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HAZOP Report for the Rutherford Appleton Laboratory (RAL) R&D Hydrogen Delivery System

Report to the Council for the Central Laboratory of the Research Councils (CCLRC)

Your Reference:

Our Reference: SA/SMS/P3986 Issue 01

Date: 09 June 2006

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Executive Summary

The Rutherford Appleton Laboratories (RAL), of the Council for the Central Laboratory of the Research Councils (CCLRC), is building an experimental physics facility which includes a hydrogen system. The aim is that this hydrogen delivery system may be upgraded to be the first (of three) MICE (Muon Ionisation Cooling Experiment) hydrogen systems.

This report presents the results of a HAZOP study, which took place on 31 May – 1 June 2006, of a proposed R&D Hydrogen Delivery System. This is a model system capable of being upgraded to be the first hydrogen system in the Muon Ionisation Cooling Experiment (MICE). The R&D system incorporates a test cryostat which mimics the final absorber system of the full MICE.

During the HAZOP study 25 Recommendations (Actions) were made by the HAZOP team as constituting a potential improvement to the existing design. In addition as part of the HAZOP process a risk ranking was applied for each principle hazard identified.

The main hazards identified were associated with a dropped load onto plant or equipment and external fire in the MICE Hall. The likelihood of the hazards identified in study should be reduced further following corrective action in line with the recommendations raised during the HAZOP.

To confirm the improved safety of the system the report recommends that a second HAZOP would assist in confirming the robustness of the final design.

There are several HAZOP recommendations which relate to the consideration of additional instrumentation or engineered modifications to enhance the safety of the system. The impact of these modifications on the overall probability of failure of the system prior to implementation can be achieved by carrying out fault tree analysis on both the current design and the modified design and thus highlight the level of improvement afforded by the redesign – this is suggested as a way forward.

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1 Introduction

The Rutherford Appleton Laboratories (RAL), of the Council for the Central Laboratory of the Research Councils (CCLRC), is building an experimental physics facility which includes a hydrogen system. The aim is that this hydrogen delivery system may be upgraded to be the first (of three) MICE (Muon Ionisation Cooling Experiment) hydrogen systems.

An internal safety review at RAL has recommended that the project carry out a full HAZOP and FMEA study on the hydrogen system. This report presents the results of a HAZOP of the proposed model hydrogen delivery system and recommendations on appropriate way forward in the development of a robust safety case for the design which may include FMEA, fault tree, event tree or consequence analysis.

This report presents the results of a HAZOP study which took place on 31 May to 1 June 2006.

2 Process and Equipment Description

The R&D Hydrogen Delivery System is a model system capable of being upgraded to be the first hydrogen system in the Muon Ionisation Cooling Experiment (MICE), which will ultimately use three independent hydrogen systems. The R&D system incorporates a test cryostat which mimics the final absorber system of the full MICE.

The main components of the R & D system are:

- Control system
- Hydrogen delivery system
- Test cryostat with liquid hydrogen test chamber
- Buffer vessel
- Vacuum pumps
- Ventilation system

2.1 Control System

The control system will be based on EPICS (Experimental Physics and Industrial Control System), a data acquisition and control system. Normal control (operations) of the hydrogen delivery system involves the following:

- Purging the delivery system with helium;
- Filling the hydrogen absorber in the test cryostat with liquid hydrogen from the hydride bed
- Controlling the liquid hydrogen level in the absorber
- Emptying the hydrogen absorber and returning the hydrogen back to the hydride bed.

Additionally it will be necessary to charge the hydride bed with hydrogen at the outset, and following any maintenance on the hydride bed.

2.2 Hydrogen Delivery System (Metal Hydride Storage Unit)

The hydride bed is used to store hydrogen in the safe form of a metal hydride compound. When warmed the bed evolves hydrogen gas, when cooled, it absorbs hydrogen. Heating and cooling is affected by the use of a water circulating loop from a heater/chiller unit.

2.3 Test Cryostat with Liquid Hydrogen Test Chamber

The test cryostat contains two chambers, one simulates the [MICE] absorber volume (22L) and the other is a condensing pot (2L). The condensing pot is large enough to accommodate the expansion of the hydrogen from the absorber volume over its operating range. In addition the absorber base plate incorporates a simple heat exchanger. Hydrogen from the hydride bed is condensed and allowed to drip into the absorber volume.

2.4 Buffer Vessel

The buffer vessel ($1m^3$) is a device to prevent rapid pressure rises and hence provides improved safety over just a piped system.

2.5 Vacuum Pumps

There are two sets of pumps for the MICE R&D system; one is used for maintaining the test cryostat vacuum, and needs to be purged due to the potential presence of hydrogen, and the other is used for purging the hydrogen delivery system. Both of these are vented through the dedicated extraction system and are located outside the building. (Note: There are no hydrogen detectors available for use in vacuum systems, so it will be necessary to locate all hydrogen detectors in the pump exhausts, venting/purging lines, and extraction hood).

2.6 Relief Valves

As the pressure rises the first stage is to vent the absorber back into the hydride bed. If the hydride bed is unable to cope with the flow rate then a secondary system vents the hydrogen into the hydrogen ventilation line where it is vented outside the hall. Hydrogen sensors will give a warning. In addition to the relief valve a burst disc gives further protection on this circuit.

Relief valves are also located on the cryostat volume in case of loss of hydrogen into this area.

The valves, are fitted with “backflow preventers”, as the outlet pressure will at times exceed the inlet pressure (e.g. when purging the system) and the valves are not designed to withstand a back-pressure.

2.7 Ventilation

The gas panel, buffer volume and hydride bed are situated under an extraction hood that exhausts outside the building. Nitrogen gas is continually fed into the line, to dilute any hydrogen gas that might be present, and thus reduce the risk of a flammable mixture being present in the hall as well as to prevent the ingress of air into the system.

2.8 Sensing Equipment

In addition to those plant items included above additional safety features are included:

- Temperature sensors for measurement and control of some aspects of the process (e.g. control & measurement of the cryocooler cold head)
- Level sensors for use in the test cryostat. There are 3 level sensors installed – one in the condensing pot and two in the absorber, thus the level of hydrogen can be monitored continuously.

- Hydrogen and oxygen sensors will be installed where appropriate (e.g. the venting lines, the hood and buffer vessel)

3 HAZOP Purpose/Objectives

The primary objective of the HAZOP study is to identify the causes, consequences and existing safeguards for credible hazards.

The hazards and operability issues identified will be used as the basis for the proposed safety case.

4 HAZOP Scope

The HAZOP scope was defined by the plant and processes outlined within the layout drawings identified in Reference 1. The intention was to confine the HAZOP study to design and normal operation of the R&D Hydrogen Delivery System.

5 HAZOP Process

The Hazard and Operability (HAZOP) study technique is a widely recognised and well-established method of safety review. It is used in a wide range of industries, including process chemicals, oil and gas and nuclear, as a technique for hazard identification and problems which may arise preventing safe and efficient operation. It was originally intended for use with new and/or novel technology where past experience was limited. However, it has been found to be very effective for use at any stage of a plant's life from design on. Optimally, from a cost viewpoint, it is best applied for new plants when the design is firm or for existing plants when a major redesign is planned. In these cases any recommended process changes can be made at minimum cost.

