



BEV RISK MITIGATION: MACLEAN APPROACH

February 9, 2023

WSN: One-Day Symposium on Battery Electric Vehicle Safety in Mines



Safety Share

Always check over your tools before doing any work, especially electrical work!



Presentation Overview

- Exciting News From MacLean
- Introduction of MacLean & MacLean Technology
- MacLean Risk Approach
- MacLean Battery Electric Vehicle Overview
- Q&A



MacLean News



- MacLean's 50th Year of Operation
- Multiple BEV Fleet Orders Including:
 - Canadian Malartic's Odyssey Mine Fleet
 - Glencore's Onaping Depth Mine Fleet
- Largest Year For BEV Production
 - 40+ BEVs to be built!



The MacLean Story

History

- Founded in 1973 in Ontario, Canada, remains privately held
- 1,000+ employees globally
- 2,400+ units commissioned to date
- World's largest Canadian-based mining OEM

Value Proposition

- Extensive hard rock mining experience
- Multi-discipline engineering
- Continental production footprint: Integrated design, manufacturing and assembly
- International sales, customer service and support



MacLean Product Lines



Utility Vehicles & Attachments

- Material Transport
- Personnel Transport
- Elevated Work Platforms
- Cassette Systems
- Graders



Bolting

- Bolters
- Small Section Bolters



Shotcrete

- Sprayers
- Transmixers
- Agitator Trucks
- Mobile Batch Plants



Ore Flow

- Explosives (Emulsion/Anfo) Loading Units
- Mobile Rock Breakers
- Secondary Ore Reduction Drills
- Hangup Removal Drills
- Water Cannons
- Scalers



MacLean Critical Technologies

Remote Systems



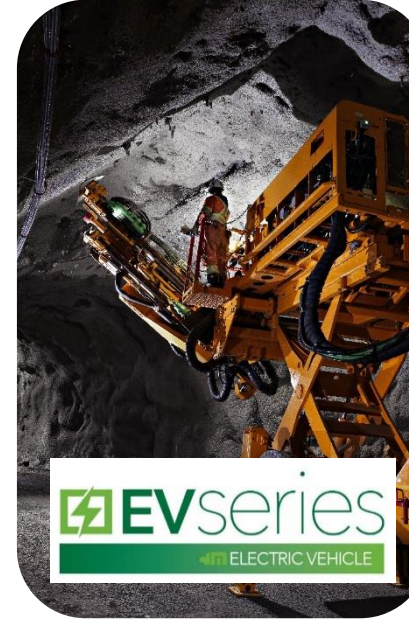
- 3 Levels of Remote
- Commonality of Hardware
- Mode Switching
- Interoperability

Digital Systems



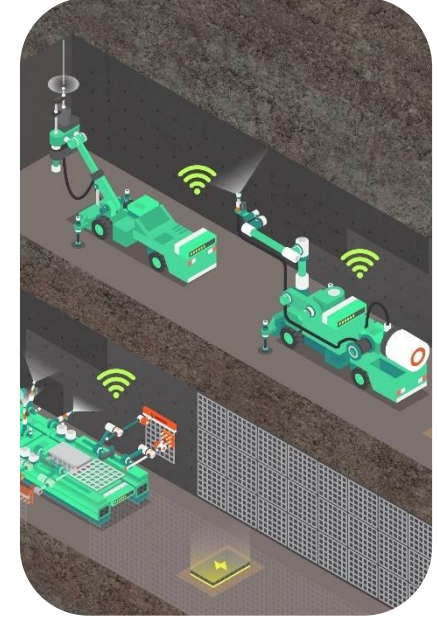
- Vehicle Telemetry
- Machine Control (5 Series)
- Customer Portal
- Data Analytics & Security
- VR Training Simulator

