SANDVIK BATTERIES
BUILT FOR MINING, ENGINEERED FOR SAFETY

MDEC 2022

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01 DESIGN AND MANUFACTURING

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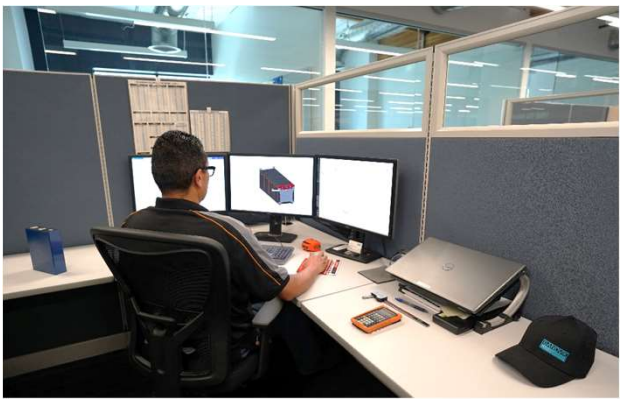
BATTERIES DESIGNED FOR MINING
PROVEN TO PERFORM



- Only OEM with in-house battery system
- Engineered specifically for UG mining
- Full control over R&D priorities, enabling rapid turnaround on customer requests
- Proven, rugged designs with over half a million operating hours underground
- 10+ years of battery expertise with Artisan®

100 MWh BATTERY FACTORY
100% DEDICATED TO MINING

- Sandvik battery factory located in Camarillo, California
- Over 100 MWh annual capacity
- High-volume flow production enables new battery production as well as rapid response to aftermarket needs
- Safety and quality culture
- Training and customer visit center

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STRATEGIC CELL SUPPLY FROM GIGAFACTORY

- One of the world's leading EV battery makers
  - Three giga-factories
    - High level of automation
      - Authorized >180 patents
      - Strategic partnership with Sandvik for mining application
  - Stringent quality and environmental control

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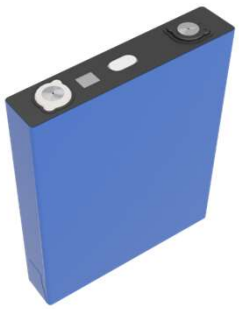
TESTED AND CERTIFIED CELLS



- ✓ Crush
- ✓ Shock
- ✓ Vibration
- ✓ Overcharge
- ✓ Thermal test
- ✓ Forced discharge
- ✓ Altitude simulation
- ✓ External short circuit

CERTIFICATIONS

- UL 1642 — Lithium battery standard
- UN 38.3 — Transport safety
- CE — HSE compliance
- IEC 62619 — Industrial application testing
- ROHS — Restriction of Hazardous substances

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02 HAZARD REDUCTION
(CELL SELECTION)

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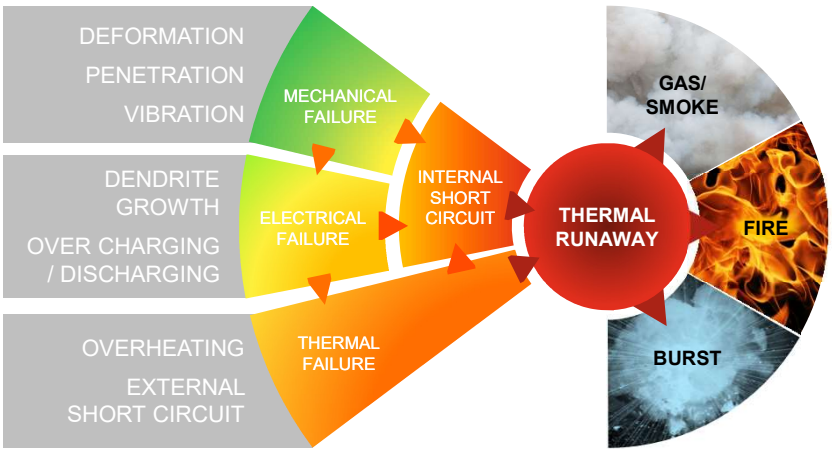
SAFETY STRATEGY FOR THERMAL RUNAWAY

