MICE HYDROGEN SYSTEM

HYDROGEN SYSTEM SAFETY INSTRUMENTED FUNCTIONS

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1. Introduction

The Safety Integrity Level Assignment performed by FSC[1] on the MICE Hydrogen Delivery System identified two hazards requiring Safety Instrumented Functions (SIFs) to reduce the risk to an acceptable level (see RD1). These are outlined in Table 2.

No.	Title	Document Reference
1	Safety Integrity Level Assignment	X589 TR 001 (2.0)
2	Cryostat Heater Interlock Settings (Issue 1)	MICEH2-TN-110501
3	Heater PSU Interlock Diagram	204/77506 Sheet 6

Table 1: Reference Documents

Hazard ID	Node	Node Description	Event (Hazard) Description	Consequences	SRS Requirement (PFD)	SRS required SIL
17-18	4	Buffer Tank	Over pressure of buffer tank	Increase pressure leading to a release of hydrogen and ignition leading to multiple deaths	1.00E-01	SIL1
27-29	7	Test Cryostat and Mass Spectrometer Port to Vent and Exhaust Vent	Build up of impurities over a period of time, pressurisation and heating of hydrogen leading to a rupture	Explosion leading to multiple deaths	6.73E-03	SIL2

Table 2: SIL Targeting Summary

This note (and accompanying documents) outlines how these hazards are addressed in terms of additional SIFs in the Hydrogen System Controls.

[1] Functional Safety Consultancy Ltd

2. Addressing the Risks

2.1. Buffer Tank Over-Pressure

This hazard would results from liquid hydrogen boil-off caused by failure of the cryo-cooler and an associated failure of the mechanical relief systems.

In this case, it is proposed to mitigate the risk by recognising an additional layer of protection in the form of a Hydrogen Detection System (HDS) installed in the MICE Hall. This will provide both visible and audible warnings on detection of hydrogen at a fraction (50% TBC) of the lower explosive limit (LEL).

2.2. Build up of impurities in the Test Cryostat (or AFC Safety Vacuum)[2]

This hazard results from the possibility that a hydrogen-air mixture has formed in the Test Cryostat vacuum space and this coincides with a failure of the absorber heaters, which could create an ignition source. It is proposed to interlock the heaters with a Safety Instrumented System (SIS), so that their operation is prevented if an explosive atmosphere could be present.

Notes and assumptions:

i. Electrical signals in the cryostat are intrinsically safe where possible
   a. Temperature sensors in the cryostat are intrinsically safe
   b. Level sensors in the cryostat are intrinsically safe
ii. The cryostat heaters cannot be intrinsically safe because of their power rating

Proposal:

i. The heater power supply is interlocked by two hardwired vacuum pressure signals to prevent / disable their operation if the cryostat vacuum is not good (i.e. above 10^{-3}mbar)[3]
ii. Heater wiring is separated from other cryostat wiring by a physical barrier or a 50mm gap
iii. The heater power supply will be UPS backed (2 hour back-up) to enable liquid hydrogen to be boiled off in the event of a power failure.

Implementation:

It has not been possible to find vacuum switches to operate at the vacuum level of 10^{-3}mbar. We therefore propose to use vacuum gauges. One already exists in the control system (Leybold PENNINGVAC PTR 225[4]) to give cryostat vacuum pressure readout and an additional vacuum gauge will be added (Leybold CERAVAC CTR 100 - 1 Torr[5]) for dual redundancy. Both gauges

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[2] Note that this report will refer to the Test Cryostat vacuum space, meaning the area around the test absorber in the R&D Hydrogen System. However, the arguments developed and solutions proposed can, and will, be applied equally well to the Absorber Focus Coil (AFC) vacuum space.
[3] This value was based on the calculations in RD2
[4] http://www.oerlikon.com/leyboldvacuum/products/produktkatalog_04.aspx?cid=2656
[5] http://www.oerlikon.com/leyboldvacuum/products/produktkatalog_04.aspx?cid=2609

will be read-out through either Leybold CENTRE TWO or CENTRE THREE controllers. A set-point from each gauge will be used to give hard wired guardline inputs to the Cryostat Heater PSU (signals also used to give PLC inputs). To energise the heaters "Guardline A", "Guardline B", "PLC Heater Enable" and "PLC Heater Control Signals" are required.

The full electrical layout and logic is shown in RD3.

3. Conclusions

The hazards that required SISs (as identified in RD1) have been addressed and proposals made for either implementing appropriate SISs, or providing additional layers of protection. It is believed that with these features, the MICE Hydrogen System can be shown to comply with the IEC61508 regulations (Functional safety of electrical/electronic/ programmable electronic safety related systems).