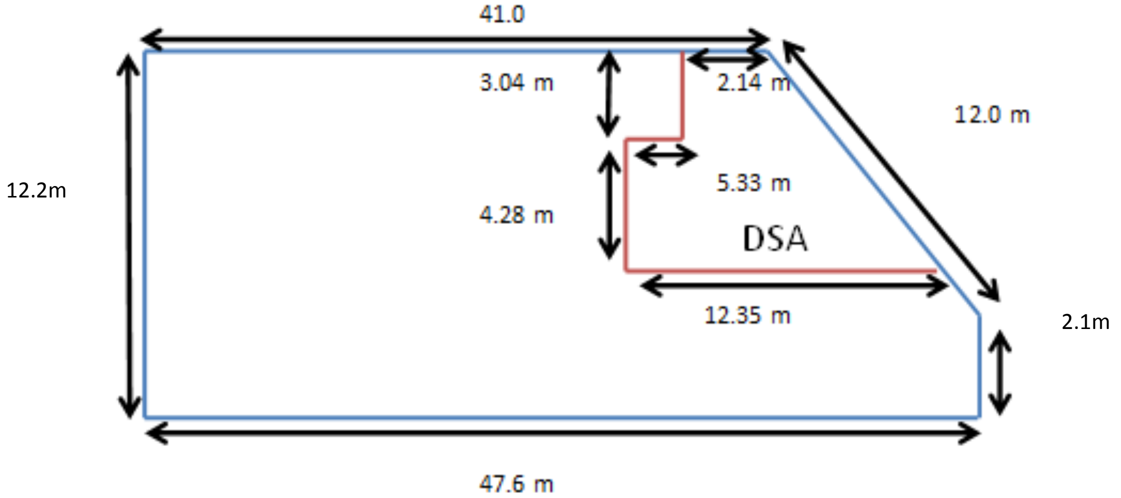
O_2 depletion hazard in the MICE Hall

Assumptions

MICE Hall Infrastructure

Plan View



Side View

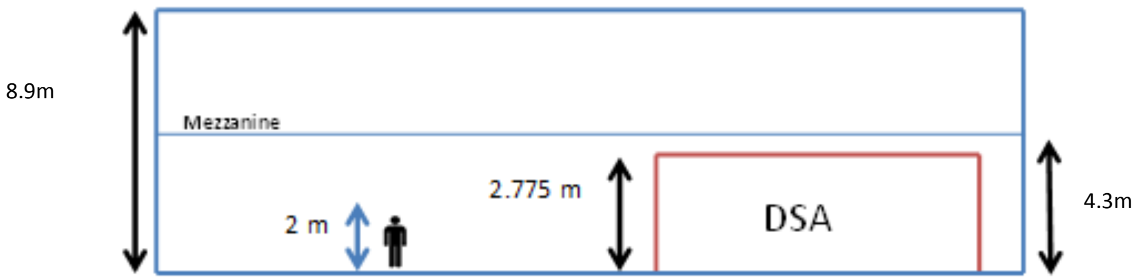


Figure 1: MICE hall geometry

The volume of the MICE hall was calculated based on the geometry in

Figure 1. It is assumed that 10% of the volume used will be taken up with objects (magnets, cupboards etc).

There is an extractor fan in the roof of the MICE Hall which results in 0.8 air changes per hour[1].

Cryogen behaviour

The expansion ratios for liquid helium (LHe) and liquid nitrogen (LN_2) to gas respectively are 1:757 and 1:696[2].

[1] 'Cryogens in the MICE hall', Tim Hayler

Magnet Capacities

Table 1: Cryogen volumes used in MICE magnets

Magnet	**LN_2 Pre-cool**		**LHe Fill**		**LHe released during quench** *(litres)*
	Liquid Volume (litres)	Operation Time *(hrs)*	Liquid Volume Boil-off (litres)	Operation Time *(hrs)*	
Focus Coils	-	-	300	1	20
Spectrometer Solenoid	3000	40	1090	6	190
Coupling Coil	-	-	-	-	25.5

Case 1: Pre-cooling and filling the Spectrometer Solenoid

Part A:

Assumptions

The Spectrometer Solenoids (SS) will be pre-cooled with LN_2 which will pass through the magnet and will be directed into a vent line that exits the MICE hall. Thus no oxygen deficiency hazard is associated with this step.

Part B:

Assumptions

The SS will be then be filled with LHe – a large proportion of this will immediately boil off and will directed into a vent line that exits the MICE Hall. Thus no oxygen deficiency hazard is associated with this step.

Case 2: Filling Focus Coil

Assumptions

The Focus Coil (FC) is initially cooled using cryocoolers, and then filled with LHe. During the LHe fill some of the helium immediately boils off and is vented into the MICE hall.

