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| ODH Safety Review of the Accelerator Buildings  16 September 2016 |
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| **Report of the review committee** |
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Meeting place: ESS Conference Room Stora Tuna - Lund, Sweden

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EXECUTIVE SUMMARY

In the frame of the ODH Safety Review of the ESS accelerator buildings, the committee was asked to evaluate the control measures foreseen against personnel’s exposure to Oxygen Deficiency Hazard (ODH) in the accelerator buildings. In particular, the committee was asked to focus on the results of the ODH safety studies as well as the strategy, architecture and layout of the ODH monitoring system. Finally, the committee was asked to provide a formal recommendation on whether the ODH monitoring system should proceed to procurement and installation phases.

The review committee acknowledges the extensive efforts made to deliver the documentation in a timely manner and the level of details presented during that review. Presentations, together with the documentation made available before the review, helped the committee members in their assessment work.

**ODH assessment’s results and control measures**

The methodology presented to assess ODH is globally satisfying and seems to be adequate and rather complete but a complementary evaluation of the evacuation time in the event of a helium/nitrogen release should be performed for each accelerator building in order to identify potential additional control measures.

The classification of the ODH areas has been defined based on the evaluation of the worst-case scenario for each accelerator building and seems appropriate. However the review committee recommends performing an ODH assessment for additional scenarios that could have a lower severity but a higher probability as it might have an impact of the final ODH classification. Additionally, overpressure caused by the sudden release of asphyxiant fluids should be estimated in areas with a significant gas/liquid inventory such as the Helium Compressor Building (HCB) and the ColdBox Building (CXB).

ESS should evaluate the needs to implement additional safety measures (e.g. mechanical barriers around pipes, limit switches on the crane, job hazard analyses) in buildings housing overhead cranes such as the HCB and the CXB in order to prevent any mechanical impact that could lead to a pipe rupture.

The control measures against ODH presented during that review seem to be appropriate and meets the ESS’ Safety objectives against ODH but the review committee recommends to re-evaluate the needs to carry personal oxygen monitors in each building potentially subject to oxygen depletion. Indeed, personal oxygen monitors might only be necessary in specific areas with major safety implications such as the Accelerator Tunnel, TS2 bunker and the Cryogenic Transfer Line Gallery (CTLG).

**Strategy, architecture and layout of the ODH monitoring system**

The review committee was impressed by the level of details presented regarding the conceptual design of the ODH monitoring system. The strategy and layout of the system is globally satisfactory and provides a good coverage of all accelerator buildings housing asphyxiant fluids.

In some areas where high equipment could obstruct wokers’ view such as the HCB and CXB, the review committee suggest to install additional and clearly visible flashing lights in the middle of those areas to improve reaction time in case of an emergency as well as signs at each entrance warning people not to enter the building if the evacuation alarm goes off.

In case of an ODH event, the cryogenic and main control room will be informed upon trigger of the ODH detection system but there is no formal ESS emergency procedure at the moment. Therefore ESS, in particular ES&H Division, needs to clarify as soon as possible the alert procedure of the rescue team in the event of an ODH. Additionally, efforts should be made to align the ODH and fire alarms and flashing lights, and to reduce the number of lights of the beam-off stations in order not to confuse the workers in case of an emergency situation, especially in the accelerator tunnel. In the same context, ESS should also consider implementing evacuation push buttons in the accelerator tunnel in order to manually trigger the evacuation in case of an ODH event.

For large buildings ESS should consider evacuating the entire building if an ODH event occurs in one of the sub-areas; i.e. if an ODH alarm goes off in the Accelerator Compressor Hall (ACH), then evacuation should be triggered in the Target Compressor Hall (TCH), High Pressure Gas Storage Area (HPGS), electrical sub-station area, HVAC room, etc. The need to have public address system in other areas than the accelerator tunnel should also be evaluated by ESS.

Considering the large volume available in the Gallery Technical Area (GTA), the committee is not concerned by ODH in that area and believes that oxygen monitors there are not necessary.