MINIMIZE **LIKELIHOOD** OF AN INCIDENT THROUGH DESIGN	REDUCE INCIDENT **SEVERITY** BY USING INTRINSICALLY SAFER CHEMISTRY	MITIGATE **EFFECTS** WITH CONTAINMENT & SUPPRESSION



- 100% incident prevention is impossible
- We employ the safest chemistry to reduce severity of an incident
- Suppression systems and containment mitigate the effects of a failure
- Our safety strategy minimizes likelihood with design controls

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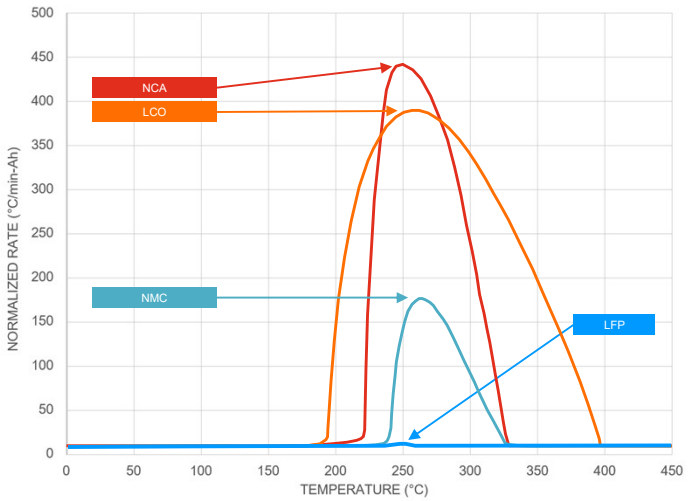
REDUCING HAZARD SEVERITY

HEAT RELEASED IN A THERMAL RUNAWAY SCENARIO



SOURCE: "New developments in battery safety for large-scale systems", Lamb et al. (2021)

- The rate of temperature rise (left) indicates severity of a thermal event
- The higher the Heat Release Rate, the harder it is to contain an incident
- The LFP rate of temperature rise is over 100x lower than other chemistries, making containment more achievable
- In thermal runaway tests, LFP cells emit flammable gaseous electrolyte but do not self-ignite
- An external ignition source, like arcing in the enclosure, can still trigger a fire

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REDUCING HARMFUL EMISSIONS

GASES FROM BATTERIES

- Lithium-ion batteries do not off-gas during normal operation, gases are produced as a result of abuse, damage, thermal runaway or fire
- In case of a fire, smoke (from burning electrolyte, plastics, rubber, paint etc.) is the primary hazard
- The new chemical to be aware of is the possible formation of HF (Hydrogen fluoride). HF can form when the fluorine ions in the electrolyte combine with hydrogen atoms from water
- LFP has been shown to produce the lowest quantities of harmful emissions (though HF gas formation is still a possibility)

NAIL PENETRATION FTIR EMISSIONS COMPARISON (PPM)

Exhaust compound	LFP	LMO	NMC
CO_2	0	0	85,959
CH_4	0	43	28
CO	4	230	4,235
NO	0	0	632
NO_2	0	0	5
NH_3	0	8	0
C_2H_6	0	25	0
C_2H_4	0	62	53
C_3H_6	0	63	280
HCL	0	0	459
CH_2O	0	19	10
HF	0	0	26,698

SOURCE: CDC (SwRI Project No. 03.24852), Jones et. al., January 8 (2021)

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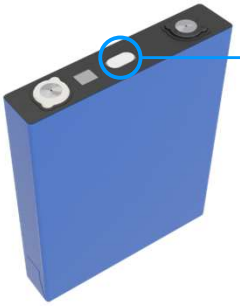
MANAGING PRESSURE RISK

CELL VENTS



- Cells in Sandvik's batteries are equipped with high reliability vents that prevent pressure build up in case of thermal runaway. Eliminating the risk of a case rupture / burst

PACK VENTS

- Gore vents and drains in the enclosure prevent pressure build up in the pack and allow vented gases to expel air in the enclosure to avoid a combustible mixture

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03 SYSTEM DESIGN

(LIKELIHOOD REDUCTION)

