Managing fire safety of Battery Electric Vehicles (BEVs) in underground mines

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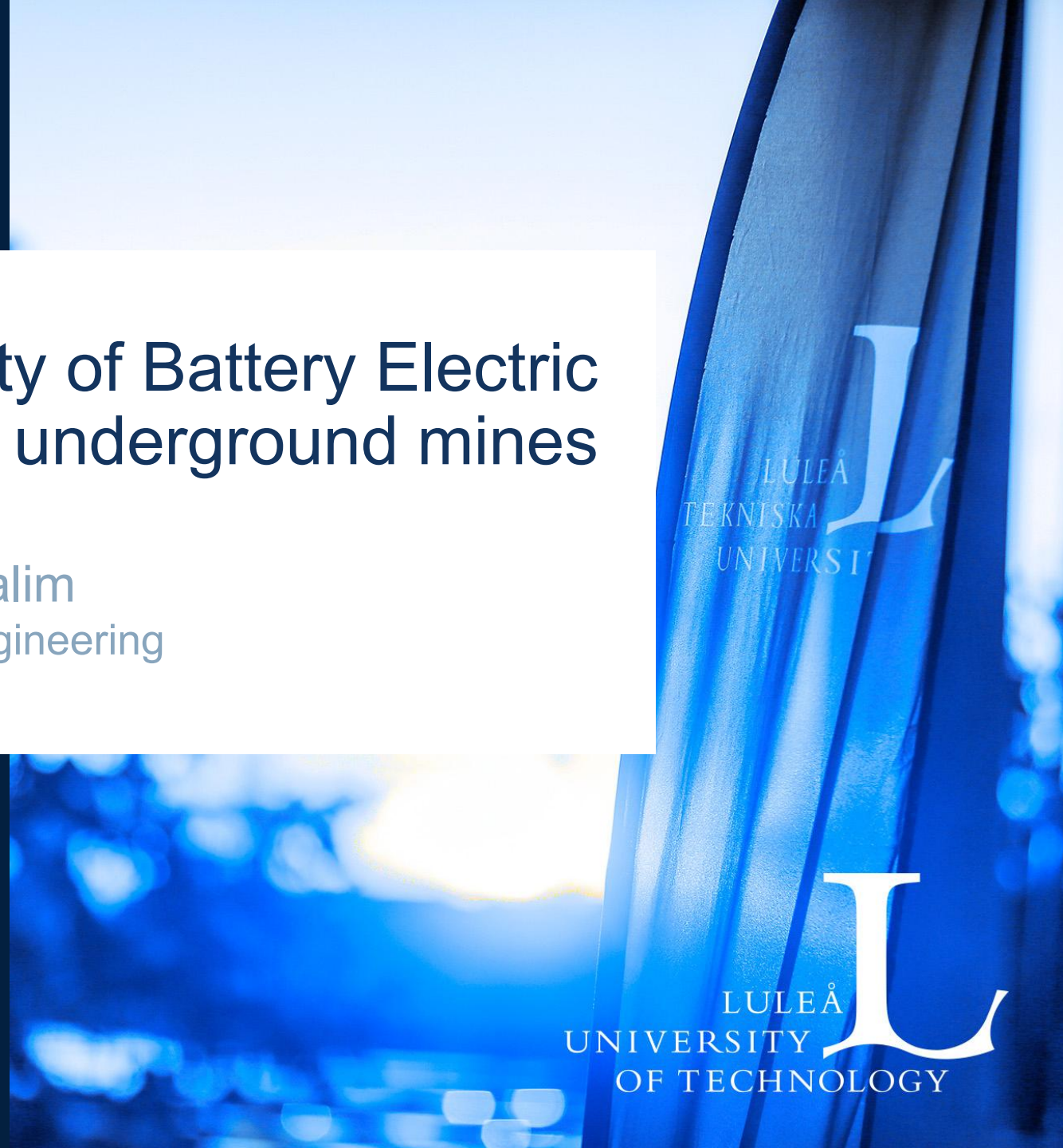
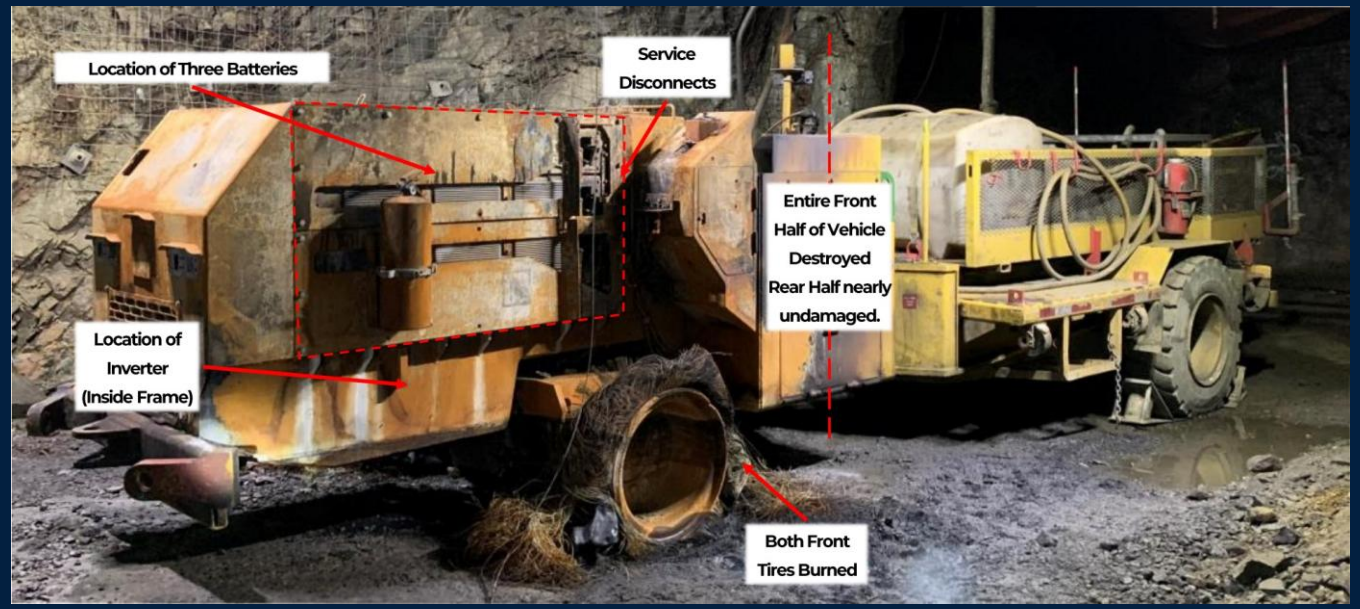