New Vehicle Systems



- Equipment Design
- Robotic Design
- Powertrain Design
- Application Design

Autonomous Systems



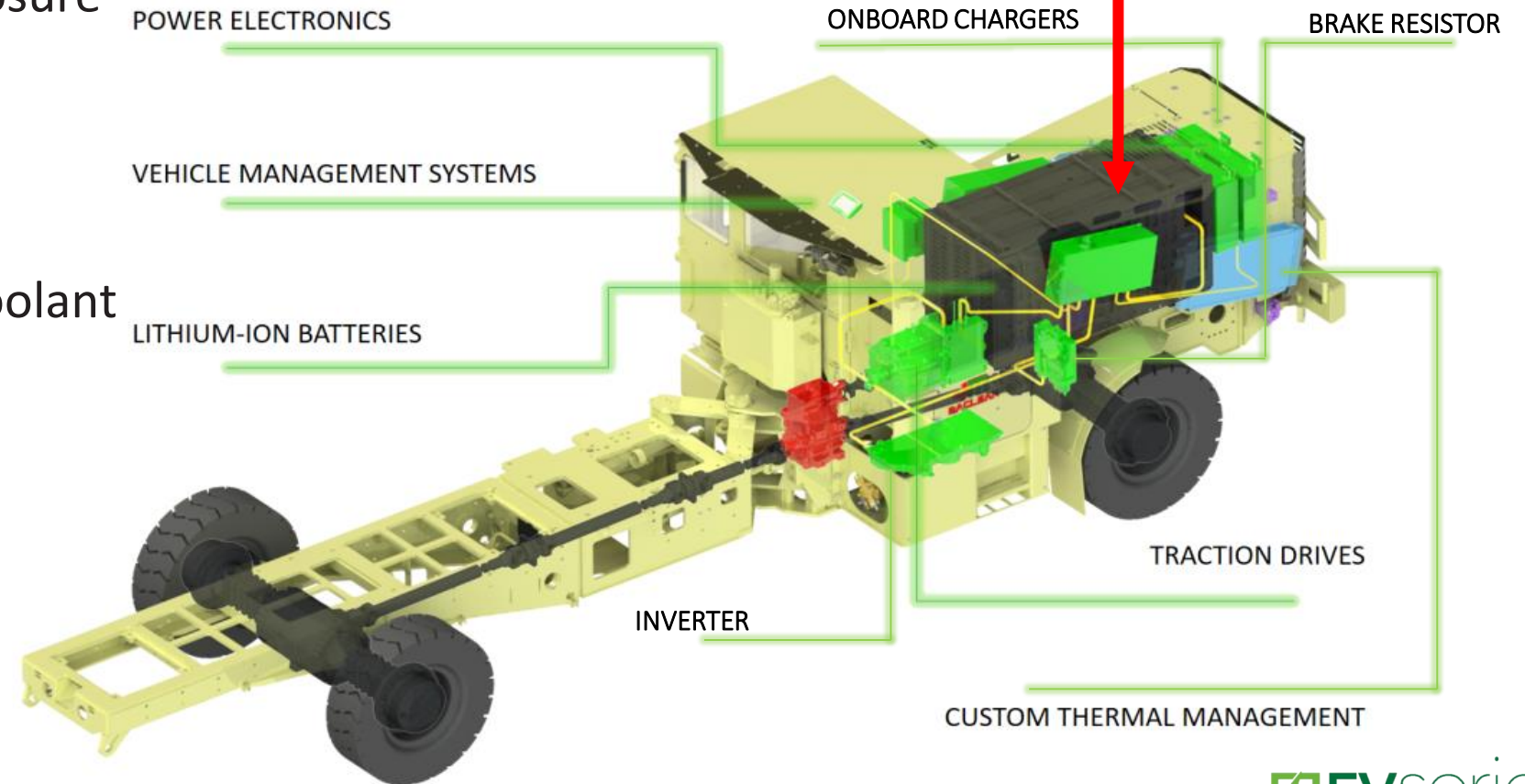
- Localization, Auto Tram & Intelligent Boom Control
- Machine Vision, Sensing & Encoding
- 3D Mapping
- Safety System



Battery Design and Location



- Centrally located within the vehicle frame
- Custom engineered steel enclosure
- Touch safe HV connections
- BMS – multiple layers of redundancy
- Custom engineered internal coolant passageways

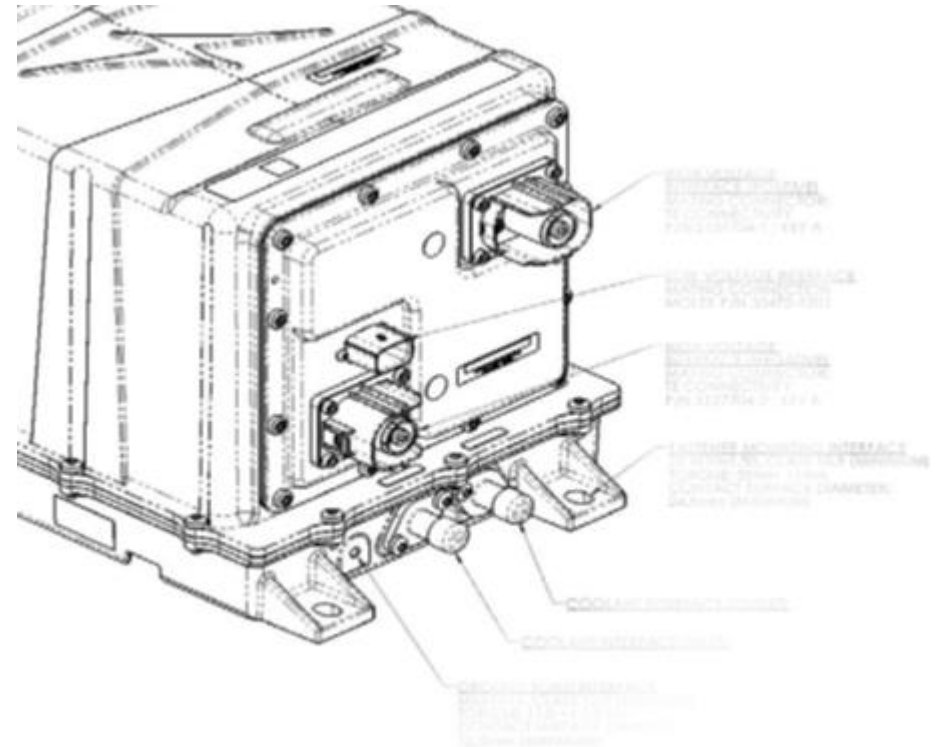


Note: This is a high-level overview, additional details available upon request.

