

HAZARD AND OPERABILITY STUDY (HAZOP) REPORT

Subject: Rebreather hoses including attachment and counter lungs.

Site: St.Petersburg, Russia Design Centre
Date: 17 January 2007, 1st part.
Time: 10:00 -19:00
Project: Provision of diver rebreather (RB) and monitoring system NR0006357.
Participants: Statoil team: Yngve Bergflodt
Technip team: Jim Holborn , Jon Are Hvalbye , John Nortcliffe, Stein Olberg,
NUI team: Kare Segadal
Deep Life team: Alex Deas, Marat Evtuhov, Alexey Bogachev, Alexander Kudyashov, Sergei Maluytin, Vladimir Davidov, Pavel Kamochkin.
Study leader: Vladimir Komarov .

General review:

Terms of reference and scope of the study are SCR hoses including attachment and counter lungs according to the project document Green Book GreenB_ORTONOR_070105.pdf and Agenda of HAZOP Study of 17.01.2007, and FMECA Volumes 1 to 4 inclusive.

The hoses comprised of gas hoses to/from counter lungs to/from mouthpiece. The cable tie caps are also part of the scope and being under consideration.

The cable ties were changed from twin cable ties to stainless steel jubilee clip as a consequence of the previous design and safety review. The meeting asked to see how the jubilee clip fails, to see whether the clip failed in a safe manner. For this purpose, a clip was tightened on a port. The grub screw failed without any failure of the overall function. The hose was then pulled until failure occurred. The port was then disassembled and it could be seen that the clamp had not torn the hose: pictures below – the failure point was the small cuts the forming tool makes on each ring, extending around the ring.

The meeting noted that the requirement for EN14143:2003 was for 25kg pull resistance, and the present design achieved 50kg. The design target is 100kg: the meeting found that 100kg was beyond the plausible tension on the hose but 50kg was not, so 100kg should remain the design target.

The MSDS for the exact EPDM used for the hoses was circulated to the meeting. This was a detailed document which the meeting found satisfactory in depth, but identified Thiram as an off-gas product. Thiram is a formaldehyde with known long term health hazards: see

<http://ptcl.chem.ox.ac.uk/MSDS/TH/thiram.html>

Action: Contact manufacturer to find a solution that does not use Thiram.

The meeting compared the kinking characteristics with hoses from other rebreathers. The samples of the design put forward to the meeting were the only ones that did not kink with a 180 change in direction. The meeting agreed that kinking was a safety hazard, as it greatly increases the work of breathing.

The findings in the FMECA Vol 4 regarding the EN14143:2003 10% and 30% extension limits creating a safety hazard, were accepted.

Action: Kare Segadal undertook to raise this with the international EN14143 committee, of which he is a member, to seek to have the standard changed. Alex Deas undertook to provide the supporting data.



Fig 1:: Hose with jubilee clip, after tensioning the clip until the grub screw failed, then tensioning the hose until the hose failed. Hose failure point is at the same point observed in the tests reported in the FMECA Vol 4



Fig 2:: Hose under tension showing cracks caused by forming tool during manufacture, from which failures extend around the hose.

The counterlung material is PU, with no plasticiser, Bayer Chemical #PU 65D. A MSDS is available. The counterlung reinforcing rings are Polyurethane Vibrathane 5008. A MSDS is available.

The hard plastic parts are Akema Kynar 700 which is tough, UV resistant and chemically inert in:

- Acids (including hot)
- Halogens (Chlorine, bromine, iodine, fluorine)

- Chlorinated & brominated chemicals
- Oxidants (peroxides, ozone,)
- Alcohols and aliphatic hydrocarbons
- Mid bases (pH under 12)
- Crude oil

The HAZOP keywords combinations:

Primarily keywords:

Tear; Flow; Pressure; Temperature;
Contamination; Offgas; Puncture;
Absence (of component); Misassembly.

Secondary keywords:

No; Under; Over; Reverse;
Other; Flooding.

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. Consider improved material for the hoses to reduce the effect of tearing, punctures or cuts.
2. Maintenance procedure for hoses has to include thorough check for puncture or cut before use. This is presently in the pre-dive positive and negative pressure checks, which are satisfactory.
3. The hose demonstrated to the meeting met the non-kinking requirement.
4. The monitoring system should detect cuts or punctures using the pre-dive check sequence, with positive and negative pressure checks.
5. The present design uses spiral hoses to limit possible water traps and contamination. Use of spiral hose was accepted by the meeting as mitigating these hazards.
6. The hoses have 400% stretch, enabling the RB to use as short hoses as possible.
7. The covers for the hoses should be oversized to allow the stretched hose to be protected. The meeting noted that the present design does this.
8. Close attention was paid to the mushroom design, including molding and choosing of right supplier.
9. The meeting reviewed the recommended cleaning solutions for hoses to avoid any contamination and accepted these from the documentation provided.
10. The training manual should follow a strict cleaning procedure for hoses.
11. The transparent colour coded silicone covers for joints and caps was considered a good design feature.
12. The training manual should contain a section setting down the operational procedure when lowering the rebreather to the seabed in a basket, or raising it, to avoid under or over-pressure.
13. A Design Verification report is required to confirm the working pressure of the under pressure valve and that this operates in both gas and water environments.
14. Include in operational procedures a check for all three OVP/UPV/ADV before the dive.
15. Include in operational procedure a requirement for acclimatization of RB before use if stored in a very hot or cold location: the electronics does this temperature check automatically as an additional monitor.
16. Action noted to resolve the negative health implications of Thiram, a softener used in the EPDM hose, which can off-gas.
17. Include in the operational procedure a requirement of limited access to the diving equipment.
18. Underline a strong necessity of proper training for all personal working with the RB.
19. The units presented to the meeting used different colours for inhale and exhale parts of the loop, for hose covers, mushroom spiders and mushroom valves. This was considered a good feature.
20. The design of the rebreather was considered and the meeting heard that each part was unique and could not be misassembled, for example, mushrooms the wrong way around.
21. During the review of these minutes, the Technip group raised a question of whether it might be possible for the 400% stretch hoses to extend fully on over pressure thus adding to the overall loop volume - is this a significant factor?
This situation was considered carefully by the Deep Life team and the conclusion is as follows:

- a. Increases in loop volume are potentially hazardous, as it may allow the PPO₂ to fall due to a fall in internal pressure. The hoses stretch 150mm on each side, with 36mm bore. This is a total of 0.3litres. The dead volume of the rebreather is 6 litres, so if the counterlungs are empty and the diver's lungs are empty, then the reduction in PPO₂ is 5%. This means if the PPO₂ is borderline at 0.209, then it can fall to 0.199. This does not represent any health hazard.
- b. The amount of hose stretch is constant between the different hoses. That is, the diver needs to move his head by 150mm, so there is 150mm of hose that needs to be expanded. When the hose is long with a 30% stretch with a 10N (1kg) load, then it provides 150mm of extra volume. When the hose is short, with a 400% stretch to provide 150mm of extra volume, the increase in loop volume is the same. Therefore there is no safety hazard from increasing the stretch in the hoses.

Enclosure: HAZOP Action worksheets – 3 pages.

HAZOP Study leader:

V. Komarov