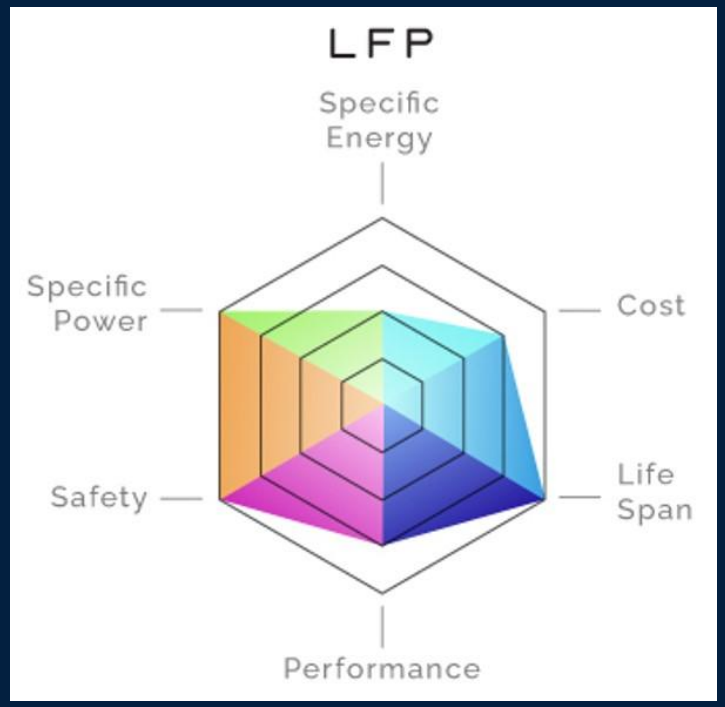
UG Mines BEV fires – What are still not understood?