The methodology involves a structured, systematic and comprehensive examination of process flow sheets, flow diagrams, plant/facility layouts or procedures in order to identify potential hazards and operability problems. The study is undertaken by a multi-disciplinary team familiar with the process undergoing examination and a chairman who should be independent of the design project. The role of the chairman, who must be experienced in the application of the HAZOP technique, is to guide and encourage the study team through the examination process to identify all possible hazard scenarios. The team also requires a secretary to formally record the discussions and findings of the study. HAZOPs, thus, provide a method for individuals in a team to visualise ways in which a plant can malfunction or mal-operate. This creative thinking of individuals has to be guided and stimulated in a systematic fashion by the use of prompt words to cover all imaginable malfunctions and mal-operations.

6 Methodology

The R&D Hydrogen Delivery System design is shown in Reference 1. To facilitate the HAZOP process, the individual process steps for construction and normal operations were reviewed and subsequently grouped to define the HAZOP nodes. A short Briefing Note was made available in advance of the HAZOP meeting that listed the Nodes and Keywords to be used [Ref. 2].

The nodes used during the HAZOP are shown in Table 1. These nodes were subject to the HAZOP study process.

The nodes were examined for deviations from the overall design intent using standard HAZOP methodology by the application of a series of keywords. Where a keyword was not applicable to a particular node or no additional hazards were identified relevant to the keyword, this was noted as such in the worksheets. The list of keywords used is given in Table 2.

Having identified the consequences and any existing safeguards, the team made a decision as to whether this is tolerable by using a simple risk ranking scale to score the severity and the likelihood of the scenario. If it was not considered tolerable, then a recommendation was made which should reduce the severity or the frequency of the consequence being realised. Each recommendation was allocated to a member of the HAZOP Team, who will be responsible for addressing the issues raised outside the HAZOP meeting.

The meeting discussions were recorded interactively by the secretary on a PC via dedicated software (PHAWorks 5.04). The HAZOP team viewed and agreed the record "live" by means of a projection system connected to the PC in the meeting room and hence the HAZOP worksheets effectively represent the minutes of the meeting. The HAZOP worksheets are presented in Appendix 4.

Risk ranking process for the identified hazards and operability issues were undertaken in accordance with Table 3.

Where additional information was required or changes to the concept design were considered by the HAZOP team as constituting a potential improvement, actions / recommendations were raised or comments made.

7 Discussion

During the HAZOP Study 25 Recommendations (Actions) were made. The Recommendations have been extracted from the worksheets and included in Appendix 3 in expanded form to be "stand alone".

As part of the HAZOP process a risk ranking was applied for each principle hazard identified. Any hazards that were "missed" have been assessed subsequently based those captured during the sessions, these are indicated in italics.

The assessed severity of the (unmitigated) hazards was spread between hydrogen explosions/fires (1 and 2 respectively) and small gas leaks (ingress or egress) and operational issues (5 and 6 respectively). Those identified as severity 1 or 2, which may be regarded as the main hazards are tabulated below – see Table 3 for severity/likelihood descriptions.

CAUSE (plus Comment)	S	L	RECOMMENDATION
7. Operator opens PV17 during operations (This cause is just one example of inappropriate action within the system)	*1*	*4*	8. Review operational sequencing for inappropriate actions
35. Fans fail to switch to high speed mode under accident conditions (Only an issue for a very high release from the cabinet)	1	5	
34. Failure of ventilation fans	*1*	*5*	
3. Dropped load from crane (This recommendation appropriate to all nodes)	2	3	4. Review appropriate methods of crane operating areas
5. and 26 External fire in the MICE Hall	2	3	7 and 19. Assess ignition sources around the hydrogen generation unit
15. Emergency venting of Hydrogen	2	4	11. Review access to roof
8. Failure of Hydride storage unit	*2*	*5*	

In addition it can be seen that the likelihood of these events, with the exception of dropped load and fire, have been assessed as unlikely or very unlikely with current safeguards in place. The likelihood of the hazards listed above should be reduced further following corrective action in line with the recommendations.

One area where the HAZOP was unable to explore in great depth was the computerised control system which has been claimed as a safeguard on at least one occasion and discussed during the sessions as preventing certain actions from being taken. This has resulted in a recommendation (no.13) to verify that the control system complies with international standard IEC61508 on the Functional safety of electrical/electronic/programmable electronic safety-related systems.

8 Recommendations

The hazards associated with the hydrogen delivery system can be reduced further by the satisfactory implementation of the outcome from the recommendations – HAZOP action sheets have been included at Appendix 5 to help facilitate this process. To confirm the improved safety of the system, a second HAZOP should be conducted on the final design.

It is important that the software interlocks be defined and incorporated into the control system and included as part of the final HAZOP. In addition the software should be compliant with IEC61508.

There are several recommendations which relate to the consideration of additional instrumentation or engineered modifications with a view to enhancing the safety of the system. It may be prudent to assess the impact of these modifications on the overall probability of failure of the system prior to implementation. This can be achieved by carrying out fault tree analysis on both the current design and the modified design. This will highlight the level of improvement afforded by the redesign. Clearly if the redesign proves to offer little improvement in system reliability, potentially costly modifications can be avoided.

9 References

1. Baynham, E. and others. R & D Hydrogen Delivery System. Version of 11 November 2005.
2. R&D Hydrogen Delivery System HAZOP Study Briefing Note. May 2006.

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Appendices

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Appendix 1
HAZOP Attendance

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HAZOP Attendance

The HAZOP took place on 31st May – 1st June 2006 in RmG06, Building R66 at Rutherford Appleton Laboratory, Chilton.

The following table indicates attendees during that time.

Name	Position	31/5	01/6
Mike Selway	HAZOP Chairman (Serco)	✓	✓
Andrew White	HAZOP Secretary (Serco)	✓	✓
Gary Allen	Target Station Controller (RAL)	✓	✓
Tom Bradshaw	Project Manager (RAL)	✓	✓
Mike Courthold	Control Engineer (RAL)	✓	✓
Matthew Hills	Mechanical Engineer (RAL)	✓	✓
Yuri Ivanyushenkov	Research Engineer (RAL)	✓	✓
Tony Jones	Mechanical Engineer (RAL)	✓	✓
Chris Nelson	Project Engineer (RAL)	✓	✓
Jane Vickers	ISIS Safety Officer (RAL)	✓	

Note:
Nodes 1 to 4 were covered on Day 1 (31 May 2006) and the remaining nodes were completed on Day 2 (1 June 2006).

