



# RHIC Service Building ODH Analysis USI and RHIC ASE additions

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# Introduction

- On August 1, 2023 at 12:31PM an electric arc formed in a feedthrough in the blue valve box in building 1004B.
- This blew a hole in the feedthrough and the adjacent bellows causing helium to vent into the vacuum jacket of the valve box.
- The pressure relieve vented the helium out of the building as designed.
- However, helium was directed at the manhole cover thermally shocking the seal causing it to leak helium into the building.
- The bellows also leaked helium into the building.
- The ventilation fans were on during the event due to the heat. No ODH detected by in place system or by Fire/Rescue's monitors.



# Introduction

- The ODH hazard in the service building was not adequately analyzed in the CAD SAD.
- We are submitting 2 USIs to address the ODH hazard analysis in the RHIC service buildings due to the cryo system
  - One for scrubbing – this USI will not need the approval of the site office.
  - One for cryo operations – this USI requires additional credited controls not in the RHIC ASE.
- We will NOT be addressing the causes of the arc. That is another review for another committee.
- These USIs analyze the ODH hazard – for which this event presents the worst case during cryo operations. This event is not possible during scrubbing.



# What does the SAD say?

- Section 4.17.3 is the relevant section.
- **“The six Service/Support buildings do not need controls;** however, the C-AD conservatively posts them as ODH 0 areas to raise ODH awareness because of the large inventory of helium in the buildings and for consistency with the ODH controls that were in place until the FY10 run. **In the summer of 2009, the C-AD modified the cryogenic valve-box’s vacuum relief valves in the Service/Support buildings to direct the relief exhaust gas directly outside the building instead of into it.** Additionally, Lexan boxes now encase the valve-box’s electrical lead penetrations, directing any helium release towards the buildings’ ceilings. **These changes prevent a significant release of cold helium from causing an ODH condition therein. “**



Table 41 ODH Classification for Collider Buildings During Normal Operations

		Bldg.	Total Fan CFM	Frequency <sup>(1)</sup>	ODH Classification	
Building No.	Name	Vol. (ft <sup>3</sup> )	(# Fans)	(per hour)	Case A <sup>(4)</sup>	Case B <sup>(5)</sup>
1005H	Compressor Building	250,000	100,000 (4 fans)	6.4x10 <sup>-6</sup>	0	0
1005R	Refrigerator Building	240,000	50,000 (2 fans)	6.6x10 <sup>-6</sup>	1	1
1001	Collider Tunnel - 1:00	310,000	60,000 (3 fans)	2.64x10 <sup>-6</sup>	1	1
1003	Collider Tunnel - 3:00	300,000	60,000 (3 fans)	2.64x10 <sup>-6</sup>	1	1
1005	Collider Tunnel - 5:00	390,000	60,000 (3 fans)	2.64x10 <sup>-6</sup>	1	1
1006	Intersection Region	NA	NA	NA	NA	NA
1007	Collider Tunnel - 7:00	400,000	60,000 (3 fans)	2.64x10 <sup>-6</sup>	1	1
1008	Intersection Region	NA	NA	NA		
1009	Collider Tunnel - 9:00	320,000	60,000 (3 fans)	2.64x10 <sup>-6</sup>	1	1
1011	Collider Tunnel - 11:00	300,000	60,000 (3 fans)	2.64x10 <sup>-6</sup>	1	1
1002B	2:00 Support Building	70,000	32,000 (2 fans)	NA <sup>(10)</sup>	NA	NA
1004B	4:00 Support Building	113,000	44,000 (2 fans)	NA <sup>(10)</sup>	NA	NA
1006B	6:00 Support Building	85,000	32,000 (2 fans)	NA <sup>(10)</sup>	NA	NA
1008B	8:00 Support Building	75,000	32,000 (2 fans)	NA <sup>(10)</sup>	NA	NA
1010A	10:00 Support Building	110,000	22,000 (2 fans) <sup>(9)</sup>	NA <sup>(10)</sup>	NA	NA
1012A	12:00 Support Building	110,000	22,000 (2 fans) <sup>(9)</sup>	NA <sup>(10)</sup>	NA	NA