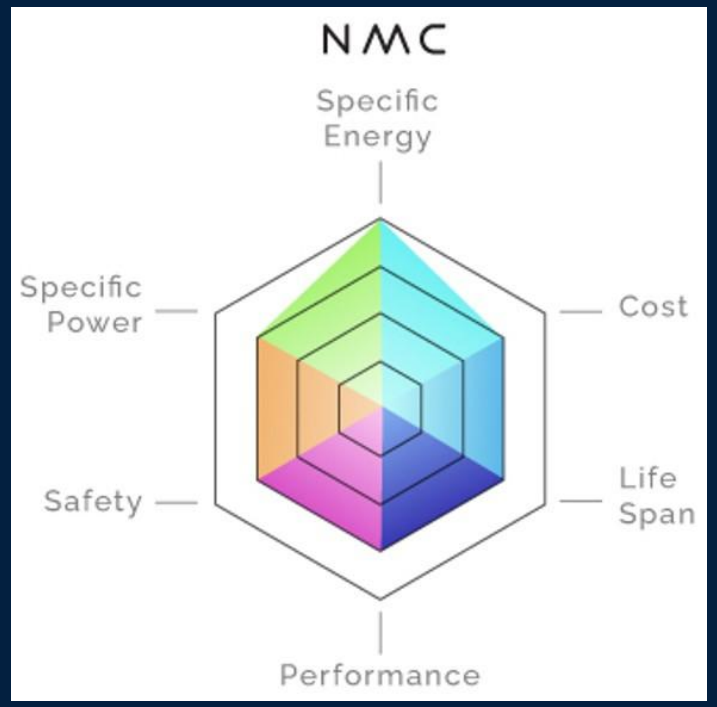
- How to extinguish a UG mines BEV fire quickly?
- How to simulate a UG mines BEV fire accurately?
- How to manage fire in a charging bay?

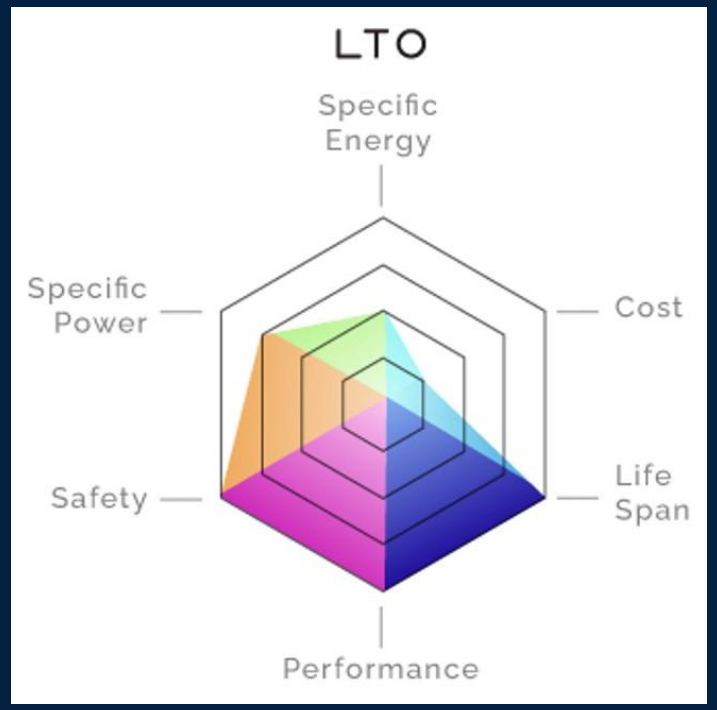


Glencore, 2020

Battery chemistry is not the main factor in thermal runaway risk!







https://elements.visualcapitalist.com

- No Epiroc BEVs has been involved in fire incidents in UG mines up to date
- This indicates that the design of the battery pack is the main factor instead of battery chemistry

Full scale fire test is the key to fully understand UG mines BEV fires

Why should it be relied upon instead of laboratory test?

- It is the only way to investigate combustion of all combustibles within a BEV, not just the battery
- It is the only way to obtain accurate input data for fire simulation
- It is the only way to properly trial manual firefighting techniques