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Appendix 2
Tables and Figures

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Tables and Figures

Table 1: HAZOP Nodes

Node	Description
1	Metal Hydride Storage Unit (Including Heater/Chiller Unit)
2	Hydrogen Bottle and line to Buffer Volume (Including lines through HA-PV05, HA-RV06 & HA-PV07)
3	Purge/Fill Helium Cylinder and line through HA-PV18
4	Buffer Tank (Including lines through HA-PV08, HA-BD09 & HA-RV10 to Vent)
5	Lines from Buffer Tank to Cryostat
6	Absorber Volume and Condensing Pot
7	Test Cryostat and Mass Spectrometer (Including coolant lines)
8	Nitrogen System - Jacket and Ventilation Purge (Including nitrogen cylinder and lines through HA-PV11, HA-BD12 & HA-PV13))
9	Gas Panel

Table 2: HAZOP Keywords

Keywords		
Level	Instrumentation	Ventilation
Flow	Operator Action	Loss Of Services
Pressure	Structural Failure	Effluent / Waste / Residue
Temperature	Corrosion / Erosion	Sampling
Composition	Contamination	External Hazards
Concentration	Impact	

Table 3: Risk Ranking Table

Severity		Likelihood	
1	Hydrogen Explosion	1	Has happened a few times
2	Hydrogen Fire	2	Has happened once
3	Other Gas Explosions	3	Is possible
4	Other Gas Implosions	4	Unlikely
5	Small Gas Leak	5	Very unlikely
6	Operational Issues		

Figure 1: Process and Instrumentation Diagram

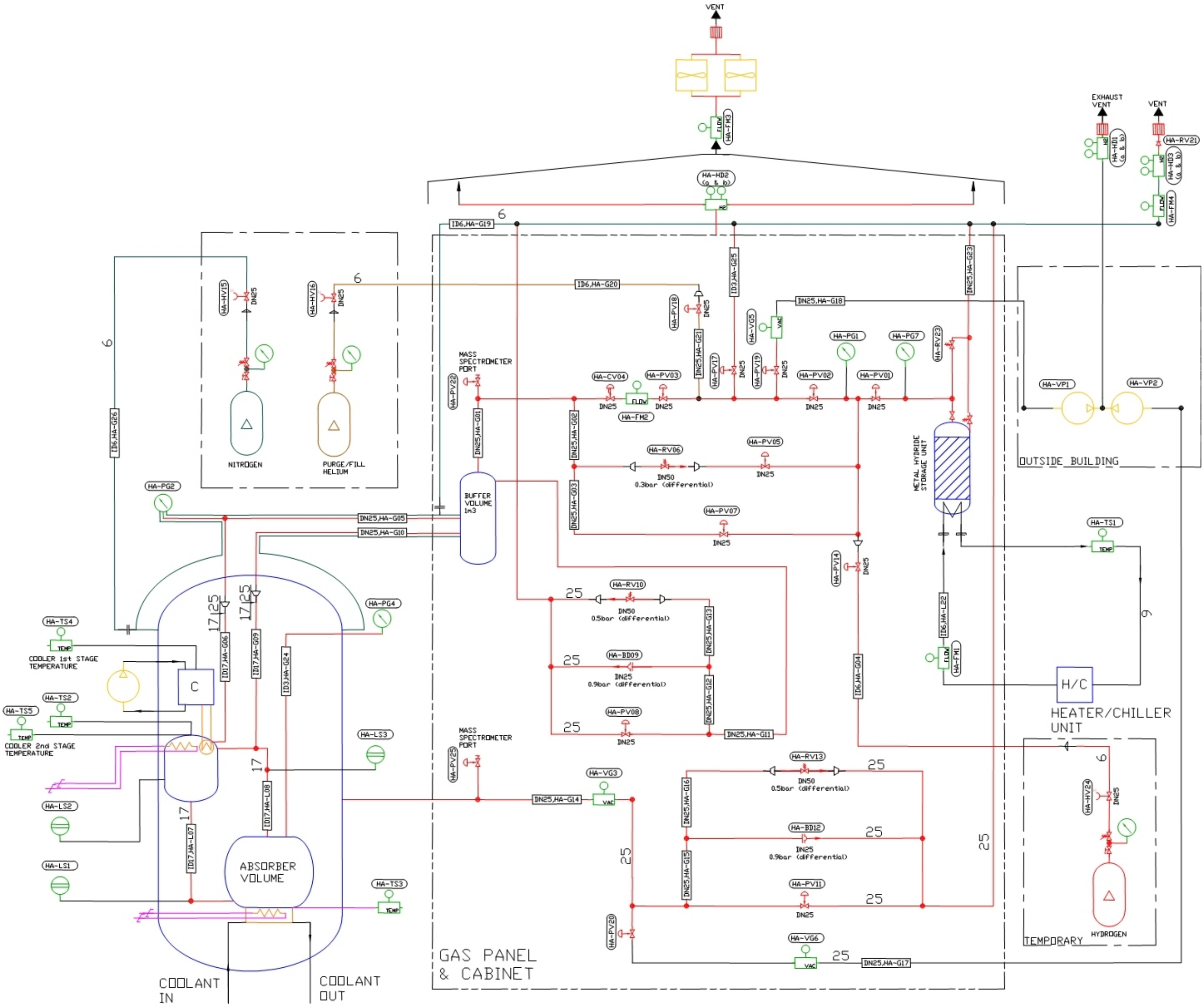


Figure 2: Hydrogen system test cryostat internal details

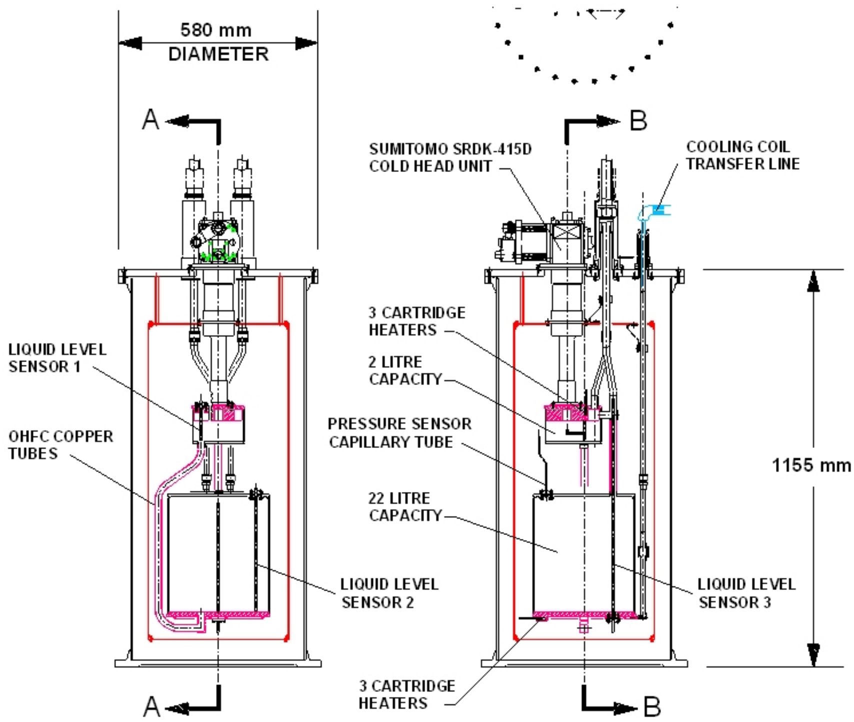
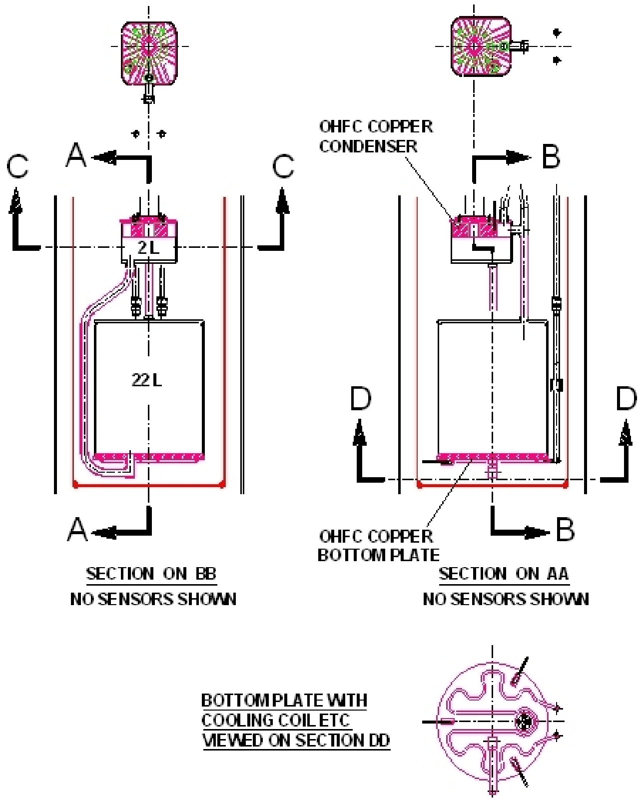