Selecting Suppliers With A Defined Safety And Testing Culture

Environmental, Safety, and Abuse Testing

- Vibration
- Mechanical Shock
- Thermal Shock
- Ingress Protection
- Composite Heat & Humidity
- Housing Load
- External Fire
- Drop Test
- Unbalanced Overcharge
- Forced Internal Coolant Leak
- Short Circuit

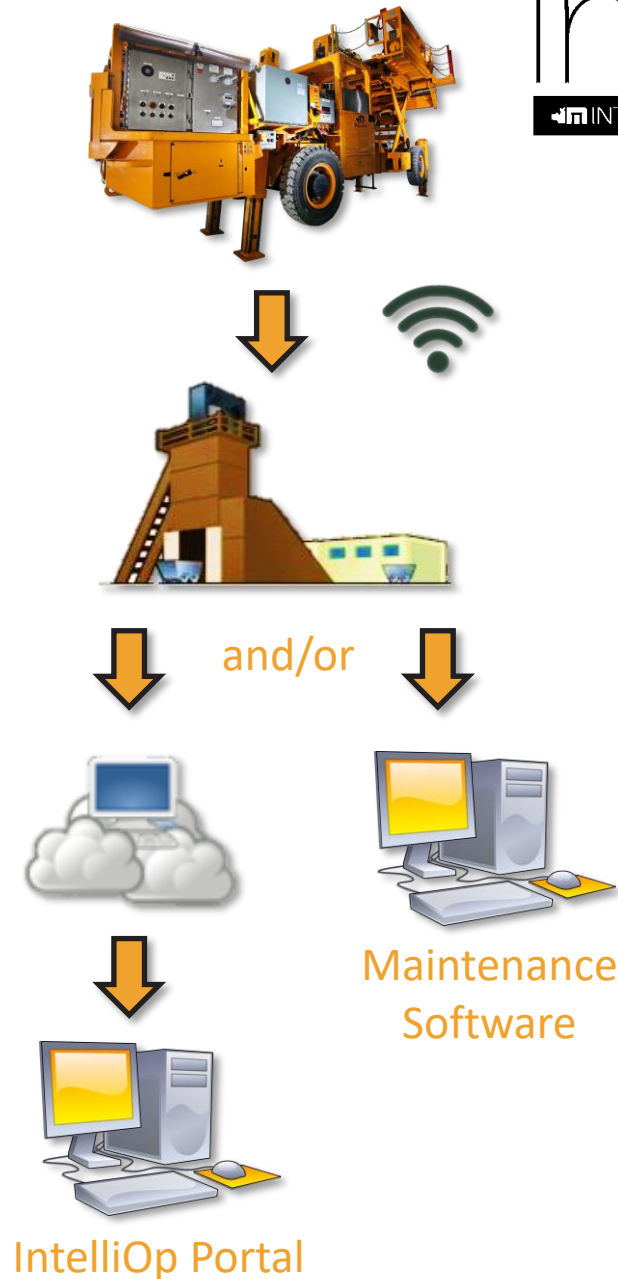


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Mine Connectivity

Telemetry is one of the most effective tools available to ensure your fleet is operating efficiently and safely.

- Basic and maintenance telemetry packages are included as a standard on all MacLean BEVs.
- Telemetry systems allow for remote diagnostics to be performed by MacLean.
- MacLean can provide automated equipment reports tailored to the needs of your operations.



Note: This is a high-level overview, additional details available upon request.

24/7 Battery Monitoring

Continuous BMS Battery Management System monitoring through MacLean onboard Vehicle Monitoring System.

This system will provide Real Time Monitoring and automatic notification generation of:

- Service or maintenance recommendations
- Circuit malfunctions
- BEV battery faults or malfunctions

Continuous monitoring (*even between shifts when no one is present*) is a safety tool in modern data Enable operations.

The equipment must be within range of the mines wireless network to receive notifications

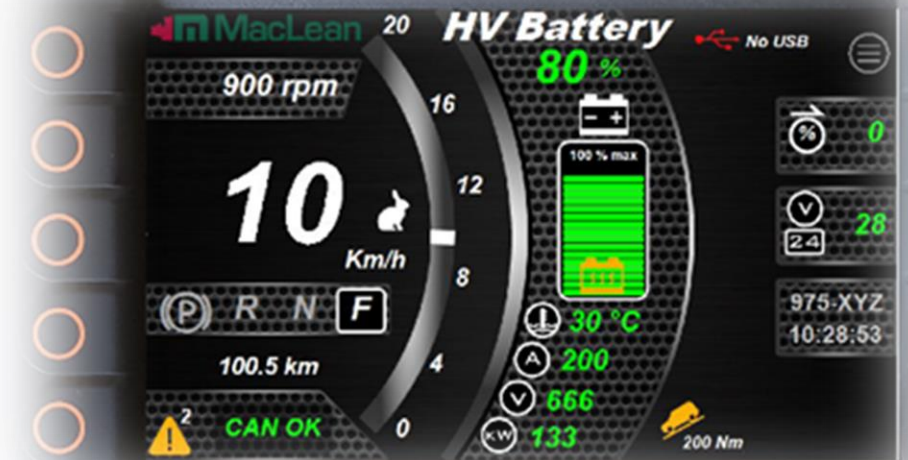


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MacLean Telemetry – IntelliOp System



