



**BEV PIONEERING PARTNERSHIP AT BORDEN
– CELEBRATE THE WINS, FACE THE
CHALLENGES...TOGETHER**

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**Our purpose is to connect people with ideas to enhance life
underground and above**



- Founded in 1973 by Don MacLean
- Largest Canadian Mining Equipment Manufacturer
- Product Types:
 - Ground Support (Bolters, Shotcrete)
 - Utility Vehicles (Boom Truck, Scissor Truck, Cassette Truck, etc)
 - Ore Flow (Blockholer Drill, Water Cannon, Rock Breaker)
- Over 2000 rigs built to date
- Approaching 1000 employees globally





Introduction to MacLean EVs

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The MacLean EV fleet by end of 2019 totals 30 vehicles and will have amassed more than 30,000 hours of run time at 6 different mine sites

15 vehicles operate at Newmont Goldcorp Borden
Newmont Goldcorp and MacLean have been partners in the BEV deployment since 2016
Results from both performance and environmental/safety benefits have been very encouraging (reference Borden survey)
Adoption by other major mining companies such as Glencore and Vale is expanding the program quickly



Our approach to EV is focused on the engineered integration of best available components to meet high performance and safety

NMC battery chemistry for larger energy density, long cycle life, and fast charge/discharge rates
On board chargers up to 100 kW capacity (allows recharge of 60% SOC within 30 minutes)
Temperature management system for cooling and heating (can operate in -25C to +40C ambient)
Full vehicle CAN network to monitor entire battery drive system (feeds into MacLean VMS)



Presentation Overview

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With success also comes challenges...we face both together

- Summarize a case where a battery entered an unexpected condition that lead to a fire
- Share takeaways that should be of interest and general benefit to the entire BEV and mining industry

Incident Summary

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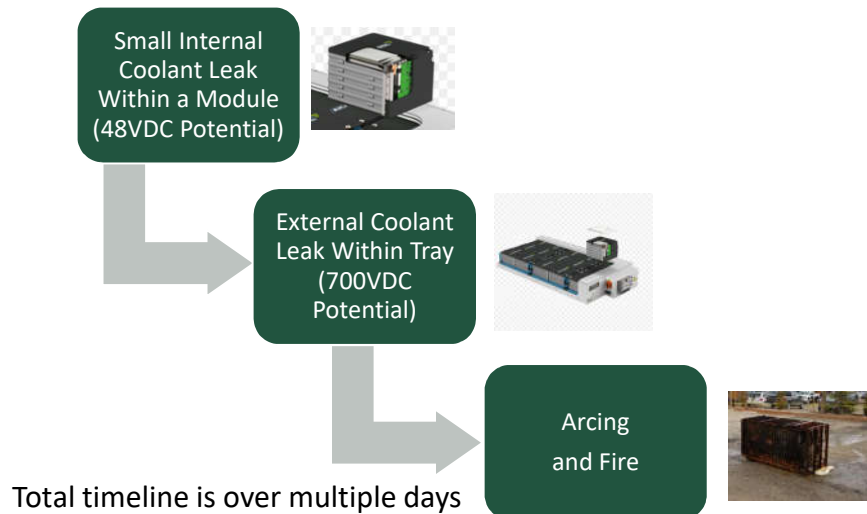
In Spring 2019 there was an incident involving a 3-tray battery pack that caught fire after it was removed from a MacLean EV unit and was sitting on surface to be returned for repair

- What occurred?
 - Battery in question had operated for 2 years
 - Battery internal temperature was <25C (ideal, not close to its thermal runaway level)
 - One tray began to arc internally causing a fire to the local area of the battery
- How did it occur?
 - Coolant leakage within the battery allowed internal conductivity of the high voltage energy source
- Why did it occur?
 - We traced the root cause to a small leak within a coolant manifold inside one module
 - Most probable cause was high coolant pressure
- How was reoccurrence mitigated?
 - Upgraded software on the MacLean VMS to detect very early symptoms of internal conductive fluid
 - Battery fault response plan to bring a faulty tray to a low voltage potential
 - Design change to cooling circuit to minimize pressure within the battery
 - Other initiatives to follow

Major Sequence of Events (Original State)