Figure 3: Details of condensing plate and absorber base



Appendix 3
HAZOP Recommendations

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HAZOP Recommendations

RECOMMENDATION	BY
1. Look at pressure of hydride bed "on a hot day" i.e. high ambient temperature	MC
2. Consider a chiller pump failure alarm for the hydride bed unit	MC
3. Review consequences of a glycol release (leak) onto plant items from the chiller	AJ
4. Review appropriate methods of crane operating areas to reduce risk of damage to plant from impact/dropped loads	AJ
5. Consider linking temperature monitor with heater chiller operation to avoid overheating in the event of thermostat failure	MC
6. Consider automation of hydride bed hand valve	MC
7. Assess ignition sources around the hydrogen generation unit to reduce possibility of fire in the MICE hall	CN
8. Review hydride bed operational sequencing for inappropriate actions	MC
9. Review process for filling hydrogen bed for indication that the bed is full (including the location of bottles during storage and filling)	MC
10. Consider back streaming with He during connection to avoid contamination with air during bottle changes	MC
11. Review access to roof to avoid exposure to vented hydrogen	CN
12. Consider test mechanism to validate (RV10) seal after discharge of cold hydrogen	MC/MH
13. Confirm that control software system conforms with IEC61508	MC
14. Identify appropriate procedure in the event of blockage due to condensation of impurities in buffer tank/cryostat line	MC/TB
15. Ensure hydrogen sensors on UPS in case of loss of power	MC
16. Consider the benefits of having all control system on UPS in the case of loss of power to prove state of system information	MC
17. Ensure that software intervenes when discrepancies are detected with provision for limited operator intervention	MC
18. Consider installation of mass spectrometer (RGA) on PV25 to monitor potential embrittlement issues	MC
19. Assess ignition sources around the cryostat unit (as for Recommendation 7)	CN
20. Review capability of bursting disc to withstand scenario of RV10 or RV23 pressure surge	MH
21. Confirm whether bursting disc would create ignition source on activation	MH
22. Consider the inclusion of a non-return valve downstream of the burst disc to avoid pressure surge from RV10 or RV23 activation	MH
23. Consider installation of flow meter(s) / indication device to alert low/ no flow from nitrogen bottle around nitrogen jacket circuit	MH
24. Consider fitting non-return valve to prevent hydrogen flow into nitrogen system on activation of RV10 or RV23	MH
25. Review need for protection/location of gas bottles to prevent vehicle (or other) impacts	AJ
26. Review methods to minimise condensation on hydrogen pipework	AJ

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Appendix 4
HAZOP Worksheets

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Node 1: Metal Hydride Storage Unit
Keyword: Flow

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
No	No Flow	1. Failure of pump	1.1. Inability to absorb hydrogen						
			1.2. Increase of pressure in system	1.2.1. Closure of valve PV01, RV23 (at 1.5bar), Hydride unit PRV (at 30bar)	5	3	1. Look at pressure of hydride bed "on a hot day"	MC	
				1.2.2. Manual valve on top of metal hydride unit could be closed			2. Consider chiller pump failure alarm	MC	
		2. Leak in pipework	2.1. Inability to absorb hydrogen						
			2.2. Increase of pressure in system	2.2.1. Closure of valve PV01, RV23 (at 1.5bar), Hydride unit PRV (at 30bar)	5	5			
				2.2.2. Manual valve on top of metal hydride unit could be closed					
			2.3. Ethylene glycol dripping onto plant/equipment				3. Review consequences of glycol release	AJ	
		3. Dropped load from crane	3.1. Damage to plant/equipment (e.g. ruptured pipework)	3.1.1. Hydrogen monitoring	2	3	4. Review appropriate methods of crane operating areas	AJ	1. This recommendation appropriate to all nodes

Node 1: Metal Hydride Storage Unit
Keyword: Temperature

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
More	Higher Temperature	4. Failure of thermostat in heating unit	4.1. Temp > 30C causing rise in pressure	4.1.1. Valve RV23 opens to vent.	6	4	5. Consider linking temperature monitor with heater chiller operation	MC	
				4.1.2. Closing the hand valve (when MICE not operating)			6. Consider automation of hydride bed hand valve	MC	
				4.1.3. Temperature monitoring equipment TS01					
		5. External fire in the MICE Hall	5.1. Possible flame impingement on metal hydride unit		2	3	7. Assess ignition sources around the hydrogen generation unit	CN	
Less	Lower Temperature	6. Failure of thermostat in cooling unit	6.1. Temp < -18C - operability issue	6.1.1. Temperature monitoring equipment TS01	6	3			

Node 1: Metal Hydride Storage Unit
Keyword: Operator Action

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
		7. Operator opens PV17 during operations	7.1. System vents to air		*1*	*4*	8. Review operational sequencing for inappropriate actions	MC	2. This cause is just one example of inappropriate action within the system

Node 1: Metal Hydride Storage Unit
Keyword: Structural Failure

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
		8. Failure of Hydride storage unit	8.1. Fire	8.1.1. Vessel pressure tested to European standards (Pressure Equipment Directive (PED))	*2*	*5*			
				8.1.2. Periodic pressure testing					

Node 1: Metal Hydride Storage Unit
Keyword: External Hazards

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
		9. Static build-up	9.1. Spark discharge resulting in, for example, possible control system interruption	9.1.1. System is adequately earthed	*5*	*5*			

Node 2: Hydrogen Bottle and line to the Buffer Volume
Keyword: Flow

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
More	More Flow	10. Pressure regulator incorrectly set/fails during initial charge	10.1. Increased pressure to hydride bed and pipework (approx 5 bar max)	10.1.1. RV23 valve will open	5	5			
No	No Flow	11. RV06 fails to operate	11.1. Increase in pressure to buffer vessel	11.1.1. RV10 valve will open - burst disc	5	4			