Sturm et al, 2021

NO FULL SCALE FIRE TESTS HAVE BEEN DONE ON MINING BEVs

WE SHOULD LEARN FROM FULL SCALE TESTS ON ROAD BEVs IN THE MEANTIME

Full scale fire tests on road BEV that are relevant to UG mines

Test provider	Tested BEV	BEV was burnt itself out?	Battery chemistry	Objective of the test	Major finding
RISE Sweden[1)]	Small SUV	No	NMC	To quantify the toxicity of the used extinguishing water	The used extinguishing water is toxic
Austrian consortium[2)]	Compact car	No	NMC	To trial two manual extinguishing tools (fire blanket and extinguishing lance) during an underground fire event	Extinguishing lance is effective to stop thermal runaway
	SUV	No	NMC		
RISE Sweden[3)]	Van	Yes	NMC	To quantify Heat Release Rate (HRR) and combustion products under the worst case scenario	• Quantification of HRR and combustion products • Significant amount of HF is released by non-battery combustibles
	Small family car	Yes	NMC		
INERIS France[4)]	French BEV 1	Yes	Not specified	To quantify Heat Release Rate (HRR) and combustion products under the worst case scenario	Preliminary quantification of HRR and combustion products
	French BEV 2	Yes	Not specified		

[1)] Hynynen et al (2023) [2)] Sturm et al (2021)
[3)] Willstrand et al (2020) [4)] Lecocq et al (2012)

Full scale fire tests on road BEV that are relevant to UG mines

Test provider	Tested BEV	BEV was burnt itself out?	Battery chemistry	Objective of the test	Major finding
DBI Denmark [5)]	Renault Fluence	No	NMC-LMO	To trial fire blanket as an extinguishing tool	Fire blanket is not effective
	Renault Fluence	No	NMC-LMO	To trial extinguishing lance as an extinguishing tool	Extinguishing lance is effective to stop thermal runaway
	Renault Fluence	No	NMC-LMO	To trial piercing device as an extinguishing tool	Piercing device is not effective
	Renault Fluence	No	NMC-LMO	To trial Jøni water curtains as an extinguishing tool	Water curtains is not effective
	Renault Fluence	No	NMC-LMO	To trial Albero water curtains as an extingushing tool	Water curtains is not effective
	Tesla 3	No	LFP	To trial low pressure water mist as an extinguishing tool	Water mist can provide indirect cooling on the battery pack
	Renault Fluence	No	NMC-LMO	To trial combination of extinguishing lance and water mist as an extinguishing tool	The combination is effective
	Nissan Leaf	No	LMO-NCA	To trial combination of extinguishing lance and fire blanket as an extinguishing tool	The combination is effective
	Renault Fluence	No	NMC-LMO	To trial combination of extinguishing lance and water curtain as an extinguishing tool	The combination is effective

[5)] Funk et al (2023)

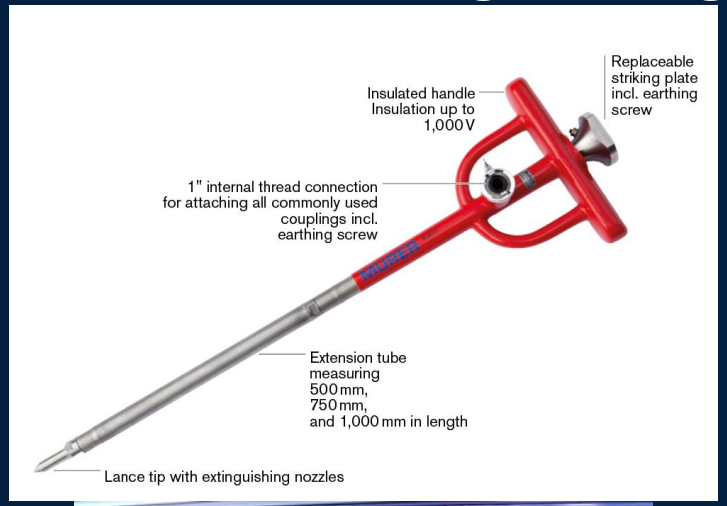
Full-scale fire test related to UG mines BEV

Test provider	Tested object	Object was burnt itself out?	Battery chemistry	Objective of the test	Major findings
RISE Sweden	Two Epiroc battery subpacks	Yes	NMC	To investigate whether an external fire (tyre fire) can initiate thermal runaway	• Took 2 hours to initiate thermal runaway in SP1 and 43 mins in SP2 • Quantification of HRR and combustion products