Notes:

(10) In 2009, all six service-buildings had their valve box vacuum space relief valves vented directly outside the building, **thus preventing a credible failure that would cause an oxygen deficiency in these buildings.**

**It is hard to argue that this failure is not credible anymore.....**

# What are we evaluating?

- We evaluate ODH hazards in the following buildings:
  - 1002B, 1004B, 1006B, 1008B, 1010A, 1012A
  - These buildings have 2 valve boxes in them, one for each ring.
  - The valve boxes are similar, but not identical.
- We evaluate ODH hazards in building 1004E
  - This small building has cryo equipment for the 56 MHz cavity
  - No valve boxes here
- We evaluate ODH hazards on the building 1010 Mezzanine (1010Mez)
  - This small room has cryo equipment for E-Lens
  - No valve boxes here
- We Evaluate ODH hazards under 2 scenarios
  - Scrubbing ( $T \geq 270\text{K}$ )
  - Other cryo operations ( $T < 270\text{K}$ )

# Scrubbing

- Scrubbing is an operation where gaseous helium with a temperature over 270K (26F, -3C), is flowed through the cryogenic system to remove contaminants in the cryogenic system.
- Without scrubbing, contaminants can remain in the cryogenic system and freeze during cooldown causing operational issues and necessitating a warmup to remove them.
- This operation is performed for approximately one month prior to cooling the RHIC rings down every run.
- It is not possible to have the type of valvebox failure that occurred in building 1004.
  - The warm helium does not provide enough cooling to make the RHIC rings superconducting.
  - We are not locking out the power supplies during scrubbing. The power supplies may be turned on during scrubbing. If damage were to occur to the electrical connections in the valve box, this damage would be limited to heat damage to the electrical connections.
  - There cannot be enough energy to cause an arc to rupture the pressure vessel.
- The helium inventory during scrubbing is limited to 24390 cubic feet. This includes the volume of the two rings and one gas tank with 2 bar pressure for makeup.

# Table 1: Unmitigated ODH analysis on RHIC service building during Scrubbing

Building	Net Building Volume (cubic ft.)	Maximum Helium Leak Rate (SCFM)	Min O2 level (%)	Time to minimum O2 level (minutes)	Unmitigated Fatality rate (per hour)	ODH class
1002B	71052	20.4	14.9%	1196	7.1e-10	0
1004B	73124	24.4	15.0%	1001	6.0e-10	0
1004E	2980	25.6	0%	953	1.3e-8	0
1006B	68896	20.4	14.7%	1196	1.4e-9	0
1008B	54498	20.4	13.4%	1196	9.4e-9	0
1010A	80991	24.4	15.5%	1001	2.6e-10	0
1010Mez	9300	20.4	1.6%	953	2e-8	0
1012A	83514	25.6	14.9%	1080	2.0e-10	0

All areas are classified as ODH 0.

Minimum oxygen concentration determined by building volume and inventory.



# Risk assessment

Table 2: Risk Scoring Matrix					
Point Value → Parameter ↓	1	2	3	4	5
Occupancy or Use (A)	≤once/year	≤once/month	≤once/week	≤once/shift	>once/shift
Severity (B)	First Aid Only	Medical Treatment	Lost Time	Partial Disability	Death or Permanent Disability
Likelihood (C)	Very Unlikely	Unlikely	Possible	Probable	Multiple
Fatality rate x/hr	$\leq 10^{-6}$	$10^{-6} < x \leq 10^{-3}$	$10^{-3} < x \leq 10^{-2}$	$10^{-2} < x \leq 10^{-1}$	$> 10^{-1}$
*Risk:	0 to 20	21 to 40	41-60	61 to 80	81 or greater
	Negligible	Acceptable	Moderate	Substantial	Intolerable

