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ESS ACCELERATOR OXYGEN DEPLETION HAZARD DETECTION SYSTEM

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Abstract

At the European Spallation Source ERIC (ESS), cryogenic cooling is essential for various equipment of the facility. The ESS Superconducting LINAC and the ESS Cryomodule Test Stand, will require major cryogenic services in order to be supplied with liquid nitrogen and helium [1]. Since the use of cryogenic fluids can be associated with Oxygen Depletion Hazard (ODH), the ESS Protection and Safety Systems group will install an ODH Detection System which is a PLC-based alarm system. This system will monitor real time Oxygen concentration levels in designated areas, with the aim to alarm personnel if the oxygen level is detected below certain thresholds. This paper gives an overview about the requirements, system architecture, hardware and software of the ODH Detection System in ESS Accelerator buildings [2].

INTRODUCTION AND REQUIREMENTS

In general, no use of asphyxiant cryogenic fluids or compressed gases is permitted at ESS without a formal evaluation of the ODH Class which shall be conducted through a specific ODH process for all activities which are physically capable of exposing individuals to an oxygen depletion. Therefore, ESS has the mandate to perform ODH assessment for any building where ODH could be present, in order to determine the necessity to install ODH Detection System and additional mitigation actions based on the results from the safety study [3].

The ODH assessment process can be divided into three main steps as shown in Figure 1. It should be noted that the process is built around quantitative assessment followed by independent expert(s) review that will provide the final clearance of the activity/area/equipment before operation [4].

Following the ODH assessment, the areas will be classified as require ODH Detection System or not. To start with development of ODH Detection System, a hazard register will be created where hazards, their initiating events, likelihoods, mitigation, human actions, etc. will be recorded. This will be followed by a Fault Tree (FTA) and Event Tree Analysis (ETA) to understand the ODH Detection Systems points of failure and also explore the consequences of failure of this system [5].

In ESS Accelerator buildings, through an ODH assessment five areas have been identified where ODH Detection System is required, the Helium Compressor Building (HCB), the Cryogenic Transfer Line Gallery (CTLG), the Cold Box Hall (CXH), the Cryomodule Test Stand and the Accelerator tunnel.

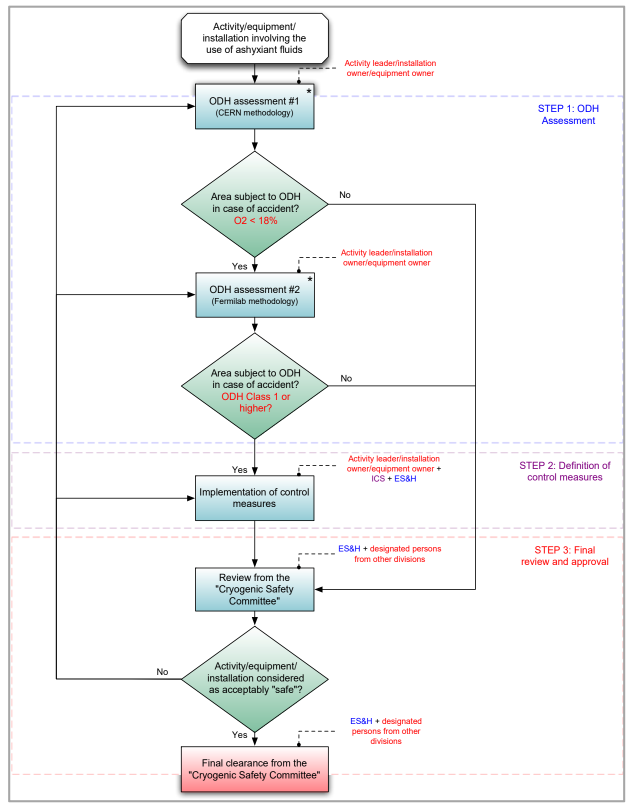

Figure 1: Flowchart of the ESS ODH assessment.

The following are the sources of ODH in the areas already mentioned:

- Warm Helium in the HCB, the CTLG and the CXH.
- Nitrogen in HCB.
- Nitrogen in the CXH.
- Liquid helium in the CXH, CTLG and Accelerator tunnel.

If the Oxygen concentration drops between 19.5% and 18%, the ODH detection system will send a warning signal to the Main Control Room and the Cryogenic Control Room where operators will be notified. The ODH evacuation alarm (red beacon lights + siren sounders) will be activated upon detection of low level of oxygen (≤18%) from at least one of the ODH monitors. The alarms will remain active as long as the digital signal from the ODH monitor is active.