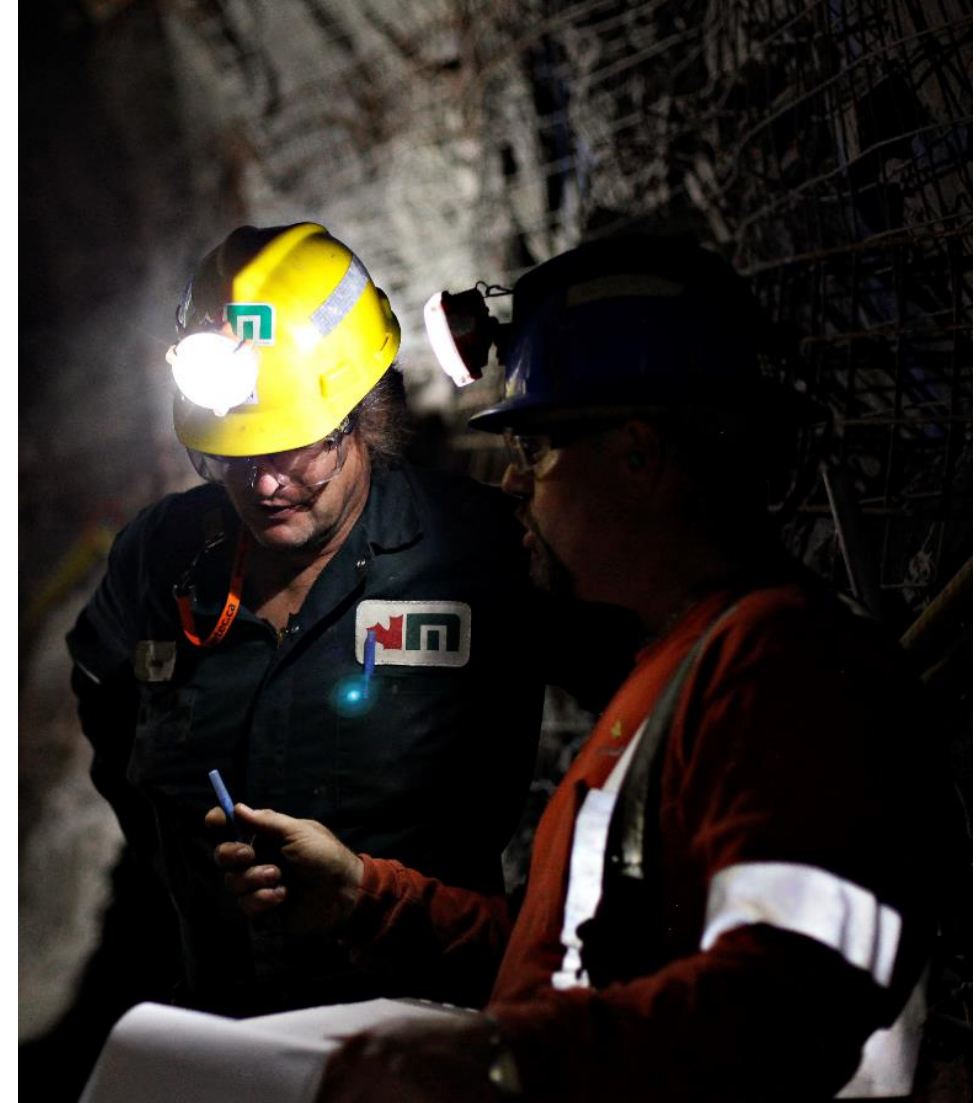
- Purpose of the MacLean's telemetry system is to provide operators and mechanics with useful live information.
- Monitoring specific sensory feedback including that of the high voltage battery system is standard on all MacLean BEVs.
- Our IntelliOp System feature:
 - Intuitive gauge cluster
 - Remote machine monitoring
 - Heads-up warnings to the operator
 - Onboard diagnostics