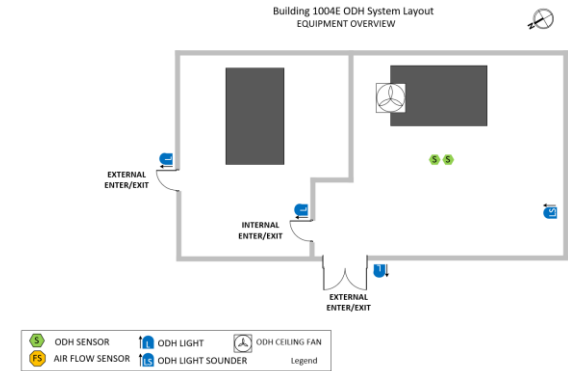
1010 Mezzanine is the worst case.  
 Assume maximum occupancy (5)  
 Consequences are the highest (5)  
 Likelihood is Very Unlikely (1)  
**Risk is  $5 \times 5 \times 1 = 25$  is Acceptable**

**No credited controls**

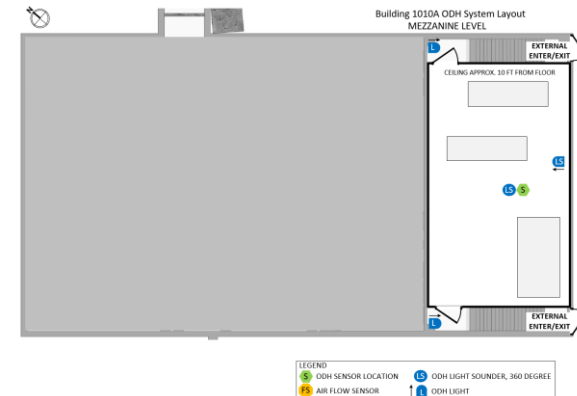
# Mitigations as required by SBMS

- Buildings 1002B, 1004B, 1006B, 1010A, 1012A
  - Only require posting as ODH0 space and training.
- Buildings 1004E and 1010 Mez
  - ODH detection system with lights and sirens inside and out.
  - System will alarm at 19.5%
  - Posting as ODH0 space
  - Training
- Buildings 1008B
  - ODH detection system with lights and sirens inside or Personal Oxygen Monitors
  - System will alarm at 19.5%
  - Posting as ODH0 space
  - Training

1004E



1010Mez



# USI Evaluation

- The ODH analysis shows that the risk of an event during scrubbing is acceptable.
- No credited controls are needed.
- Given the low fatality rates for an ODH event during scrubbing, all 6 of the USI questions evaluate to No.
- We evaluate that scrubbing does not present a USI

# Other cryo operations

- Here we evaluate all other cryo operations below  $T=270$ .
- The worst case is when the rings are at 4 K.
- In this case, we assume that the event of August 1 can occur again.
  - In fact it represents the worst case for the valve boxes.
- The analysis for buildings 1004E and 1010 Mezzanine does not change in this case, except that the leak rate is increased.
  - The min ODH is 0%
  - The valve box event cannot occur in these buildings (no valve boxes!)
  - The fatality rates don't change.
  - No changes to requirements in 1004E and 1010Mez.

## Table 1: Unmitigated ODH analysis on RHIC service building during normal helium operations below 270 K

Building	Net Building Volume (cubic ft.)	Maximum Helium Leak Rate (SCFM)	Min O2 level (%)	Unmitigated Fatality rate (per hour)	ODH class
1002B	71052	1769	0%	5.75e-4	2
1004B	73124	1769	0%	6.34e-4	2
1004E	2980	128	0%	1.3e-8	0
1006B	68896	1769	0%	8.81e-4	2
1008B	54498	1769	0%	5.75e-4	2
1010A	80991	1769	0%	6.57e-4	2
1010Mez	9300	128	0%	2e-8	0
1012A	83514	1769	0%	6.47e-4	2

## Table 3: Unmitigated MCI for all service buildings during cryogenic operations

Hazard	Risk Value
ODH in service building 1004E and 1010Mez	25
ODH in service Buildings 1002B, 1004B, 1006B, 1008B, 1010A, and 1012A	50

The risk analysis for 1004E and 1010Mez is unchanged. The other buildings have a risk of 50 – moderate. This is because the likelihood is “Unlikely” – 2. They require controls.