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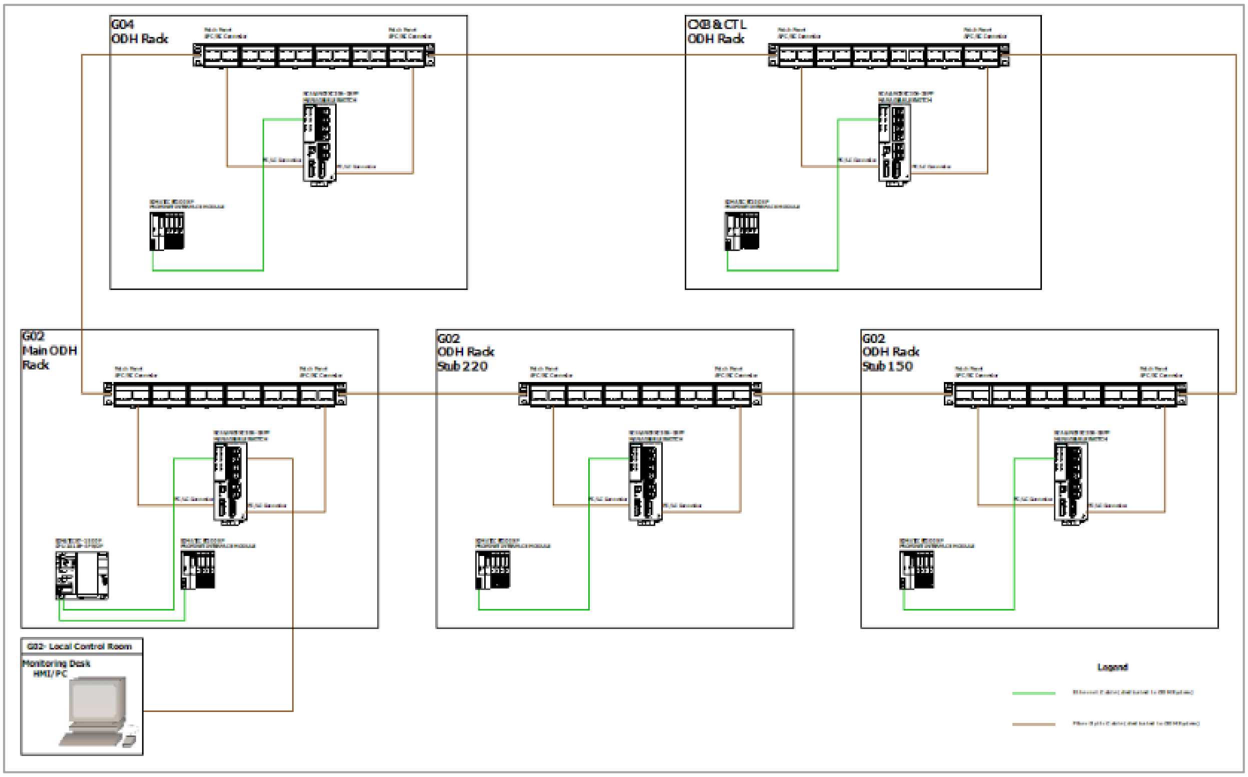

Figure 2: Accelerator ODH Detection System Physical Topology.

ARCHITECTURE

The Accelerator ODH Detection System consists of a single-train system using Siemens S7 1500 series safety PLC's (Figure 3). At ESS, the ODH Detection Systems will be completely independent from Personnel Safety Systems.


Figure 3: Siemens S7-1500 series PLC.

The system will use fibre connections from the main PLC rack to the distributed I/O (ET200SP) by means of a ring topology over PROFINET protocol. Figure 2 shows the physical topology of the Accelerator ODH Detection System.

All signal paths are hardwired from equipment (sensors and actuators) to the peripheral modules, which are: analog input (AI), digital input (DI) and digital output (DQ).

CONTROLLED DEVICES

The following components have been used to develop Accelerator ODH Detection System:

ODH Monitors

The O2iM monitors manufactured by Oxigraf were chosen as they had already been installed and operated successfully in similar facilities. The ODH monitors measure and display the oxygen concentration in a gas sample drawn through the instrument. Gas is pumped sequentially from up to four input sample ports, through the oxygen sample cell, and out the exhaust port. An internal filter in the input line prevents contamination of the sensor. Figures 4 and 5 show an ODH monitor, its installation and peripherals in one of ESS Accelerator buildings.

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Figure 4: O2iM 4-port mounted in a pillar at the HCB.

The O2iM has a Laser diode absorption spectroscopy system, which assures stable, long-life oxygen measurement: The laser diode technology is rated for more than 100,000 hours mean time to failure. The laser diode is thermally and electronically tuned to measure the absorption of oxygen at 763 nm, and also periodically measures the background to provide an automated zero (self-calibration).

Oxigraf O2iM single port and multiport are used in the implementation of the ODH Detection System. Single port will provide a faster sampling of oxygen while the multiport will provide a wider area-coverage. Both O2iM models are fitted with a warning horn and strobe.

Figure 5: Detail of a filter for the micro-pipe input line.

Alarm Devices

The alarm devices are comprised of red beacon lights and siren sounders. These devices are used to alert the personnel in the hazardous areas in order to facilitate their safe and fast evacuation in case of oxygen depletion. Flashing lights are installed in the lateral walls of the rooms while rotating lights are installed in the central areas of the rooms in order to reach a good visibility from every point.

Figure 6: Werma Halogen Rotating light.