NEXGEN SIMS, 2024; Willstrand, 2021

Manual BEV firefighting techniques

E-löschlanze – Extinguishing lance



https://www.murer-feuerschutz.de/e-loeschlanze/

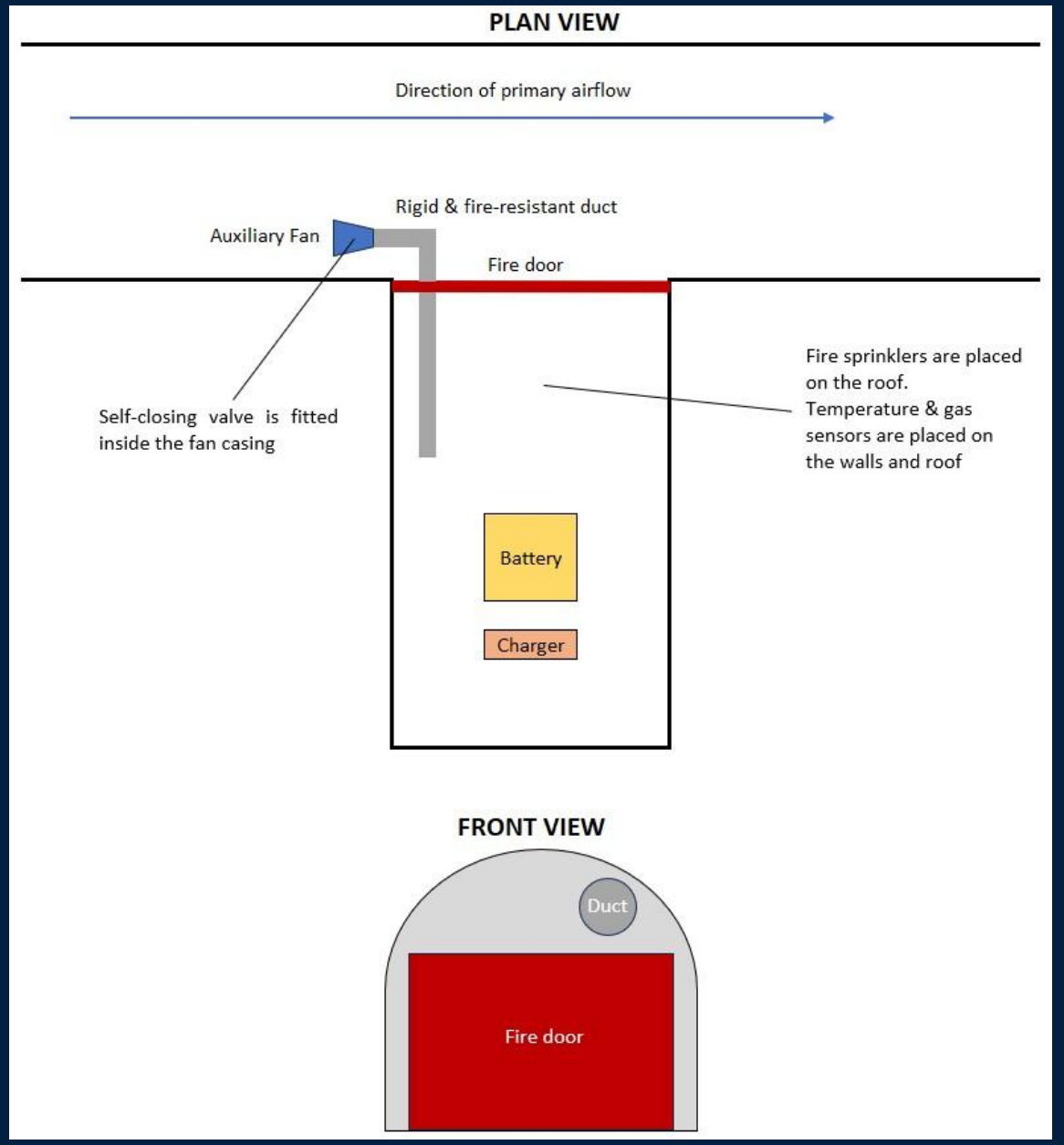
Quenching port

Courtesy of Mr. Tim Paquin from BBA Consultants Canada

Full scale test of the extinguishing lance

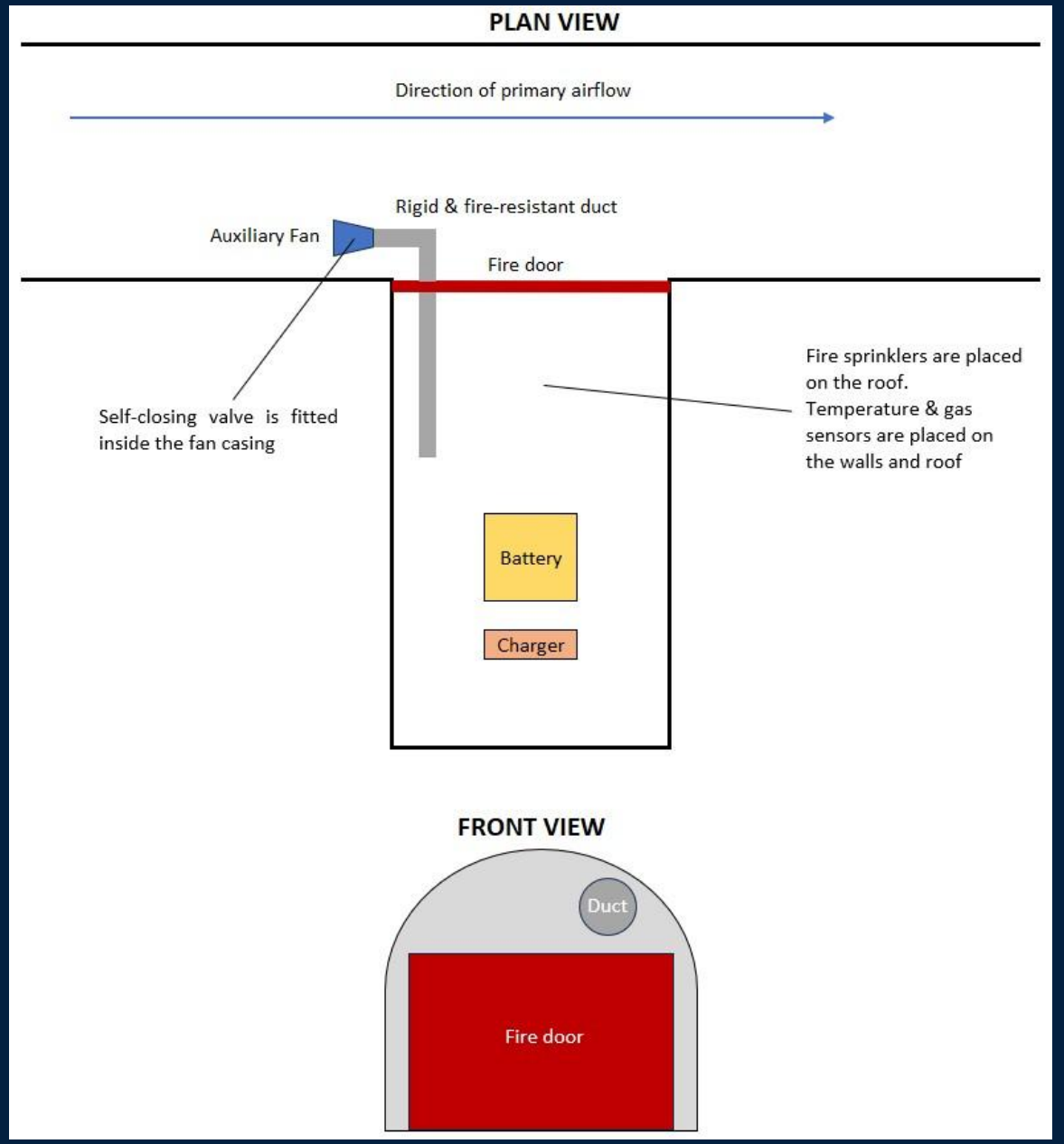
Fire safety of charging bays

- The bay should be placed inside a dead-end heading fitted with fire door, auxiliary ventilation system, fire sprinklers, temperature & gas sensors
- The bay should not be placed in a connection to primary exhaust airway because:
  - ✓ Severe consequences of rollback upon the whole mine ventilation circuit
  - ✓ The fire is very difficult to extinguish due to continuous oxygen supply
  - ✓ Charger and the battery are exposed to oil mist and dust
  - ✓ May not be possible due to BEV productivity



Fire safety of charging bays

- Oxygen starvation is the key to extinguish fire
- Need investigation on how to release combustion products
- Need investigation on how to drain extinguishing water safely
- Need investigation on how to activate the system when a person cannot exit the bay



Conclusions

- We need full scale fire tests on UG mines BEV in the near future in order to formulate adequate strategies to manage BEV fires in UG mines
- We can learn from full scale tests on road BEV in the meantime (with a grain of salt)
- Mines should prioritize prevention measures

Acknowledgement

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Questions?