# Mitigations for Buildings 1002B, 1004B, 1006B, 1008B, 1010A, and 1012A

- ODH monitors trigger at 19.5%
- Lights inside and outside at entrances
- Minimum of 2 fans in each building.
  - Fan speeds and ramp up times measured.
  - Slowest speed assumed for both fans in each building.
  - Rampup times vary from 15 to 105 seconds
    - Three minutes assumed for all fans
  - One fan credited for each building
  - Maintenance will be performed on the fans
- Fan flows measured by ODH system
- Dual chain systems
- UPS
- Emergency Generator
- Postings
- Training
- These are the same controls utilized for sPHENIX.

**Table 4: Mitigated ODH analysis on RHIC service buildings 1002B, 1004B, 1006B, 1008B, 1010A, and 1012A during normal helium operations below 270 K**

Building	Net Building Volume (cubic ft.)	Maximum Helium Leak Rate (SCFM)	One Ventilation Fan Flow operating at 80% capacity (SCFM)	Min O2 level (%)	Mitigated Fatality rate (per hour)	ODH class
1002B	71052	1769	10310	17.4%	7.04E-10	0
1004B	73124	1769	12260	18.0%	7.75E-10	0
1006B	68896	1769	13040	18.2%	1.08E-9	0
1008B	54498	1769	12960	18.1%	7.02E-10	0
1010A	80991	1769	8140	16.4%	8.25E-10	0
1012A	83514	1769	7610	16.1%	8.09E-10	0

**Table 5: Mitigated MCI in service buildings 1002B, 1004B, 1006B, 1008B, 1010A, and 1012A during cryogenic operations**

Hazard	Risk Value
ODH in service Buildings 1002B, 1004B, 1006B, 1008B, 1010A, and 1012A	25

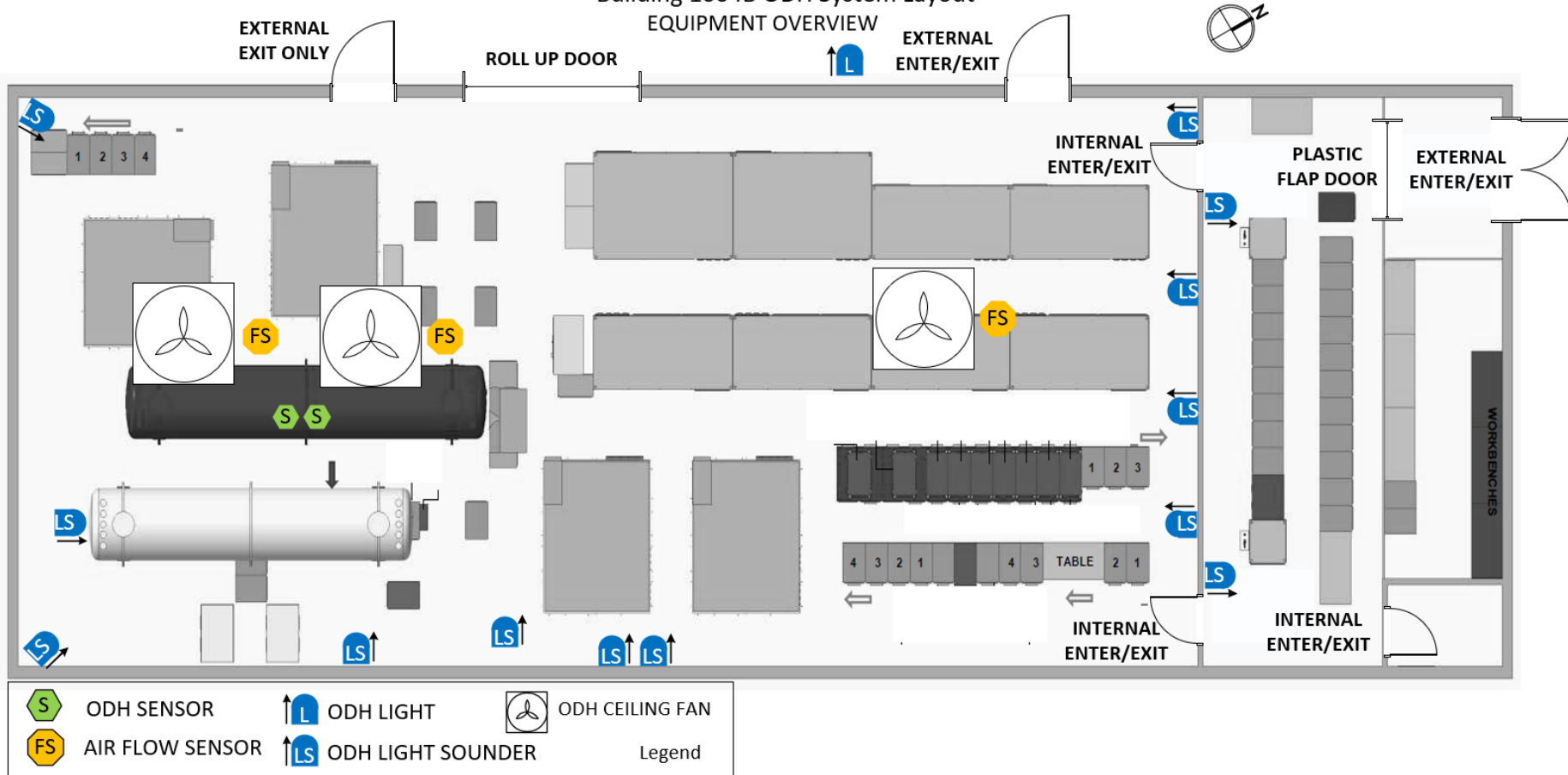
Mitigations reduce the risk to 25 – Acceptable.