Node 2: Hydrogen Bottle and line to the Buffer Volume
Keyword: Pressure

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
More	Higher Pressure	12. Excessive hydrogen delivered to hydride bed	12.1. Venting of hydrogen	12.1.1. PG07 for initial indication of pressure	5	4	9. Review process for filling hydrogen bed for indication that the bed is full (including the location of bottles during storage and filling)	MC	
				12.1.2. RV23 valve opens					
Less	Lower Pressure	13. Gas bottle empties before hydride bed is full	13.1. Possible contamination of hydride bed with water / air	13.1.1. Close PV14 prior to gas bottle becoming empty	5	3			

Node 2: Hydrogen Bottle and line to the Buffer Volume
Keyword: Contamination

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
		14. Failure to purge hydrogen filling line	14.1. Contaminated hydride bed		5	5	10. Consider back streaming with He during connection	MC	

Node 2: Hydrogen Bottle and line to the Buffer Volume
Keyword: Effluent / Waste / Residue

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
		15. Emergency venting of Hydrogen	15.1. Potential explosive atmosphere at roof level	15.1.1. Flame arrestors on vent line protects in-building equipment	2	4	11. Review access to roof	CN	

Node 3: Purge / Fill Helium Cylinder and line through HA-PV18
Keyword: Flow

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
More	More Flow	16. PV18 fails open	16.1. Inefficient operations		6	4			

Node 4: Buffer Tank
Keyword: Pressure

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
		17. RV10 operates and discharges cold hydrogen	17.1. Potential to result in failure to reseal		*5*	*3*	12. Consider test mechanism to validate seal after discharge	MC /M H	

Node 4: Buffer Tank
Keyword: Operator Action

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
		18. Operator accidentally opens PV08	18.1. Air ingress to system	18.1.1. Software interlock	5	4	13. Confirm that software system conforms with IEC61508	MC	

Node 5: Lines from Buffer Tank to Cryostat
Keyword: Flow

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
No	No Flow	19. Condensation of impurities	19.1. Pressure rise in the absorber volume	19.1.1. Second line available	6	3	14. Identify appropriate procedure in the event of blockage	MC /TB	3. PG2 and PG4 should show similar readings
				19.1.2. PG2 and PG4 pressure gauges					

Node 6: Absorber Volume and Condensing Pot
Keyword: Level

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
More	Higher Level in condensing pot	20. To much hydrogen into test cryostat	20.1. Condensation limited	20.1.1. Level sensor (LS3) on absorber	6	5			
				20.1.2. Level sensor (LS2) in condenser pot					

Node 6: Absorber Volume and Condensing Pot
Keyword: Temperature

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
More	Higher Temperature	21. Heater fails on high temperature on condensing pot	21.1. No condensation of hydrogen	21.1.1. Temperature sensors (TS2 and TS5) - different types of sensor	6	3			
		22. Heater fails on high temperature on absorber volume	22.1. Hydrogen begins to evaporate	22.1.1. Temperature sensor (TS3)	*5*	*4*			

Node 6: Absorber Volume and Condensing Pot
Keyword: Instrumentation

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
		23. Loss of power	23.1. Inability to monitor state of system		5	3	15. Ensure hydrogen sensors on UPS	MC	
							16. Consider the benefits of having all control system on UPS	MC	

Node 6: Absorber Volume and Condensing Pot
Keyword: Operator Action

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
		24. Operator makes wrong decision	24.1. Cryostat fills with air if, for example, PV25 opened.		5	3	17. Ensure that software intervenes when discrepancies are detected with provision for limited operator intervention		

Node 6: Absorber Volume and Condensing Pot
Keyword: Structural Failure

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
		25. Hydrogen embrittlement issues	25.1. Leak of hydrogen		5	3	18. Consider installation of mass spectrometer (RGA) on PV25	MC	

Node 6: Absorber Volume and Condensing Pot
Keyword: External Hazards

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
		26. External fire in the MICE Hall	26.1. Possible flame impingement on cryostat (and affect internals)		2	3	19. Assess ignition sources around the cryostat unit	CN	

Node 7: Test Cryostat and Mass Spectrometer Port to Vent and Exhaust Vent
Keyword: Pressure

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
More	Higher Pressure	27. Continuous small leak from system (air)	27.1. Large amounts of oxygen in cryostat leading to possible flammable mixture	27.1.1. Synthetic oil in rotary pumps 27.1.2. Safety feature on rotary pump if volume excessive, then the pump shuts down 27.1.3. Hydrogen detector within pumping line (exhaust vent - HD1 and HD2) 27.1.4. Nitrogen jacket to avoid air (oxygen) leaking into the cryostat	5	5	:		4. Requires multiple failures
		28. Activation of RV10 (from buffer volume) or RV23 (hydride bed)	28.1. Disc bursts and hydrogen ingress to cryostat		5	3	20. Review capability of bursting disc to withstand scenario	MH	

		resulting in high pressure on upstream side of BD12					21. Confirm whether bursting disc would create ignition source on activation	MH	
							22. Consider inclusion of NRV downstream burst disc	MH	

Node 7: Test Cryostat and Mass Spectrometer Port to Vent and Exhaust Vent
Keyword: Loss of Services

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
		29. Failure of VP2	29.1. NSC		-	-			

Node 8: Nitrogen System - Jacket and vent purge
Keyword: Flow

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
No	No Flow	30. Empty gas bottle	30.1. Air in ventilation line and cryostat jacket		5	3	23. Consider installation of flow meter(s) / indication device	MH	
Reverse	Reverse Flow	31. Discharge through RV10 or RV23	31.1. Hydrogen into nitrogen line		5	3	24. Consider fitting NRV	MH	

Node 8: Nitrogen System - Jacket and vent purge
Keyword: Pressure

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
Less	Lower Pressure	32. Empty gas bottle	32.1. Air in ventilation line and cryostat jacket		*5*	*4*			5. See Recommendation 23

Node 8: Nitrogen System - Jacket and vent purge
Keyword: Impact

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
		33. Vehicle impact with cylinder bottle storage	33.1. Potential rupture of cylinder		5	4	25. Review need for protection/location of gas bottles	AJ	

Node 9: Gas Panel
Keyword: Ventilation

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
		34. Failure of ventilation fans	34.1. Inability to remove hydrogen	34.1.1. Standby fan 34.1.2. UPS system	*1*	*5*			
		35. Fans fail to switch to high speed mode under accident conditions	35.1. Inability to remove hydrogen		1	5			6. Only an issue for a very high release from the cabinet

Node 9: Gas Panel
Keyword: External Events

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	RECOMMENDATIONS	BY	COMMENTS
		36. High moisture content	*36.1. Condensation on hydrogen pipework leading to pools of water on floor*		*6*	*3*	*26. Review methods to minimise condensation on hydrogen pipework*	*AJ*	

Bringing service to life

Appendix 5 HAZOP Action Tracking Forms

Contents

	Rutherford Appleton Laboratory R&D Hydrogen Delivery System HAZOP Action Tracking Form		
HAZOP Action No.	1	By	MC
Response Date			

HAZOP Action: Look at pressure of hydride bed "on a hot day" i.e. high ambient temperature

HAZOP Action Response:

Response Made By	Name (Print):	Signature:	Date:
Response Checked By	Name (Print):	Signature:	Date:
Action Status (circle)	Accepted	Ongoing	Rejected

Comments (include reasons for action rejection or 'Ongoing' classification):

Revised Action Response Due Date**	

NB. Please return this form to the HAZOP Co-ordinator.