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Battery Isolation Monitoring

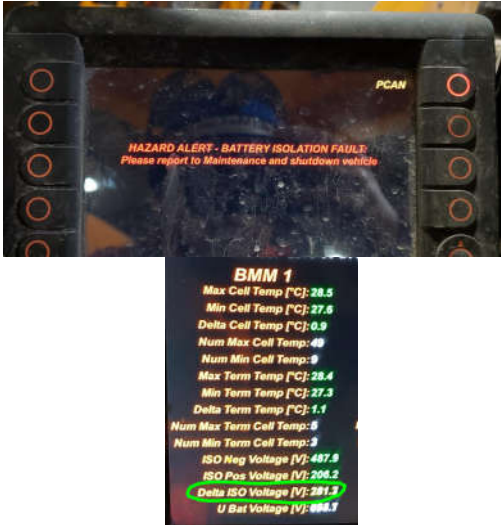
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- Each tray has its own BMS that monitors its isolation integrity at positive/negative ends
- For a 700VDC system it will read +350VDC and -350VDC within Δ0-10V
- If a conductive fluid (e.g. coolant, condensation, pressure washing) is present in the battery it can start to widen this delta by even small amounts
- Before the arcing event occurred, the voltage asymmetry exceeded Δ600V
- The BMS by the design regulation has a shutdown point set if either end is < 90V
- MacLean has adapted its VMS to use the existing data within the BMS to detect 20x earlier (if the asymmetry exceeds Δ30V and triggers an alert directly to the operator and via WiFi)



Vehicle Monitoring System Enhancements

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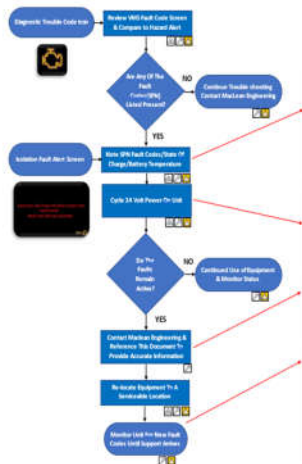


- Warning screen now appears if a battery isolation pre-fault condition is detected
- Key BMS parameters were only accessible via laptop but now Operators or Maintenance can directly view
- Values displayed are colour coded to provide guidance on severity and which tray is affected
- WiFi data upload can allow notifications via email, SMS, or other methods



Battery Isolation Fault Response Plan

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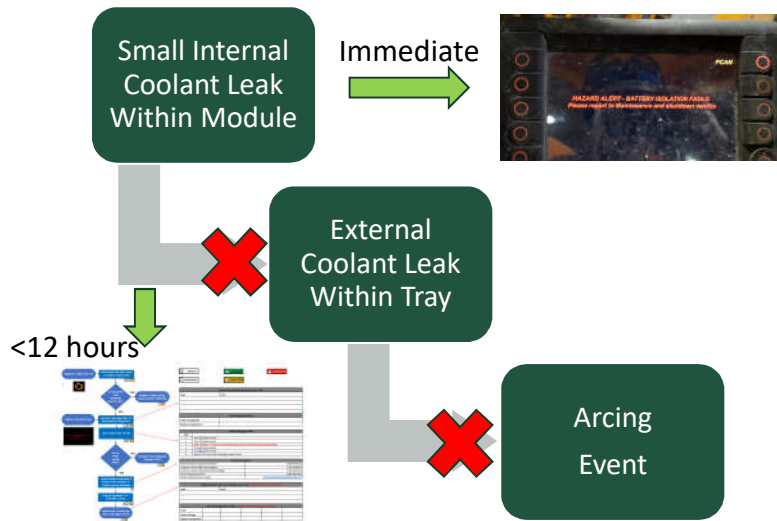


	Likelihood	Impact (EVU) Consequences			
		Minor	Moderate	Major	Max
Contained to a Single Module (Bus Bars Removed)					
Battery Assembly Removed from EV (Surface or Underground)					
EV Located Underground in Shop with Battery Assembly Isolated					
EV Located Underground in Heading with Battery Assembly Isolated					
		Risk Ranking			
Almost Certain	Defka Voltage Value (Red) & Value Increasing Over Time	L	M	H	H
Likely	Defka Voltage Value (Red) & Stable	L	M	H	H
Possible	Defka Voltage Value (Yellow) & Value Increasing Over Time	L	M	M	M
Unlikely	Defka Voltage Value (Yellow)	L	L	M	M
Rare	Defka Voltage Value (Green)	L	L	L	L