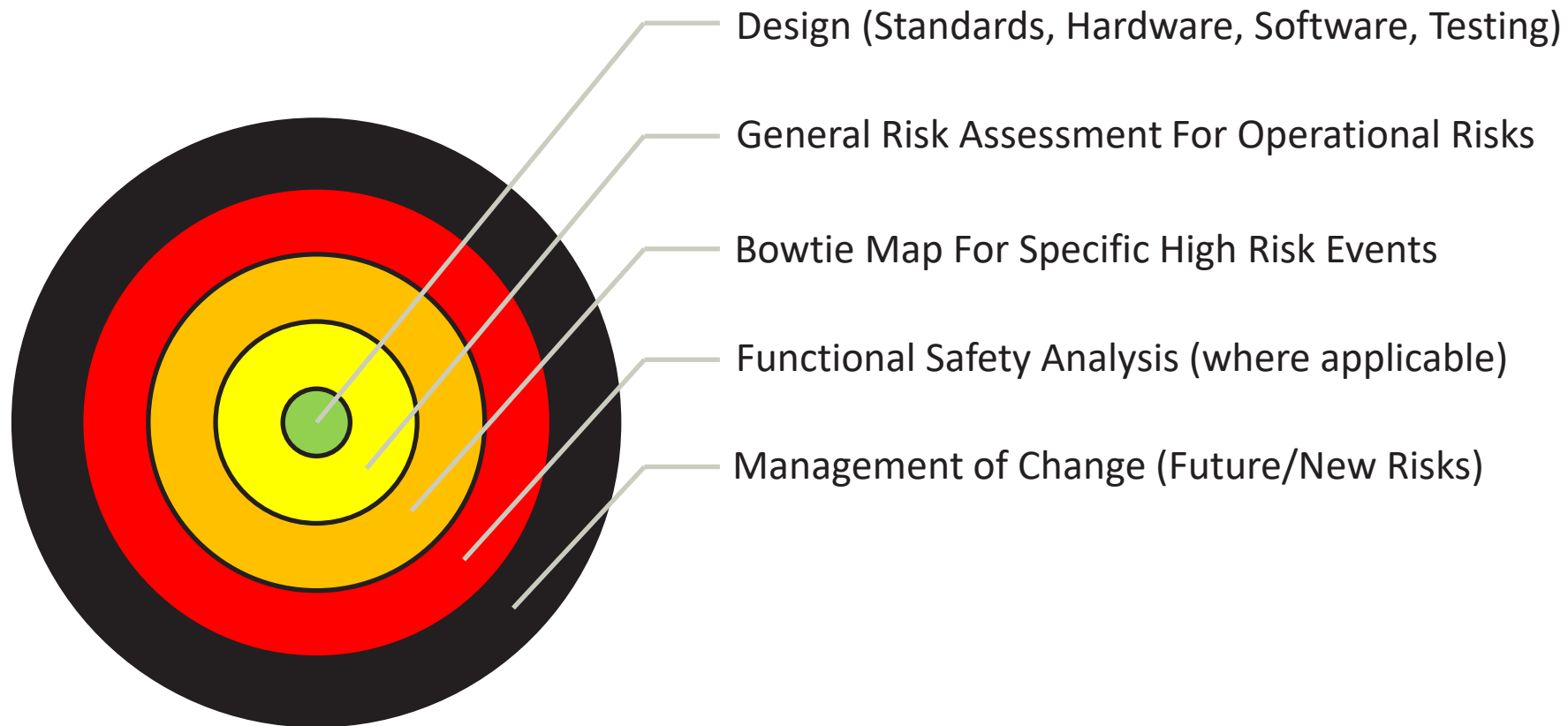
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Standards & Guidelines

- Participated in drafting GMG BEV Guidelines, Rev3.
 - *Recommended Practices For Battery Electric Vehicles In Underground Mining, Rev3*
- Participated in updating CSA standard.
 - *CSA M424-4-22 Electric Non-Gassy UG Mines*
- Staying current and designing in accordance with all BEV standards is also a primary feature of our approach to safety.



MacLean BEV Risk Assessment – Layers



Note: This is a high-level overview, additional details available upon request.

MacLean BEV General Risk Assessment For Operational Risks

- Breakdowns
- Emergency Response
- General Use
- Operating
- Planned Maintenance
- Pre-Op Check
- Storage
- Transport

Risk Assessment – General BEV Operational Risks

Risk Assessment - MacLean BEV		General Operational Risks	
Risk ID	Description	Severity	Frequency
1	Vehicle stability during operation	High	Low
2	Charging system malfunctions	Medium	Medium
3	Battery management system errors	Low	High
4	Brake system performance	Medium	Low
5	Steering and suspension issues	Low	Medium
6	Lighting and visibility	Medium	Low
7	Interior noise and vibration	Low	Medium
8	Exterior damage and aesthetics	Low	High
9	Software updates and bugs	Medium	Low
10	Customer service and training	Low	High

Risk Assessment - MacLean BEV		General Operational Risks	
Risk ID	Description	Severity	Frequency
11	Performance under load	Medium	Low
12	Range and energy efficiency	Low	Medium
13	Climate control and battery heating	Medium	Low
14	Connectivity and data collection	Low	High
15	Regulatory compliance	High	Low
16	Supply chain and component availability	Medium	Low
17	Manufacturing quality control	Low	Medium
18	Recall and warranty management	Medium	Low
19	Environmental impact and emissions	Low	High
20	Future-proofing and scalability	Medium	Low