* Delete as required.
** Applicable only to 'Ongoing' actions or 'Rejected' responses.

	Rutherford Appleton Laboratory R&D Hydrogen Delivery System HAZOP Action Tracking Form		
HAZOP Action No.	2	By	MC
Response Date			

HAZOP Action: Consider a chiller pump failure alarm for the hydride bed unit

HAZOP Action Response:

Response Made By	Name (Print):	Signature:	Date:
Response Checked By	Name (Print):	Signature:	Date:
Action Status (circle)	Accepted	Ongoing	Rejected

Comments (include reasons for action rejection or 'Ongoing' classification):

Revised Action Response Due Date**	

NB. Please return this form to the HAZOP Co-ordinator.

*   Delete as required.
** Applicable only to 'Ongoing' actions or 'Rejected' responses.

	Rutherford Appleton Laboratory R&D Hydrogen Delivery System HAZOP Action Tracking Form		
HAZOP Action No.	3	By	AJ
Response Date			

HAZOP Action: Review consequences of a glycol release (leak) onto plant items from the chiller

HAZOP Action Response:

Response Made By	Name (Print):	Signature:	Date:
Response Checked By	Name (Print):	Signature:	Date:
Action Status (circle)	Accepted	Ongoing	Rejected

Comments (include reasons for action rejection or 'Ongoing' classification):

Revised Action Response Due Date**	

NB. Please return this form to the HAZOP Co-ordinator.

* Delete as required.
** Applicable only to 'Ongoing' actions or 'Rejected' responses.

	Rutherford Appleton Laboratory R&D Hydrogen Delivery System HAZOP Action Tracking Form		
HAZOP Action No.	4	By	AJ
Response Date			

HAZOP Action: Review appropriate methods of crane operating areas to reduce risk of damage to plant from impact/dropped loads

HAZOP Action Response:

Response Made By	Name (Print):	Signature:	Date:
Response Checked By	Name (Print):	Signature:	Date:
Action Status (circle)	Accepted	Ongoing	Rejected

Comments (include reasons for action rejection or 'Ongoing' classification):

Revised Action Response Due Date**	

NB. Please return this form to the HAZOP Co-ordinator.

* Delete as required.
** Applicable only to 'Ongoing' actions or 'Rejected' responses.

	Rutherford Appleton Laboratory **R&D Hydrogen Delivery System** **HAZOP Action Tracking Form**		
HAZOP Action No.	5	By	MC
Response Date			

HAZOP Action: Consider linking temperature monitor with heater chiller operation to avoid overheating in the event of thermostat failure

HAZOP Action Response:

Response Made By	Name (Print):	Signature:	Date:
Response Checked By	Name (Print):	Signature:	Date:
Action Status (circle)	Accepted	Ongoing	Rejected

Comments (include reasons for action rejection or 'Ongoing' classification):

Revised Action Response Due Date**	

NB. Please return this form to the HAZOP Co-ordinator.

*   Delete as required.
** Applicable only to 'Ongoing' actions or 'Rejected' responses.

	Rutherford Appleton Laboratory **R&D Hydrogen Delivery System** **HAZOP Action Tracking Form**

HAZOP Action No.	6	By	MC
Response Date			

HAZOP Action: Consider automation of hydride bed hand valve

HAZOP Action Response:

Response Made By	Name (Print):	Signature:	Date:
Response Checked By	Name (Print):	Signature:	Date:
Action Status (circle)	Accepted	Ongoing	Rejected

Comments (include reasons for action rejection or 'Ongoing' classification):

Revised Action Response Due Date**	

NB. Please return this form to the HAZOP Co-ordinator.

* Delete as required.
** Applicable only to 'Ongoing' actions or 'Rejected' responses.

<table>
<tr><td></td><td colspan="3">Rutherford Appleton Laboratory
R&D Hydrogen Delivery System

HAZOP Action Tracking Form</td></tr>
<tr><td>HAZOP Action No.</td><td>7</td><td>By</td><td>CN</td></tr>
<tr><td>Response Date</td><td colspan="3"></td></tr>
<tr><td colspan="4">HAZOP Action: Assess ignition sources around the hydrogen generation unit to reduce possibility of fire in the MICE hall</td></tr>
<tr><td colspan="4">HAZOP Action Response:</td></tr>
</table>

Response Made By	Name (Print):	Signature:	Date:
Response Checked By	Name (Print):	Signature:	Date:
Action Status (circle)	Accepted	Ongoing	Rejected

<table>
<tr><td colspan="2">Comments (include reasons for action rejection or 'Ongoing' classification):</td></tr>
<tr><td>Revised Action Response Due Date**</td><td></td></tr>
</table>

NB. Please return this form to the HAZOP Co-ordinator.

* Delete as required.
** Applicable only to 'Ongoing' actions or 'Rejected' responses.

	Rutherford Appleton Laboratory R&D Hydrogen Delivery System HAZOP Action Tracking Form		
HAZOP Action No.	8	By	MC
Response Date			

HAZOP Action: Review hydride bed operational sequencing for inappropriate actions

HAZOP Action Response:

Response Made By	Name (Print):	Signature:	Date:
Response Checked By	Name (Print):	Signature:	Date:
Action Status (circle)	Accepted	Ongoing	Rejected

Comments (include reasons for action rejection or 'Ongoing' classification):

Revised Action Response Due Date**	

NB. Please return this form to the HAZOP Co-ordinator.

* Delete as required.
** Applicable only to 'Ongoing' actions or 'Rejected' responses.

	Rutherford Appleton Laboratory **R&D Hydrogen Delivery System** **HAZOP Action Tracking Form**

HAZOP Action No.	9	By	MC
Response Date			

HAZOP Action: Review process for filling hydrogen bed for indication that the bed is full (including the location of bottles during storage and filling)

HAZOP Action Response:

Response Made By	Name (Print):	Signature:	Date:
Response Checked By	Name (Print):	Signature:	Date:
Action Status (circle)	Accepted	Ongoing	Rejected

Comments (include reasons for action rejection or 'Ongoing' classification):

Revised Action Response Due Date**	

NB. Please return this form to the HAZOP Co-ordinator.

* Delete as required.
** Applicable only to 'Ongoing' actions or 'Rejected' responses.

	Rutherford Appleton Laboratory R&D Hydrogen Delivery System HAZOP Action Tracking Form		
HAZOP Action No.	10	By	MC
Response Date			

HAZOP Action: Consider back streaming with He during connection to avoid contamination with air during bottle changes
HAZOP Action Response:

Response Made By	Name (Print):	Signature:	Date:
Response Checked By	Name (Print):	Signature:	Date:
Action Status (circle)	Accepted	Ongoing	Rejected

Comments (include reasons for action rejection or 'Ongoing' classification):

Revised Action Response Due Date**	

NB. Please return this form to the HAZOP Co-ordinator.

