Petersburg Design Centre
Date:	19 January 2007, 3d part, with review updates in Sweden July 2009 and FS compliance review 16 Aug 2010.
Time:	10:00 -18:00
Participants and Contributors:	<u>YB</u> , JH, JAH, JNO, SO, KS, AD, MY, AB, AK, SM, VD, PK, VK, BS, OL, JS, JB, KS
Study leader:	VK, Review leader AD.

### General summary:

Terms of reference and scope of the study are rebreather O-rings used in the project document Green Book GreenB\_ORTONOR\_070105.pdf and Agenda of HAZOP Study of 19.01.2007.

Each of the following O-ring positions was reviewed:

1. Hoses, Breathing. Dual EPDM 70 Dur O Rings, Ambient to Surface to Ambient pressure
2. Hoses, Electrical, Dual EPDM 70 Dur O Rings, Ambient to Surface pressure
3. Hoses, Gas Intermediate Pressure, Dual EPDM 70 Dur, Ambient to Surface to Ambient + 10 bar
4. Scrubber canister seal, Single thick, Silicone 70 Dur, Ambient to Ambient
5. Scrubber cartridge seal, Large lip seal 50 Dur, Ambient to Surface to Ambient
6. Pressure sensors (Gas contents), single EPDM 70 Dur, Ambient to High Pressure
7. Thermal expansion oil piston seals, single EPDM 70 Dur, Ambient to Ambient
8. Gas injector, dual EPDM 70 Dur, Ambient to Surface pressure
9. Counter Lung retaining ring, single + seal EPDM rings, Ambient to Ambient.
10. HP Valves, Single, Viton 90 Dur, HP Gas to Ambient
11. HP Regulators, Single, Viton 90 Dur, HP Gas to Ambient
12. HP Regulators, Single, Viton 70 Dur, LP Gas to Ambient
13. Hoses, Medium Pressure, Dual EPDM 70 Dur, LP Gas to Ambient.
14. Hoses, standard fittings, Single EPDM 70 Dur, LP Gas to Ambient.
15. Scrubber canister window, Single EPDM 70 Dur, Static Ambient to Ambient
16. Mushroom valve webs, Single EPDM 70 Dur, Static Ambient to Ambient.
17. ALVBOV 3D Lip Seals, Silicone 50 Dur, Ambient to Ambient.

The reliability of O rings and lip seals were reviewed with comparison to hydraulic pistons in dirty environments such as on excavators.

The following seal principles were applied in all O.R. rebreather models:

1. Where there is a moving surface that is potentially rough, then lip seals provide the most reliable seal. These seals are from silicone to prevent them forming a set (deforming under pressure, and holding the deformation when pressure is released). These seals are the most appropriate for the ALVBOV moving surfaces and the EAC cartridge seal, so are used.
2. The discussion on the scrubber canister seal concurred with the design decision that one thick O-ring was safer than two thin O Rings in this application.
3. O-rings should be as thick as possible. One thick O-ring is preferred over two thin O-rings, where it is not possible to fit two large cross section O-rings.
4. Dynamic O-rings or O-rings on assemblies that are fitted and dismantled by the diver or technical frequently should be dual O-rings where possible: one O-ring acts as the wiper and the other the seal, but if the seal should fail then there is a second barrier to prevent leaks. This applies to all hose ports that may be connected or disconnected by the diver, other than where a specific seal is mandated by a standard, such as the HP port of a regulator for a pressure gauge.

The above guidelines appear to have been applied uniformly. Specific O-rings were selected for detailed scrutiny. The durometer of O-rings is correct in each application.

The EPDM O-Rings are all black EPDM, which has good chemical resistance, good UV and ozone resistance, and is strong mechanically with good wear properties. A detailed MSDS for Black EPDM was considered.

Butyl O-rings were considered unsuitable, and are not used.

Viton is disliked by multiple reviewers because it breaks down under ozone (which is formed in welding environments), it is weak, and Viton O-rings fail more frequently than EPDM O-rings. Viton is used only for seals that may come into contact with high pressure oxygen.

It was noted that the dual Ambient to Ambient seals may provide Ambient to Surface and Surface to Ambient, on the Umbilical models so the sealing pressure needs to be high as well as reliable. This is achieved by the relevant seals.

The keywords combinations:

Primarily keywords:

Pressure; Temperature; Corrode;  
Absence.

Secondary keywords:

No; Under; Over; Reverse;  
Other.

During the HAZOP study sessions all the combinations of primarily and secondary keywords were considered. Action worksheets have been filled out (attached).

Recommended Actions:

1. Include in a checks when fitting a scrubber cartridge a visual check of scrubber O-rings. Damage to the end of the scrubber cartridge could act as a cutting tool on the O-ring. **Follow Up Action Taken:** Added risk to FEMCA Vol 4 for O-ring and scrubber canister.
2. Include in the mushroom valve check a visual check of the port O rings.
3. Replicate the pre-dive check results to the supervisor.
4. It is very important that only approved O2 compatible grease is used to prevent releasing potentially anesthetic or toxic chemicals into the breathing loop.
5. **Follow Up Action Taken:** The effect of omission of the scrubber O-ring was tested and it was found that the rebreathers pass neither a positive or a negative pressure test with that O-ring omitted, so if pre-dive procedures are followed, this fault should not lead to any adverse effect on the diver. Water ingress is very slow and a complete test dive was performed with that O-ring missing: there was an obvious leak, but it was slow enough to allow the water to be dumped periodically. The scrubber lip seal was omitted and the rebreather tested for CO2: the rise in CO2 is very small – at the beginning of the dive it was 0.25 % SEV and by the end of the dive there was no increase measured (the EAC is a close fit with the scrubber barrel, and swells into the barrel during the dive).
6. It is very important that the rebreather does positive and negative pre-dive checks to identify any sources of leakage from O-ring failure.
7. Include in operational procedure a requirement to check physical presence of the O-rings when disassembled. This is implemented in the form of pre-shipment checklists, and pre-dive checklists.
8. Underlines a strong necessity of proper training for all personal working with the RB.

Enclosure: HAZOP Action worksheets – 2 pages.