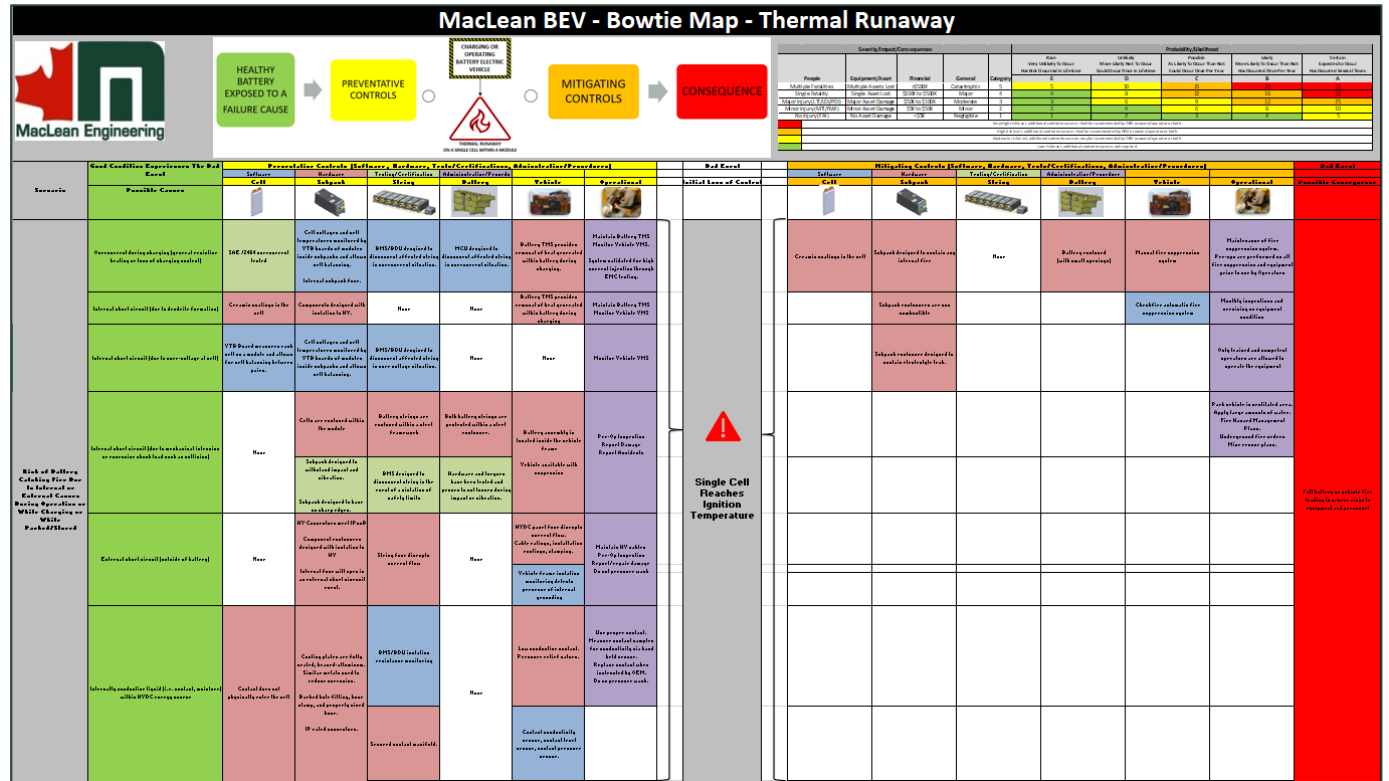


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MacLean BEV Bowtie Map For Specific High-Risk Events