* Delete as required.
** Applicable only to 'Ongoing' actions or 'Rejected' responses.

<table>
<tr><td></td><td colspan="6">Rutherford Appleton Laboratory
R&D Hydrogen Delivery System

HAZOP Action Tracking Form</td></tr>
<tr><td>HAZOP Action No.</td><td colspan="3">11</td><td>By</td><td colspan="2">CN</td></tr>
<tr><td>Response Date</td><td colspan="6"></td></tr>
<tr><td colspan="7">HAZOP Action: Review access to roof to avoid exposure to vented hydrogen</td></tr>
<tr><td colspan="7">HAZOP Action Response:</td></tr>
<tr><td>Response Made By</td><td>Name (Print):</td><td colspan="2">Signature:</td><td colspan="3">Date:</td></tr>
<tr><td>Response Checked By</td><td>Name (Print):</td><td colspan="2">Signature:</td><td colspan="3">Date:</td></tr>
<tr><td>Action Status (circle)</td><td>Accepted</td><td colspan="2">Ongoing</td><td colspan="3">Rejected</td></tr>
<tr><td colspan="7">Comments (include reasons for action rejection or 'Ongoing' classification):</td></tr>
<tr><td colspan="3">Revised Action Response Due Date**</td><td colspan="4"></td></tr>
</table>

NB. Please return this form to the HAZOP Co-ordinator.

* Delete as required.
** Applicable only to 'Ongoing' actions or 'Rejected' responses.

<table>
<tr><td></td><td colspan="4">Rutherford Appleton Laboratory
R&D Hydrogen Delivery System

HAZOP Action Tracking Form</td></tr>
<tr><td>HAZOP Action No.</td><td>12</td><td>By</td><td colspan="2">MC/MH</td></tr>
<tr><td>Response Date</td><td colspan="4"></td></tr>
<tr><td colspan="5">HAZOP Action: Consider test mechanism to validate (RV10) seal after discharge of cold hydrogen</td></tr>
<tr><td colspan="5">HAZOP Action Response:</td></tr>
</table>

<table>
<tr><td>Response Made By</td><td>Name (Print):</td><td>Signature:</td><td>Date:</td></tr>
<tr><td>Response Checked By</td><td>Name (Print):</td><td>Signature:</td><td>Date:</td></tr>
<tr><td>Action Status (circle)</td><td>Accepted</td><td>Ongoing</td><td>Rejected</td></tr>
<tr><td colspan="4">Comments (include reasons for action rejection or 'Ongoing' classification):</td></tr>
<tr><td colspan="2">Revised Action Response Due Date**</td><td colspan="2"></td></tr>
</table>

NB. Please return this form to the HAZOP Co-ordinator.

* Delete as required.
** Applicable only to 'Ongoing' actions or 'Rejected' responses.

	Rutherford Appleton Laboratory **R&D Hydrogen Delivery System** **HAZOP Action Tracking Form**

HAZOP Action No.	13	By	MC
Response Date			

HAZOP Action: Confirm that control software system conforms with IEC61508
HAZOP Action Response:

Response Made By	Name (Print):	Signature:	Date:
Response Checked By	Name (Print):	Signature:	Date:
Action Status (circle)	Accepted	Ongoing	Rejected

Comments (include reasons for action rejection or 'Ongoing' classification):

Revised Action Response Due Date**	

NB. Please return this form to the HAZOP Co-ordinator.

* Delete as required.
** Applicable only to 'Ongoing' actions or 'Rejected' responses.

	Rutherford Appleton Laboratory **R&D Hydrogen Delivery System** **HAZOP Action Tracking Form**		
HAZOP Action No.	14	By	MC/TB
Response Date			

HAZOP Action: Identify appropriate procedure in the event of blockage due to condensation of impurities in buffer tank/cryostat line
HAZOP Action Response:

Response Made By	Name (Print):	Signature:	Date:
Response Checked By	Name (Print):	Signature:	Date:
Action Status (circle)	Accepted	Ongoing	Rejected

Comments (include reasons for action rejection or 'Ongoing' classification):	
Revised Action Response Due Date**	

NB. Please return this form to the HAZOP Co-ordinator.

* Delete as required.
** Applicable only to 'Ongoing' actions or 'Rejected' responses.

	Rutherford Appleton Laboratory R&D Hydrogen Delivery System HAZOP Action Tracking Form		
HAZOP Action No.	15	By	MC
Response Date			

HAZOP Action: Ensure hydrogen sensors on UPS in case of loss of power
HAZOP Action Response:

Response Made By	Name (Print):	Signature:	Date:
Response Checked By	Name (Print):	Signature:	Date:
Action Status (circle)	Accepted	Ongoing	Rejected

Comments (include reasons for action rejection or 'Ongoing' classification):	
Revised Action Response Due Date**	

NB. Please return this form to the HAZOP Co-ordinator.

* Delete as required.
** Applicable only to 'Ongoing' actions or 'Rejected' responses.

	Rutherford Appleton Laboratory **R&D Hydrogen Delivery System** **HAZOP Action Tracking Form**		
HAZOP Action No.	16	By	MC
Response Date			

HAZOP Action: Consider the benefits of having all control system on UPS in the case of loss of power to prove state of system information

HAZOP Action Response:

Response Made By	Name (Print):	Signature:	Date:
Response Checked By	Name (Print):	Signature:	Date:
Action Status (circle)	Accepted	Ongoing	Rejected

Comments (include reasons for action rejection or 'Ongoing' classification):

Revised Action Response Due Date**	

NB. Please return this form to the HAZOP Co-ordinator.

* Delete as required.
** Applicable only to 'Ongoing' actions or 'Rejected' responses.

	Rutherford Appleton Laboratory **R&D Hydrogen Delivery System** **HAZOP Action Tracking Form**		
HAZOP Action No.	17	By	MC
Response Date			

HAZOP Action: Ensure that software intervenes when discrepancies are detected with provision for limited operator intervention

HAZOP Action Response:

Response Made By	Name (Print):	Signature:	Date:
Response Checked By	Name (Print):	Signature:	Date:
Action Status (circle)	Accepted	Ongoing	Rejected

Comments (include reasons for action rejection or 'Ongoing' classification):

Revised Action Response Due Date**	

NB. Please return this form to the HAZOP Co-ordinator.

* Delete as required.
** Applicable only to 'Ongoing' actions or 'Rejected' responses.

	Rutherford Appleton Laboratory **R&D Hydrogen Delivery System** **HAZOP Action Tracking Form**		
HAZOP Action No.	18	By	MC
Response Date			

HAZOP Action: Consider installation of mass spectrometer (RGA) on PV25 to monitor potential embrittlement issues

HAZOP Action Response:

Response Made By	Name (Print):	Signature:	Date:
Response Checked By	Name (Print):	Signature:	Date:
Action Status (circle)	Accepted	Ongoing	Rejected

Comments (include reasons for action rejection or 'Ongoing' classification):

Revised Action Response Due Date**	

NB. Please return this form to the HAZOP Co-ordinator.

