HAZARD AND OPERABILITY STUDY (HAZOP) REPORT

Subject: Rebreather on/off algorithm.

Site:	St.Petersburg, Russia Design Centre
Date:	HAZOP 17 January 2007, 2d part, with further review Sweden July 2009, St Petersburg April 2010 with scope covering all O.R. Rebreathers
Time:	10:00 -19:00
Project:	Provision of diver rebreather (RB) and monitoring system NR0006357.
Participants and Contributors:	YB , JH, JAH, JNO, SO, KS, AD, MY, AB, AK, SM, VD, PK, VK, BS, OL, JS, JB, KS
Study leader:	Vladimir Komarov with follow up reviews by AD.

General summary:
Terms of reference and scope of the study are SCR on/off algorithm according to the project document Green Book GreenB_ORTONOR_070105.pdf and Agenda of HAZOP Study of 17.01.2007.
There is a special algorithm of Rebreather ON/OFF described in above documents with definitions of ON and OFF status:

- Definition: OFF means the unit is not providing breathing gas but in fact the electronics is always on if there is either battery power or umbilical power and if it detects a PPO2 of less than 0.3, will turn on to inject gas to raise the PPO2 in the loop.
- Definition: ON means the unit is fully functional.
- The Rebreathers are OFF when powered up.
- Rebreather switches ON using the following Boolean expression:
  IF (0.7 <= absolute_ambient _pressure_bar <= 1.086) AND
  (PPO2 < max(0.16, 0.20 * absolute_ambient_pressure_bar)) THEN TRUE
  ELSE IF (PPO2 < 0.4 atm) OR
  (PPO2 drops by 0.1 in 10 minutes) OR
  (PPO2 >= 0.7 atm) OR
  (Umbilical Power is on) OR
  (USB Power is ON)
  THEN TRUE
  ELSE FALSE.

  Removing all oxygen cells and external power (Umbilical or USB) causes the rebreather to be OFF.
- The unit switches OFF if the PPO2 has not fallen for 15 minutes AND the gas injector is fully closed AND none of the ON conditions are TRUE.
- When the unit is switched OFF, the voice annunciation in the mouthpiece will announce this and the HUD lights will then go off.
- When the unit is switched ON, the unit will perform its pre-dive checks, the voice annunciation will declare “Ready” and the HUD lights will go on. From the moment of the “Ready” announcement, the unit will be ready for diving, but the diver should also carry out pre-dive positive and negative pressure checks (the unit does all the others automatically).
- The unit can be switched on by USB diagnostics, or in diagnostics mode from the Top Side Unit for the Umbilical model. It cannot be switched off by the Top Side Unit or the USB port.

The meeting agreed that PPO2 falling below safety level is a Critical Failure and should be carefully dealt with.

The keywords combinations:

Primarily keywords:	Secondary keywords:

Pressure; Corrode; PPO2 level;	No; Under; Over; Reverse;
Shutdown; Start-up; Humidity; Wet.	Other.

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

Observations and Recommendations:

1. Meeting considers battery low/flat as a critical characteristic for monitoring of PPO2 level. Reliable management of battery low/flat is believed to have been implemented. **Follow Up Action:** a separate DV report on the battery charging system was produced.
2. Operational procedure has to check and eliminate battery flat in pre-dive check. No power – no dive. It's recommended to use colour lights to indicate battery status.
3. PPO2 alarm level of 0.4 atm should be suppressed when the rebreather is on the surface, to PPO2 0.20 at 1 atm, to avoid the unit running the battery flat or annoying the diver with spurious alarms which could result in behaviour that leads to a diver ignorning a genuine alarm. The alarm level should be adjusted with ambient pressure across normal atmospheric limits, but should never be allowed to fall below 0.16 atm (in mountain diving).
4. The operational limits for O2 sensors should be changed from not permitting the unit to enter normal dive mode after pre-dive checks with more than one sensor down per side, to allowing up to two of the four sensors down per side. This still leaves 4 good sensors in the Umbilical rebreather, and the sensor elimination algorithm should detect the faulty sensors. For rebreather models where there are three or four sensors, at least three sensors must be good to start a dive.
5. JAH noted that in the ON/OFF algorithm two separate safety systems have to work together: one controlled by diver himself and second is monitoring by supervisor. The software was modified accordingly.
6. Meeting considers software security as a critical point and underlines necessity to prevent unauthorized intervention. Sergei Malyutin describes security system and several level of authorization of software. **Follow Up Action:** Pavel Pyankov described security arrangements in writing.
7. **Follow Up Action:** ask Vladimir Vikulin, hardware engineer, to add a special field for rebreather serial number to be written into database rather than rely on data coming from the specified rebreather.
8. Meeting noted and agreed with operational instruction that the sensors be from two different batches. The diver has to be trained to change sensors during maintenance.
9. The meeting noted that the sensor circuit includes a DAC to ensure that only the correct type of sensors are fitted by measurement of resistance, capacitance, charge transfer and voltage.
10. The calibration process uses pure air, and can then be checked using any other gas. The meeting agreed that air was the correct calibration gas as it is known. On a ship it may be necessary to have a source of compressed air, as room air may have a lower PPO2.
11. A requirement was added to the operational procedures to avoid storing the rebreather in water or wet.
12. **Follow Up Action:** The use of wet contacts was revisited: they were identified by the meeting as are as a source of problems, particularly when the harness is wet.

Enclosure: HAZOP Action worksheets – 2 pages.

HAZOP Study leader: V. Komarov