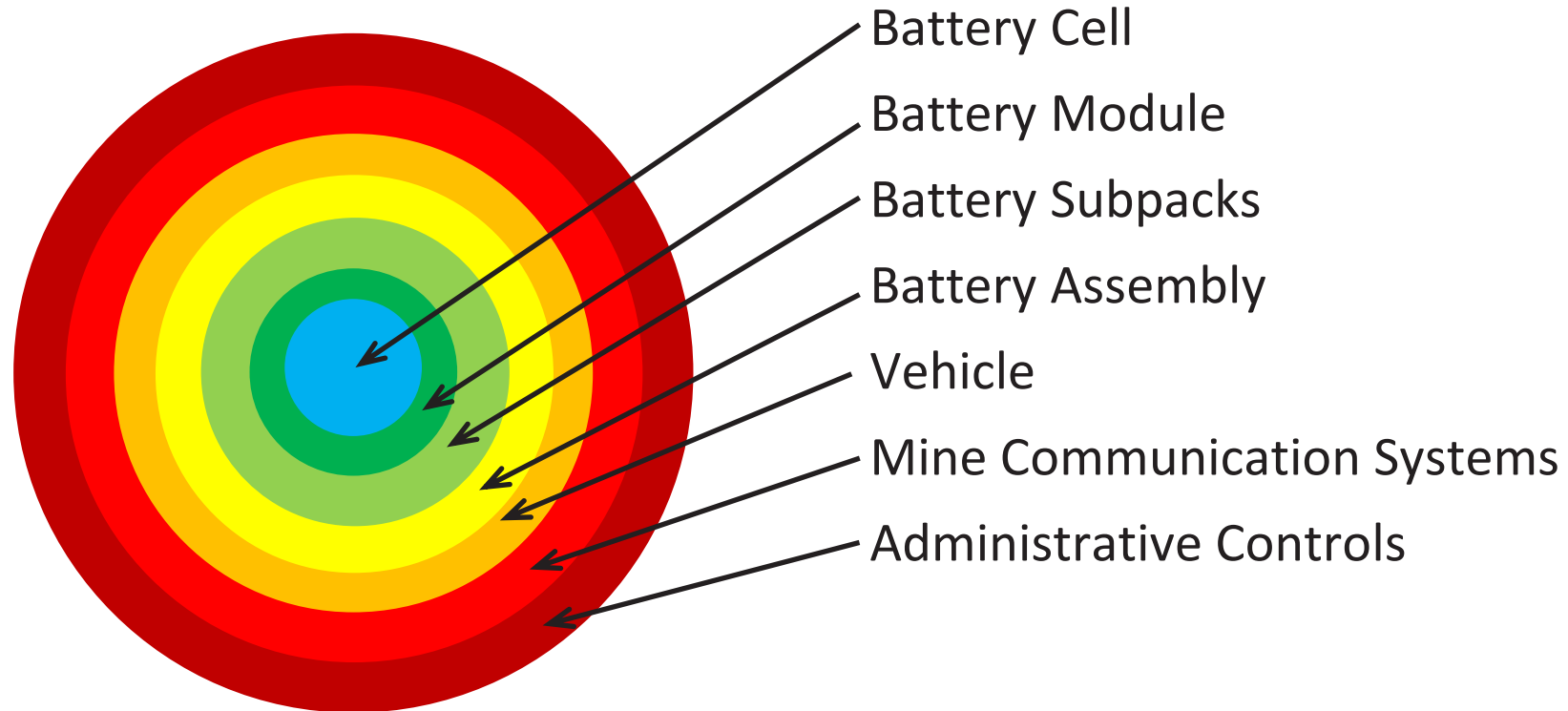
- High Voltage Electrical Exposure
- Short Circuit
- Thermal Runaway