* Delete as required.

** Applicable only to 'Ongoing' actions or 'Rejected' responses.

	Rutherford Appleton Laboratory **R&D Hydrogen Delivery System** **HAZOP Action Tracking Form**		
HAZOP Action No.	19	By	CN
Response Date			

HAZOP Action: Assess ignition sources around the cryostat unit (as for Recommendation 7)
HAZOP Action Response:

Response Made By	Name (Print):	Signature:	Date:
Response Checked By	Name (Print):	Signature:	Date:
Action Status (circle)	Accepted	Ongoing	Rejected

Comments (include reasons for action rejection or 'Ongoing' classification):

Revised Action Response Due Date**	

NB. Please return this form to the HAZOP Co-ordinator.

* Delete as required.
** Applicable only to 'Ongoing' actions or 'Rejected' responses.

<table>
<tr><td></td><td colspan="4">Rutherford Appleton Laboratory
R&D Hydrogen Delivery System

HAZOP Action Tracking Form</td></tr>
<tr><td>HAZOP Action No.</td><td colspan="2">20</td><td>By</td><td>MH</td></tr>
<tr><td>Response Date</td><td colspan="4"></td></tr>
<tr><td colspan="5">HAZOP Action: Review capability of bursting disc to withstand scenario of RV10 or RV23 pressure surge</td></tr>
<tr><td colspan="5">HAZOP Action Response:</td></tr>
<tr><td>Response Made By</td><td>Name (Print):</td><td>Signature:</td><td colspan="2">Date:</td></tr>
<tr><td>Response Checked By</td><td>Name (Print):</td><td>Signature:</td><td colspan="2">Date:</td></tr>
<tr><td>Action Status (circle)</td><td>Accepted</td><td>Ongoing</td><td colspan="2">Rejected</td></tr>
<tr><td colspan="5">Comments (include reasons for action rejection or 'Ongoing' classification):</td></tr>
<tr><td colspan="2">Revised Action Response Due Date**</td><td colspan="3"></td></tr>
</table>

NB. Please return this form to the HAZOP Co-ordinator.

* Delete as required.
** Applicable only to 'Ongoing' actions or 'Rejected' responses.

	Rutherford Appleton Laboratory **R&D Hydrogen Delivery System** **HAZOP Action Tracking Form**		
HAZOP Action No.	21	By	MH
Response Date			

HAZOP Action: Confirm whether bursting disc would create ignition source on activation

HAZOP Action Response:

Response Made By	Name (Print):	Signature:	Date:
Response Checked By	Name (Print):	Signature:	Date:
Action Status (circle)	Accepted	Ongoing	Rejected

Comments (include reasons for action rejection or 'Ongoing' classification):

Revised Action Response Due Date**	

NB. Please return this form to the HAZOP Co-ordinator.

* Delete as required.
** Applicable only to 'Ongoing' actions or 'Rejected' responses.

	Rutherford Appleton Laboratory R&D Hydrogen Delivery System HAZOP Action Tracking Form		
HAZOP Action No.	22	By	MH
Response Date			

HAZOP Action: Consider the inclusion of a non-return valve downstream of the burst disc to avoid pressure surge from RV10 or RV23 activation

HAZOP Action Response:

Response Made By	Name (Print):	Signature:	Date:
Response Checked By	Name (Print):	Signature:	Date:
Action Status (circle)	Accepted	Ongoing	Rejected

Comments (include reasons for action rejection or 'Ongoing' classification):

Revised Action Response Due Date**	

NB. Please return this form to the HAZOP Co-ordinator.

* Delete as required.
** Applicable only to 'Ongoing' actions or 'Rejected' responses.

	Rutherford Appleton Laboratory **R&D Hydrogen Delivery System** **HAZOP Action Tracking Form**		
HAZOP Action No.	23	By	MH
Response Date			

HAZOP Action: Consider installation of flow meter(s) / indication device to alert low/ no flow from nitrogen bottle around nitrogen jacket circuit
HAZOP Action Response:

Response Made By	Name (Print):	Signature:	Date:
Response Checked By	Name (Print):	Signature:	Date:
Action Status (circle)	Accepted	Ongoing	Rejected

Comments (include reasons for action rejection or 'Ongoing' classification):

Revised Action Response Due Date**	

NB. Please return this form to the HAZOP Co-ordinator.

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<table>
<tr><td></td><td colspan="4">Rutherford Appleton Laboratory
R&D Hydrogen Delivery System

HAZOP Action Tracking Form</td></tr>
<tr><td>HAZOP Action No.</td><td>24</td><td>By</td><td colspan="2">MH</td></tr>
<tr><td>Response Date</td><td colspan="4"></td></tr>
<tr><td colspan="5">HAZOP Action: Consider fitting non-return valve to prevent hydrogen flow into nitrogen system on activation of RV10 or RV23</td></tr>
<tr><td colspan="5">HAZOP Action Response:</td></tr>
<tr><td>Response Made By</td><td>Name (Print):</td><td>Signature:</td><td colspan="2">Date:</td></tr>
<tr><td>Response Checked By</td><td>Name (Print):</td><td>Signature:</td><td colspan="2">Date:</td></tr>
<tr><td>Action Status (circle)</td><td>Accepted</td><td>Ongoing</td><td colspan="2">Rejected</td></tr>
<tr><td colspan="5">Comments (include reasons for action rejection or 'Ongoing' classification):</td></tr>
<tr><td colspan="2">Revised Action Response Due Date**</td><td colspan="3"></td></tr>
</table>

NB. Please return this form to the HAZOP Co-ordinator.

* Delete as required.
** Applicable only to 'Ongoing' actions or 'Rejected' responses.

	Rutherford Appleton Laboratory **R&D Hydrogen Delivery System** **HAZOP Action Tracking Form**		
HAZOP Action No.	25	By	AJ
Response Date			

HAZOP Action: Review need for protection/location of gas bottles to prevent vehicle (or other) impacts
HAZOP Action Response:

Response Made By	Name (Print):	Signature:	Date:
Response Checked By	Name (Print):	Signature:	Date:
Action Status (circle)	Accepted	Ongoing	Rejected

Comments (include reasons for action rejection or 'Ongoing' classification):	
Revised Action Response Due Date**	

NB. Please return this form to the HAZOP Co-ordinator.

* Delete as required.
** Applicable only to 'Ongoing' actions or 'Rejected' responses.

	Rutherford Appleton Laboratory **R&D Hydrogen Delivery System** **HAZOP Action Tracking Form**				
HAZOP Action No.	26		By	AJ	
Response Date					
HAZOP Action: Review methods to minimise condensation on hydrogen pipework					
HAZOP Action Response:					
Response Made By	Name (Print):	Signature:		Date:	
Response Checked By	Name (Print):	Signature:		Date:	
Action Status (circle)	Accepted	Ongoing		Rejected	
Comments (include reasons for action rejection or 'Ongoing' classification):					
Revised Action Response Due Date**					

NB. Please return this form to the HAZOP Co-ordinator.

* Delete as required.
** Applicable only to 'Ongoing' actions or 'Rejected' responses.