SYSTEM DESIGN

1. CELL
Chemical energy storage element with safe chemistry and built-in protections

2. MODULE
Low voltage for safe service. Voltage / temperature monitoring (BMS) and cooling

3. PACK
Mechanical protection, safety disconnects, isolation monitoring, fire detection and suppression

4. CAGE
Robust mechanical protection, mobility and swap-ability

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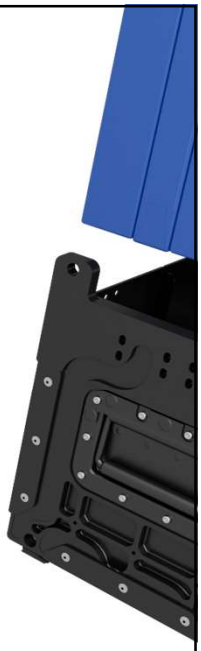
CELL SAFETY FEATURES

PRESSURE VENTS
Burst prevention

LASER WELDED ALUMINUM HOUSING
Thermal conduction and mechanical safety with mylar and polycarbonate insulation

LFP CHEMISTRY
Low heat release rate from thermal runaway



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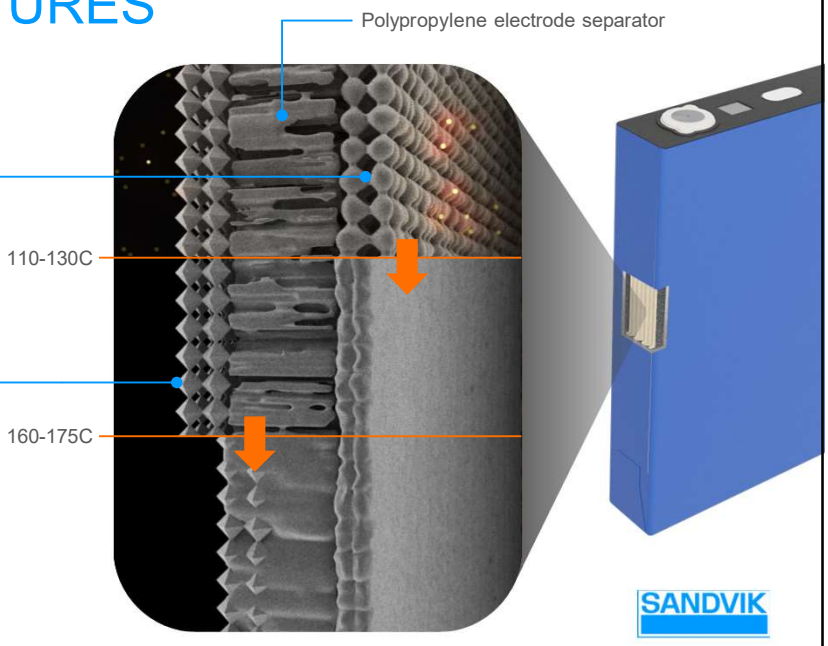
CELL SAFETY FEATURES



SHUTDOWN SEPARATOR COATING
If 110-130C is reached, this coating melts and blocks ion flow through the separator to interrupt current and prevent further temperature increase

CERAMIC SEPARATOR COATING
If 160-175C is reached the polypropylene separator will melt and bond with this porous coating to help block dendrites and provide structural support to prevent shrinkage and maintain the separation of electrodes

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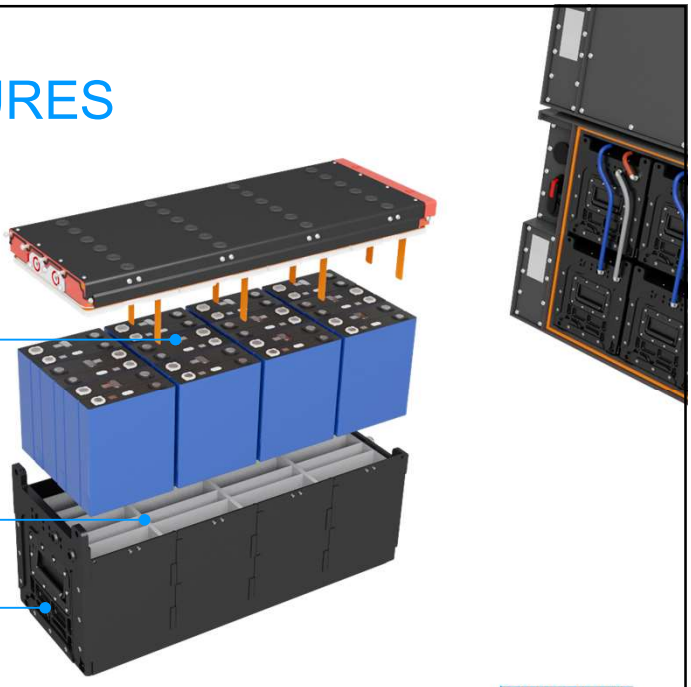
MODULE SAFETY FEATURES