The review committee acknowledges the decision to have ODH monitors with multiport sampling in the accelerator tunnel but recommends also considering the implementation of ODH monitors with fast sampling (single port) and a longer distance between monitors as well as reducing the number of sirens/flashing lights which might have been overestimated.

Experience showed that sampling pipes could easily get obstructed. Thus special attention should be paid to the maintenance of the sampling pipes as they might be subject to dust. Therefore, regular maintenance of the filters and the pipes should be done to prevent clogging. Maintenance activities will have to be aligned with the planned machine-operation if any access to the accelerator tunnel is needed.

The committee encourages ESS to re-evaluate the needs for back-up generators (UPS) for oxygen monitors as well as flashing lights, sirens and beam-off stations in all accelerator buildings as one-hour back-up might not be sufficient from a safety perspective.

Finally, the committee recommends evaluating the necessity for keeping trends/records of the data from the oxygen monitors at ESS, as it might be useful for guiding people in emergency situations (control room, intervention, crisis management team, etc.) as well as post-mortem to understand causes of incident (e.g. location and duration of leaks).

RECOMMENDATIONS

The review committee recommends the following:

1. The risk assessment has been done with the aim to define control measures but the ultimate goal of reaching a level of acceptable residual risk should be defined in further detail, including what that level of acceptable risk actually is.
2. ESS are recommended to follow up the calculated oxygen levels in the buildings over time by also estimating:
3. The propagation speed (typically for tunnels);
4. The detection time;
5. The triggering time for the alarms;
6. The pre-movement time;
7. The evacuation time – including people working in remote places e.g. at height, etc. from where it should be possible to evaluate if people can evacuate safely at all times.
8. Priority should be given to the evaluation of the evacuation time in the event of a helium/nitrogen release that should be performed for each accelerator building.
9. Additional scenarios with a lower severity but a higher probability should be evaluated in each accelerator building as it might have an impact of the final ODH classification of those areas.
10. Overpressure caused by the sudden release of asphyxiating fluids should be evaluated in areas with a significant inventory such as the HCB and the CXB.
11. ESS should evaluate the needs to implement additional safety measures (e.g. mechanical barriers around pipes, limit switches on the crane, job hazard analyses) in buildings housing overhead cranes such as the HCB and the CXB in order to prevent any mechanical impact that could lead to a pipe rupture.
12. ESS should re-evaluate the needs to carry personal oxygen monitors in each building potentially subject to oxygen depletion.
13. ESS should re-calculate the leak duration for the HPGS in case of a helium release.
14. ESS should demonstrate that the technology selection for the fixed ODH monitors is fit-for-purpose. In particular, the sensitivity to dust collecting inside the 2 mm sampling pipes, and the ability of the protective filters to adequately deal with this, should be verified. The maintenance intervals of the equipment need to be compatible with machine operations.
15. ESS should evaluate the necessity of establishing a philosophy for the flashing lights including the aspect of not entering the hazardous area (e.g. visible from every position in the hazardous area, at every entrance, etc.).
16. ESS needs to clarify as soon as possible the alert procedure of the rescue team in the event of an ODH.
17. ESS should align the ODH and fire alarms and flashing lights, and consider reducing the number of lights of the beam-off stations.
18. ESS should evaluate the necessity of triggering flashing lights close to the release point (typically for tunnels), which would guide people to move away from the detection point during an evacuation.
19. ESS should develop a strategy for evacuation alarms if local legislation is lacking (sound pattern, sound levels, etc.).
20. ESS should also consider implementing evacuation push buttons (‘break glass’) in the accelerator tunnel in order to manually trigger the evacuation in case of an ODH event, fire, etc.
21. ESS should evaluate the necessity of a policy for evacuating adjacent areas and buildings if an ODH event occurs (e.g. case by case following a Risk Assessment, systematically or other). The ODH action matrix should also be updated accordingly.
22. ESS should evaluate the required detection time for the ODH monitors.
23. ESS should re-evaluate the needs for back-up generators (UPS) for oxygen monitors as well as flashing lights, sirens and beam-off stations in all accelerator buildings as one-hour back-up might not be sufficient from a safety perspective.
24. ESS should evaluate the necessity for keeping trends/records of the data from the oxygen monitors at ESS, as it might be useful for guiding people in emergency situations (control room, intervention, crisis management team, etc.) as well as post-mortem to understand causes of incident (e.g. location and duration of leaks).
25. ESS should evaluate the necessity of a confined space policy (classification, safety precautions, training requirements, emergency procedures, etc.).