Taking credit for a second fan does not appreciably change the Fatality Rate, but they do raise the oxygen concentration to 18.6% in the worst case. (1010A)

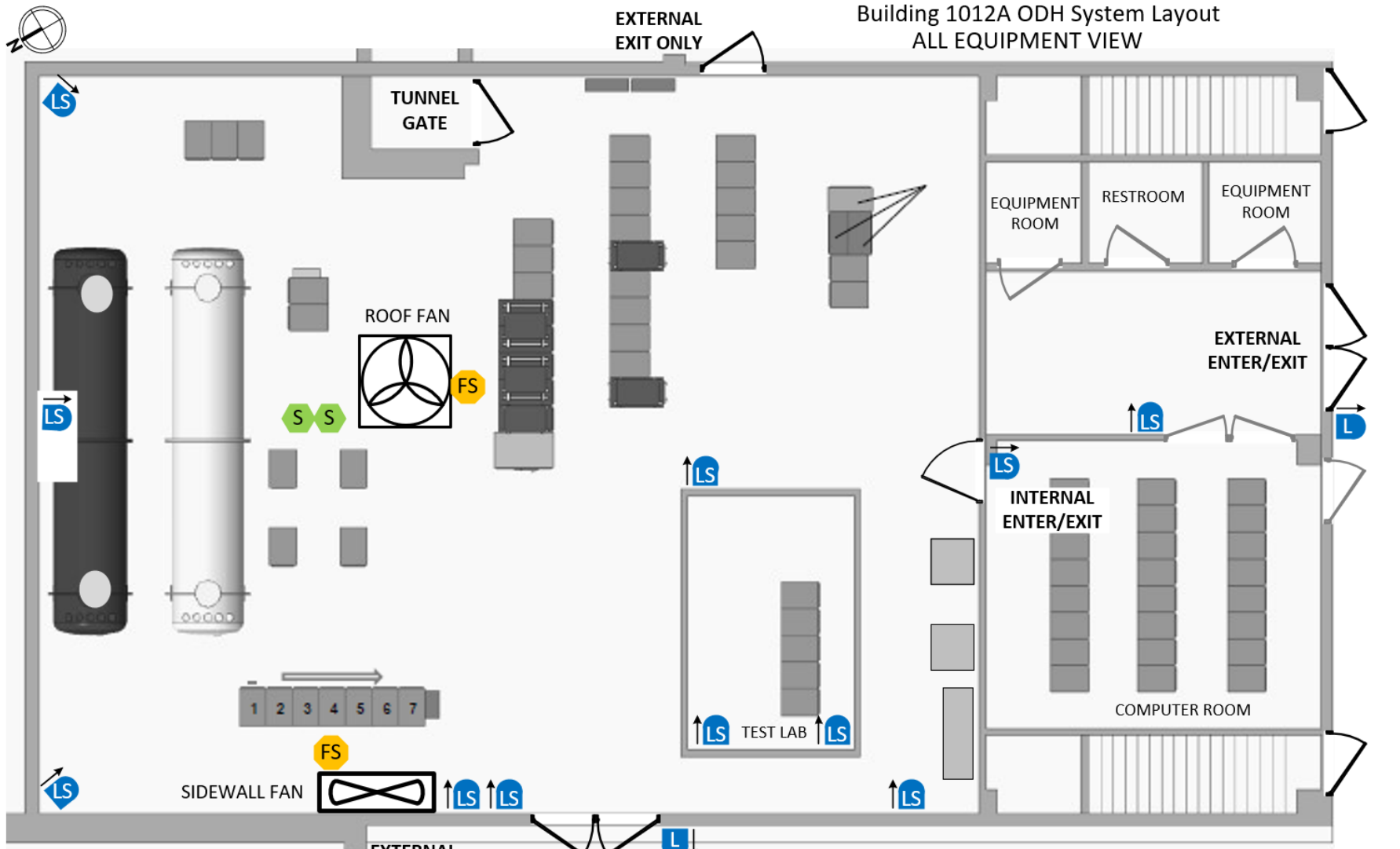


# Zooming in on 1004

Building 1004B ODH System Layout  
EQUIPMENT OVERVIEW



# Zooming in on 1012A



LEGEND

- S ODH SENSOR
- FS AIR FLOW SENSOR
- LS ODH LIGHT SOUNDER
- L ODH LIGHT
- ODH CEILING FAN
- ODH SIDE WALL FAN



# USI Evaluation

- The ODH analysis shows that the probability of an event during cryogenic operations is significantly increased from the SAD
- The ODH analysis shows that the consequence of an event during cryogenic operations is significantly increased from the SAD
- The possibility of an electrical arc in a feedthrough in the valve box was not considered in the SAD.
  - An arc in the magnet cryostats was!
- The ODH systems that are presently in place are considered defense in depth controls. Now they are augmented and elevated to credited controls.
- 4 of the 6 questions are “Yes”

# New Credited Controls Building 1002B

- When helium with a temperature below 270 K is present in Building 1002B, at least one chain of the Building 1002B ODH system must be capable of providing local audio and visual alarms and turn on a ventilation fan capable of achieving at least 10310 SCFM within 3 minutes.
- When helium with a temperature below 270 K is present in Building 1002B if redundancy in the ODH monitoring and alarming system or ventilation has been lost, access and activities in those areas shall be limited to those necessary to restore ODH system redundancy.