ISOLATING FOAM POTTING
Blocks moisture and prevents isolation faults

THERMAL CONDUCTION
Conducts heat away from a hot cell and distributes it across the entire module

ENVIRONMENTAL PROTECTION
Keeps dust, water and contaminants away from conductors and protects against mechanical damage

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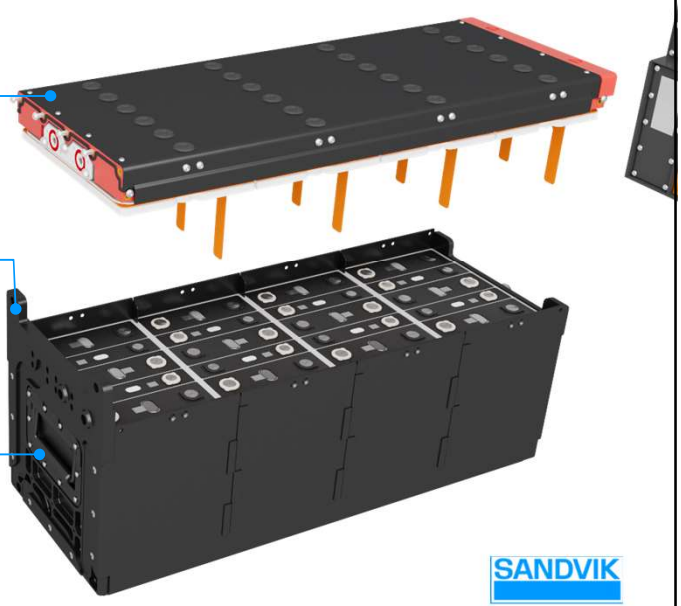
MODULE SAFETY FEATURES

BATTERY MONITORING SYSTEM
Continuous voltage and temperature monitoring. Resistive balancing to equalize State of Charge (SoC)

TOUCH- AND TOOL SAFE
No exposed live conductors, low-voltage (40V) to mitigate shock

ASSEMBLY PROOF
Only one way to assemble, reducing risk of mistakes



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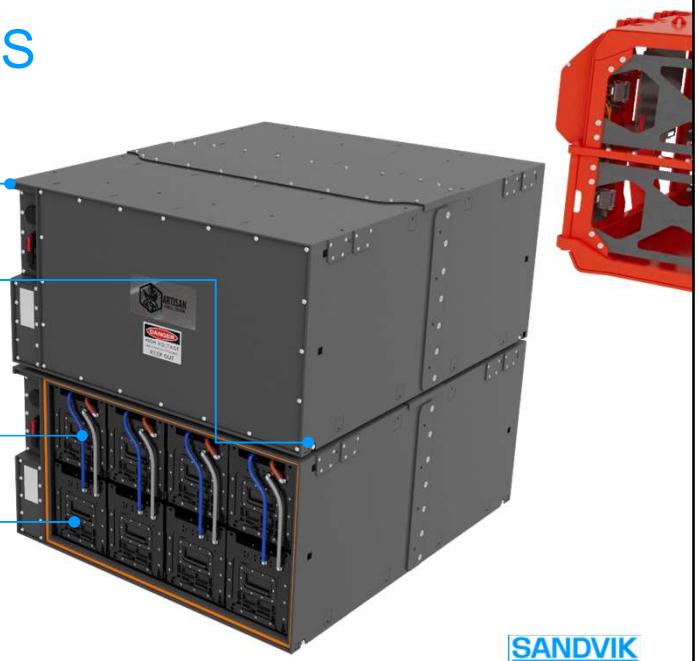
PACK SAFETY FEATURES