Report prepared by the review committee, 18 September 2016.

Appendix 1

**Documentation relevant to the safety review**

1. GENERAL ABOUT THIS SAFETY REVIEW
   1. Purpose

The main objective of this ODH Safety Review is to evaluate the control measures taken against personnel’s exposure to Oxygen Deficiency Hazard (ODH). The committee will review the ODH assessments as well as the technical, organisational and administrative measure foreseen for the following areas based on the deliverables and presentations given during that review:

* Helium Compressor Building (HCB) including ACCP Hall (ACH), TMCP Hall (TCH) and HP Gas Storage (HPGS).
* CTL Gallery (CTLG).
* Coldbox Building (CXB).
* Gallery Technical Area (GTA) including the cryomodule Test Stand (TS2).
* Accelerator Tunnel (AT).

The members of the review committee can be found in Appendix 2.

* 1. Charge

Based on the deliverables listed in Appendix 1 and presentations given during the ODH Safety Review, the Review Committee is asked to:

1. Review the relevancy of the failure scenarios considered for the ODH study
2. Review the strategy and layout of the ODH monitoring system
3. Review the relevancy of the ODH calculation model chosen for the study
4. Advice on control measures to be put in place to guarantee the safety of the activity/equipment/installation
5. Provide a formal recommendation on whether the ODH monitoring system should proceed to procurement and installation phases
   1. Supporting information

The review committee has received the following information that can be found on <https://indico.esss.lu.se/event/625/>:

1. The ODH assessment report of the areas housing asphyxiant fluids.
2. The technical report including the ODH system architecture, type, number and location of ODH monitors and maintenance plan.
3. The action matrix describing the immediate actions taken by the ODH monitoring system in case of an ODH event.

All the presentations can be found in the Indico page: <https://indico.esss.lu.se/event/625/>.

Appendix 2

**Review Committee**

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| Name | Organisation | Appointment for Safety review |
| Duy Phan | ESS, Accelerator Safety Engineer | Chairman of the Review Committee |
| John Weisend II | ESS, ACCSYS Deputy Project Leader | Reviewer |
| Peter Jacobsson | ESS, ES&H Division Head | Reviewer |
| Henrik Carling | ESS, Integrated Control System Division Head | Reviewer |
| Simon Marsh | CERN, Mechanical Safety Engineer | Reviewer |
| Nicolas Broca | CERN, ODH Monitoring System Technician | Reviewer |
| Silvia Grau | CERN, Alarm Systems Section Leader | Reviewer |
| Gunnar Lindell | CERN, ODH safety specialist | Reviewer |
| Jaroslaw Fydrych | ESS, Cryogenic Distribution Project Engineer | Reviewer |
| Annika Nordt | ESS, Protection Systems Group Leader | Reviewer |
| Philipp Arnold | ESS, Cryogenics Section Head | Reviewer |
| Wolfgang Hees | ESS, Test Stand Engineer | Reviewer |
| Christine Darve | ESS, WP4/WP5 Deputy Leader (Spoke & Elliptical Cryomodules) | Reviewer |
| Linda Coney | ESS, Target Control Group Leader | Reviewer |
| Stuart Birch | ESS, ICS Personnel Safety Systems | Presenter |
| Yong Kian Sin | ESS, ICS Electrical Controls Engineer | Presenter |