- Building 1002B ODH monitoring and alarming system shall be functionally tested at an interval not to exceed 15 months.
- Building 1002B Ventilation Fans Flow Meters must undergo annual calibration check (not to exceed 15 months).
- When helium with a temperature below 270 K is present, the Building 1002B ODH UPS shall be functionally tested monthly.
- When helium with a temperature below 270 K present, the Backup Diesel Generator for building 1002B ODH systems shall be functionally tested monthly.

Controls for other buildings are word for word the same except for the building number\*, and the fan speed.

A total of 35 controls are added.

# One Modified ASE control

- The building 1008 Generator is already in the ASE to support the sPHENIX ODH system.
- This control needs a small modification from  
“Backup Diesel Generator for buildings 1008A and 1008F ODH system shall be functionally tested monthly.”  
to  
“Backup Diesel Generator for buildings 1008A, 1008B, and 1008F ODH system shall be functionally tested monthly.”

# Conclusion

- On August 1, 2023 at 12:31PM an electric arc formed in a feedthrough in the blue valve box in building 1004B potentially causing an ODH condition in the building.
- The CAD SAD does not adequately analyze the hazard in the service buildings.
- 2 USI Evaluations were performed to analyze the hazard under different conditions.
  - Scrubbing – during scrubbing no credited controls are required.
  - Normal Operations – buildings 1002B, 1004B, 1006B, 1008B, 1010A, 1012A require credited controls
- The controls have been presented for each service building.