ROBUST
Designed for mining conditions, fabricated from 6mm plate steel

STRATEGICALLY SEALED WITH DRAINS
Limits ingress of dust and contaminants but allows fluids to drain rather than collect

COOLING
Non-conductive coolant to manage temperature during charging

SERVICEABLE
Modular, drawer-style connections, no live work needed – arc-flash safe



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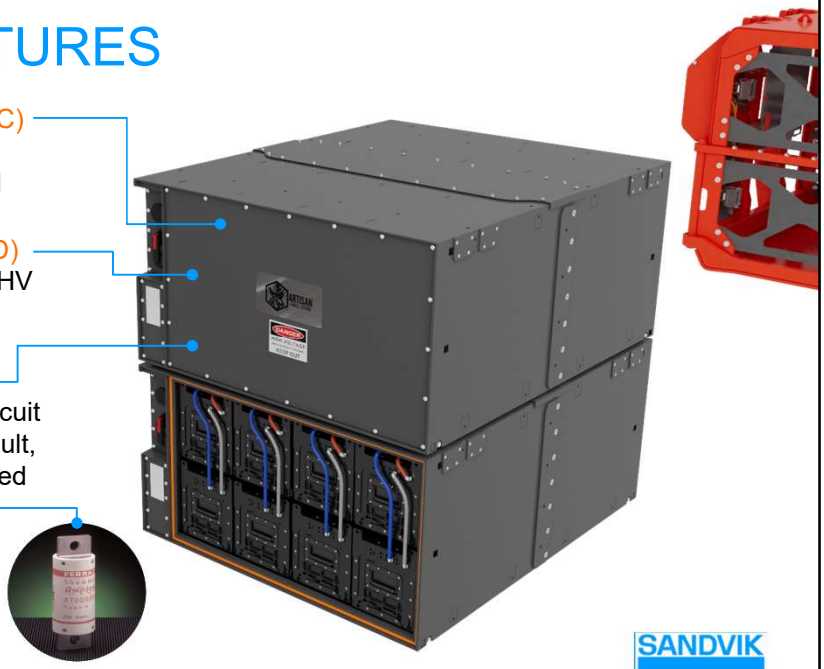
PACK SAFETY FEATURES

BATTERY SYSTEM CONTROLLER (BSC)
Monitors all safety thresholds and disconnects battery contactors if required

ISOLATION MONITORING DEVICE (IMD)
Monitors electrical isolation between the HV circuit and the chassis

BATTERY CONTACTORS
Redundant configuration (2x) to break circuit in case of over/under voltage, isolation fault, over temperature or over current. Triggered also by HVIL

600A FUSES
Overcurrent protection and protection against damage from external shorts



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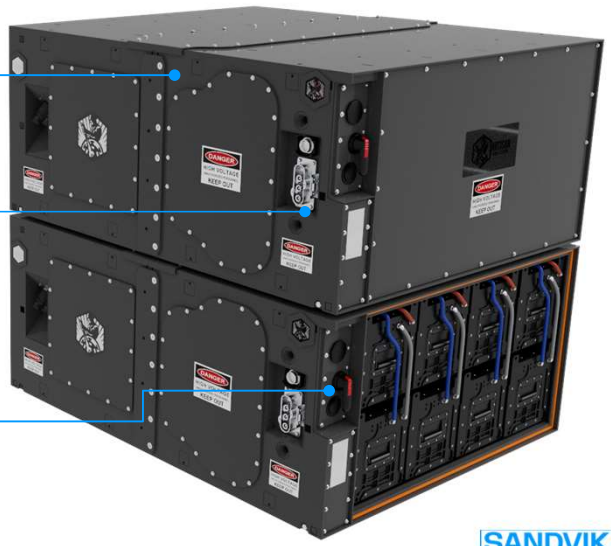
PACK SAFETY FEATURES

FIRE SUPPRESSION SYSTEM
Thermally activated, designed for electrical systems, intended to suppress fires in their early stages

HAZARDOUS VOLTAGE INTERLOCK LOOP (HVIL)
Directly depowers contactors in the event that any manually actuated electrical connection is opened