The flashing lights are assembled with the siren sounders into an alarm plate. According to the noise maps of the equipment installed in the buildings, the maximum sound power level at 1 meter distance (without insulation) from these equipment is 108 dB. Therefore, the sound output of the selected sounders is 115 dB. The selected lights and sounders are suitable for both indoor and outdoor installation (IP65). Figure 6 and 7 show samples of alarm units installed for the Accelerator ODH Detection System.

Figure 7: Alarm plate installed in the facade of the HCB.

SOFTWARE

The ODH Detection System software will be developed using Siemens TIA Portal SIMATIC S7. The software is following the activation matrix which summarize the requirements of ODH, as shown in Figure 8.

Once the percentage of Oxygen is ≤19.5% or ≤18%, the PLC will process according to the activation matrix to activate the necessary signals and/or alarms.

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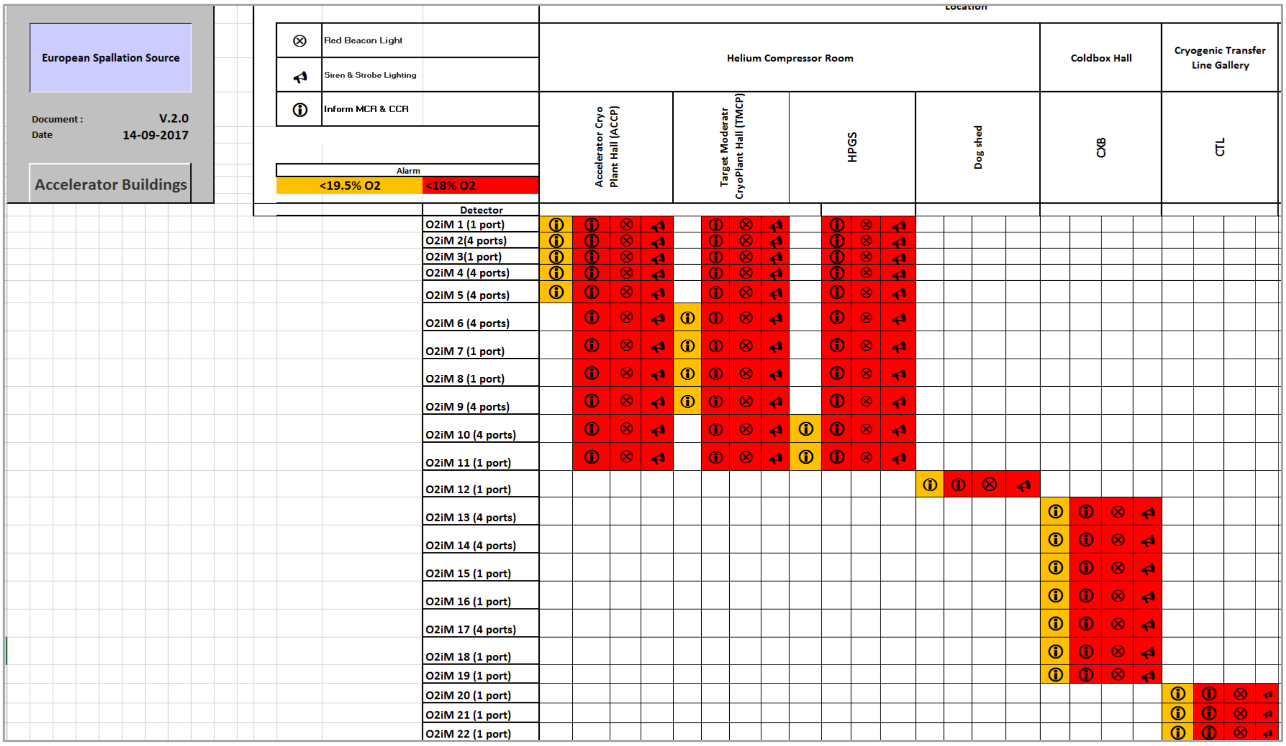

Figure 8: Activation matrix.

Two modes of operation can be configured in the ODH monitors; normal mode and channel relay mode. For ESS applications, normal mode is chosen to show more detailed information in each relay. The individual relay is connected to the Digital Input of the PLC and the PLC software will determine the action needed upon activation / deactivation of the relays, (see Table1).

Table 1: Operation Modes from O2iM

Relay	**Normal Mode**	**Channel Rel. Mode**
Horn/Strobe	On when limit and warning conditions specified by the Horn/Strobe setup are true	
System OK	On when self-test is good and absorption line lock achieved	On when a channel 1 alarm state is active
Warning	On when warning status is active for low supply voltage, low sample flow, high pump drive, high or low cell pressure, or absorption over range	On when channel 2 alarm state is active
Limit A / B	On when O2 is greater than High Threshold A / B or lower than Low Threshold A / B. Disabled when both limit value set to zero.	On when channel 3 / 4 alarm state is active

CONCLUSION

The Accelerator ODH Detection System installation is being carried out in two phases. Phase one is nearly finished and comprises of HCB, CTLG and CXH buildings. The second phase comprises of the Cryomodule Test Stand and the Accelerator tunnel. In addition, Target and Neutron Instrument(s) ODH Detection Systems will be developed in future.

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