Helium above 40K is less dense than air and would rise. If we assume that no one is on the upper mezzanine, the worst-case scenario would be if it mixed evenly with the entire volume of air– this is possible due to the air conditioning in the hall.

Since staff could be going on the upper mezzanine, the scenario where all the helium rises and settles in only the upper volume of the hall (above the mezzanine) is also considered. This scenario would be redundant if the air conditioning was known to cause sufficient mixing of air in the Hall. The air conditioning will be running when the focus-coil magnets are filled.

[2] 'Safe use of Cryogenic materials', STFC Safety Code No 3, Rev 1.2 May 2013

Case 3: Single Spectrometer Solenoid Quench

Assumptions

During initial commissioning of the magnets, a quench will cause a large volume of cold helium gas to be released into the MICE hall from a single SS magnet within a few minutes.

This gas would be released under pressure (i.e. turbulently) and experience tells us that this gas tends to rise. If we assume that no one is on the mezzanines, the worst-case scenario is that the gas mixes evenly throughout the hall volume. The impact of the air-conditioning is discounted as the air-conditioning units are not interlocked to the power supplies and the dispersal of the helium gas by the air-conditioning units would not have an impact on the lowest oxygen levels immediately following the quench.

Since staff could be going on to the mezzanines, the scenario where all the helium rises and settles in only the upper volume of the hall (above the mezzanines) is also considered. This scenario would be redundant if the air conditioning was known to cause sufficient mixing of air in the Hall. While the air-conditioning units will be on during operation, they are not interlocked to the magnet power supplies.

Case 4: Beamline Quench Step IV

Assumptions

During a beamline quench a large volume of cold helium gas would be released into the MICE hall from two SS magnets and the FC magnet within a few minutes.

This gas would be released under pressure (i.e. turbulently) and experience tells us that this gas tends to rise. If we assume that no one is on the mezzanines, the worst-case scenario is therefore that the gas mixes evenly throughout the volume of the Hall. The impact of the air-conditioning is discounted as the air-conditioning units are not interlocked to the power supplies and the dispersal of the helium gas by the air-conditioning units would not have an impact on the lowest oxygen levels immediately following the quench.

Since staff could be going on the upper mezzanine, the scenario where all the helium rises and settles in only the upper volume of the hall (above the mezzanine) is also considered. This scenario would be redundant if the air conditioning was known to cause sufficient mixing of air in the Hall. While the air-conditioning units will be on during operation, they are not interlocked to the magnet power supplies.

Case 5: Beamline Quench Cooling Demonstration

Assumptions

During a beamline quench a large volume of cold helium gas would be released into the MICE hall from two SS magnets and two FC magnets within a few minutes.

This gas would be released under pressure (i.e. turbulently) and experience tells us that this gas tends to rise. If we assume that no one is on the mezzanines, the worst case scenario is therefore that the gas mixes evenly throughout the hall volume. The impact of the air-conditioning is discounted as the air-conditioning units are not interlocked to the power supplies and the dispersal of the helium gas by the air-conditioning units would not have an impact on the lowest oxygen levels immediately following the quench.

Since staff could be going on the mezzanines, the scenario where all the helium rises and settles in only the upper volume of the hall (above the mezzanine) is also considered. This scenario would be redundant if the air conditioning was known to cause sufficient mixing of air in the Hall. While the air-conditioning units will be on during operation, they are not interlocked to the magnet power supplies.

Summary

	Upper mezzanine out of bounds **OR** air conditioning causes even mix of Helium *(He mixes evenly)*	Staff on upper mezzanine *(Helium rises)*
Case 1: Pre-cooling the Spectrometer Solenoid	21.0	-
Case 1: Filling the Spectrometer Solenoid	21.0	21.0
Case 2: Filling Focus Coil	20.0	19.1
Case 3: Single Spectrometer Solenoid Quench	20.3	19.7
Case 4: Beamline Quench Step IV	19.5	18.2
Case 5: Beamline Quench Cooling Demo	19.5	18.0

Implications

SHE CODE 3 recognises symptoms for asphyxiation when the O2 levels drop below 19.5%. SHE group advised that it is acceptable for staff to work in an area where, in a failure scenario, the O_2 level could drop to between 19-19.5%, so long as there are suitable warning systems in place to alert them and they immediately left the area[3].

Operation should not include scenarios where people could be exposed to atmospheres of less than 19% oxygen.

Applying the SHE CODE to the MICE Hall implies that the mezzanines should be out of bounds when both spectrometer solenoids are powered at the same time. This condition will be enforced by the PPS system since the MICE Hall will be searched and locked during magnet powering.

[3] Matt Dickson, private communication