DISCONNECT SWITCH
Lockable 2-pole manual disconnect



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CAGE SAFETY FEATURES

ROBUSTNESS
Additional mechanical safety for packs

SWAPPING ABILITY
Design enables safe operation from the cabin while performing a battery change

MODULE ACCESS PANELS
Quick access to pack modules without cage disassembly

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BATTERY MANAGEMENT SYSTEM

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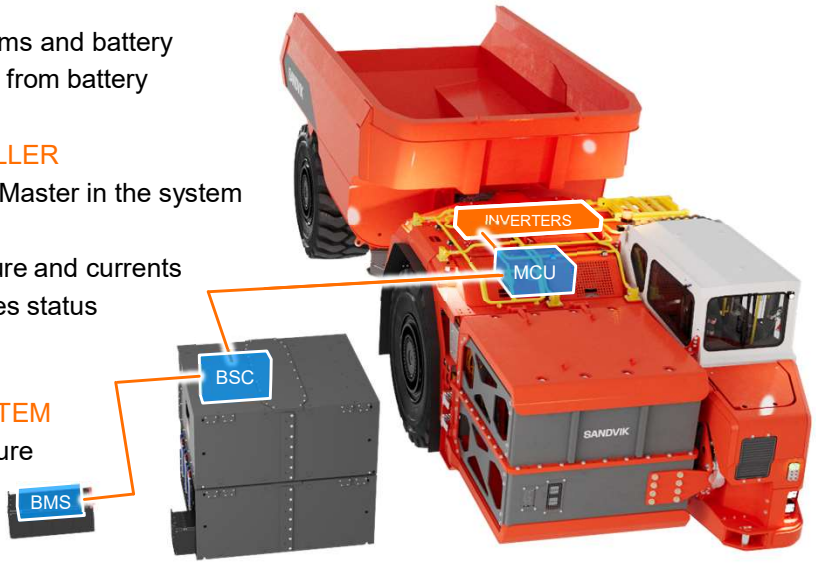
MCU: MASTER CONTROL UNIT
- Communicates with machine systems and battery
- Ensures machine is following limits from battery

BSC: BATTERY SYSTEM CONTROLLER
- Responsible for protecting battery. Master in the system
- Calculates limits / thresholds
- Monitors HVIL, isolation, temperature and currents
- Connects battery and communicates status
- Opens contactors as last resort

BMS: BATTERY MONITORING SYSTEM
- Monitors cell voltage and temperature
- Manages cell balancing
- Communicates data to the BSC

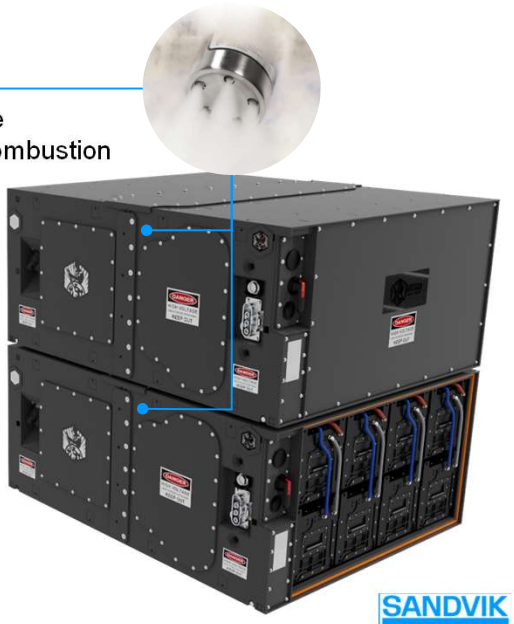


FIRE SUPPRESSION

HEAT ACTIVATED AEROSOL GENERATORS
Electrically non-conductive fire suppression system that fills the pack interior with an aerosol agent that chemically interrupts combustion

NON-DESTRUCTIVE ON DISCHARGE
Fire suppression agent does not damage the pack interior components

QUICK MAINTINENCE
Discharged media stays in the air and can be blown out of the enclosure. Used suppression canisters are simple to replace



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BUILT FOR REAL-WORLD USE

- Structural design as robust as any conventional machine
- Batteries can withstand significant impact damage without incident
- Attachment between battery cage and frame of machine is both robust and tight. LH518B battery attachment is designed to exceed ISO standard (1.5x machine weight)