- A response plan was developed to guide the team through the appropriate steps if an alert was detected
- Following this plan keeps the team informed at every step as to the current risk level and gives instructions to reduce to lowest risk possible

Major Sequence of Events (Current State, All EV's Upgraded)

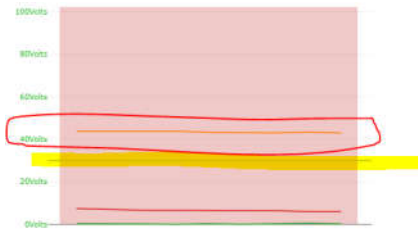
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Have These Provisions Worked?

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Early formation of isolation faults from internal coolant leaks have been found using the enhanced VMS program



Response plan is able to safely service the vehicle and return it to operation within 1 shift

Other Initiatives Low Conductivity Coolants

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Electrical conductivity is measured in uS/cm (micro-siemens per centimeter)



The lower the number the less conductive (therefore the higher the voltage required to support electron transfer)



Diesel coolants have additives and more free ions that raise the conductivity to 3000-5000 uS/cm



Drinking water has a range of 50-500 uS/cm

Water Type	Conductivity (µS/cm)
totally pure water	0.055
typical deionized water	0.1
distilled water	0.5-3.0
reverse osmosis water	50-100
domestic "tap" water	500-800
potable water	1,055 max
sea water	56,000
brackish water	100,000

Physical parameters at 20°C

Appearance	Milky, liquid, odourless	
Storage	Dry, protect from direct solar radiation and heat	
	Keep the containers tightly sealed	
Risk of explosion	The product is not explosive	
Maximum storage temperature	°C	60
Frost resistance	°C	-25
Melting point	°C	-30
Boiling point	°C	185 - 189
Vapour pressure	mbar	~ 0,1
Density	g/cm³	1,04
pH value		~ 8
Electrical conductivity	µS/cm	< 10
Specific heat	kJ/kg*K	3,7
Thermal conductivity	W/m*K	0,4
Kin. viscosity	mm²/s	5
Canister / container	l	20
Part number	-	10046559



Other Initiatives Portable Battery Monitoring

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Battery storage outside of a vehicle means it is no longer being monitored

MacLean has developed a portable version of its VMS that connects to the battery for constant monitoring

Fits within a pelican case and includes the same display as found on MacLean EV vehicles

Can be connected to any 120V power outlet



Other Initiatives Battery Safety Containers

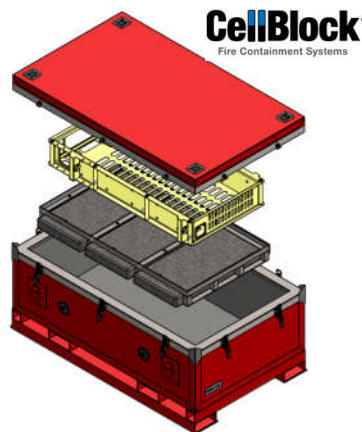


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Mines and OEMs should be giving consideration to safe handling of batteries for both ramp and cage access

In cases where a battery is considered at risk for transportation it should be placed into a properly designed safety container


OEMs of such containers are already constructing these for the EV automotive industry








Takeaways


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The adoption of BEVs is an expanding reality for underground mining and will continue
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The use of liquid cooled battery technology and advanced chemistries will become more common as the performance expectations for range, speed, and fast charging increases
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Well designed battery systems are very capable of safely handling a wide range of predicted fault conditions but abnormal cases that could occur
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Allowance for any form of conductive liquid (coolant leak, condensation, pressure washing, etc) entering a high voltage energy source has to be prevented or controlled
- 

Risk assessments, active fault monitoring, emergency response plans, and safe battery transportation and storage solutions are important ingredients to a responsible BEV program
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Partnerships and transparency within the industry between OEMs and Customers are a key part of the BEV success



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Thank You

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