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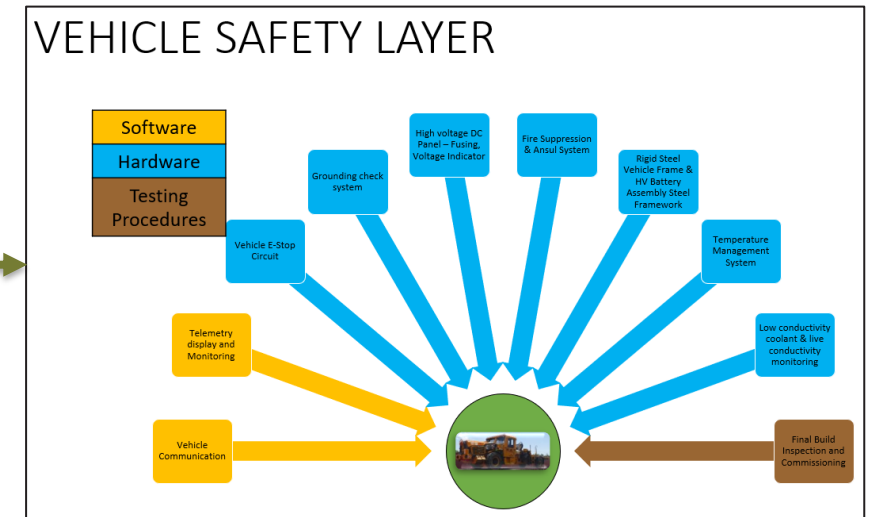
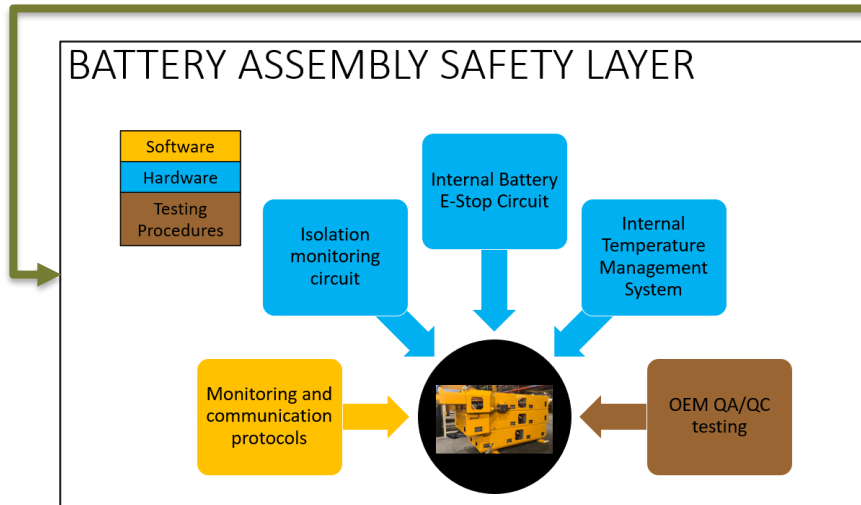
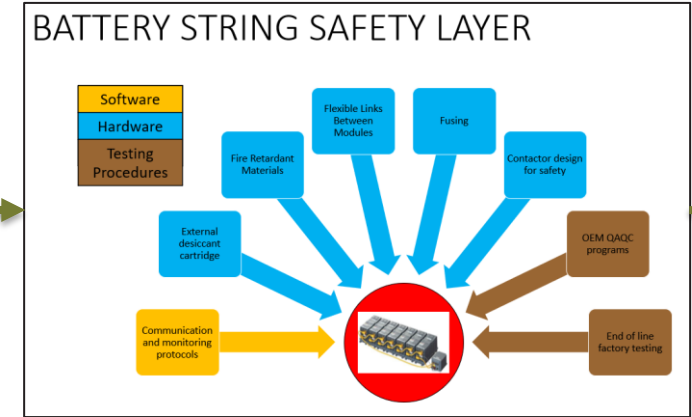
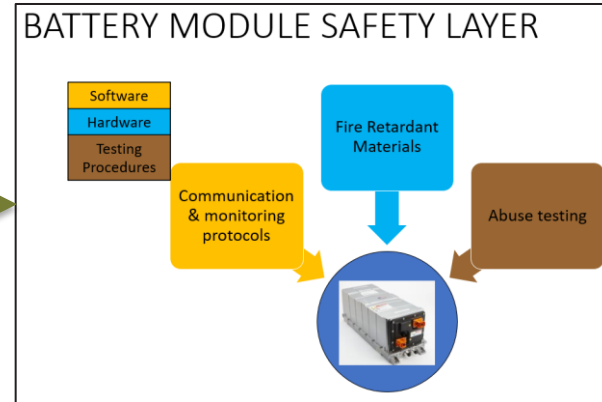
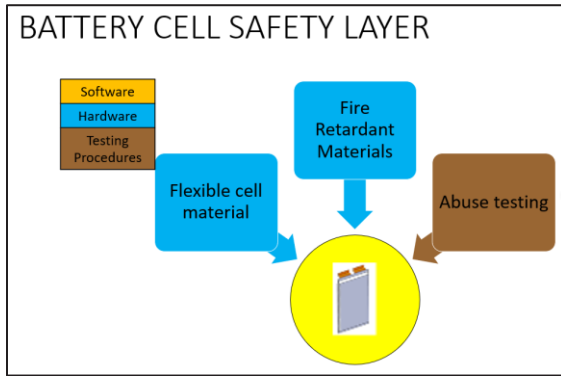


MacLean BEV Design – Safety Layers



Note: This is a high-level overview, additional details available upon request.

MacLean BEV Design Safety Layers



Note: This is a high-level overview, additional details available upon request.

Administrative Controls

- Contingency Planning
 - Transporting batteries
 - Towing vehicles
 - Resources in case of emergency
- Trade Qualifications
 - Mechanic
 - Electrician
- Training
 - Operator
 - Maintenance



Note: This is a high-level overview, additional details available upon request.

Battery Transportation and Handling *(Both Healthy and Unhealthy)*



Battery OEM Hazards During Transport and Storage

Hazards During Transport and Handling

- Do not lift heavy parts without use of appropriate lifting tools or industrial vehicles.
- Battery system components can tip over, swing out or fall down during lifting/handling operations. This can directly cause severe injuries or even death and considerable material damage.
- The battery system poses a specific risk when dropped or pushed to the floor. Immediate attention must be given around the damaged battery system and before the battery is reconnected. Observe the correct fire period of a minute after a short without observation of gases, sparks, noise, the battery system to a sealed area only accessible to authorized personnel.

The following must be observed in order to prevent danger of suspended load:

- Never stand under or within the swinging range of suspended load.
- Only use load order equipment.
- Before assembling the battery system, check for transport damage and completeness. Clean the battery system components. Damaged battery system components shall not be assembled.
- Transport the battery system components using a pallet vehicle and pallet in a crane. These must be designed for the weight of the parts to be transported. Observe rules on the transport signs of the site.
- When transporting the battery system components by crane, use all the lifting points. Observe crane safety manual in the manual of the transport equipment.
- When transporting the battery system, note the center of gravity and guide the ropes in such a way that the components hang horizontally.
- Select transport aids (cranes with 3-hooks or cranes) according to the weight of the cells or components and do not try to store corners, edges, wires or belts.
- Only use approved transport aids that are not damaged.
- Before leaving the workplace, suspended loads must be set down.
- Do not contact the battery system mechanically during transport and lifting (twist, bend, crush, etc.).
- When lifting and handling, the battery system must be protected against falling over or coming loose if any case.
- Only use approved training elements for lifting, handling and mounting.

The following must be observed in order to prevent danger due to use of industrial vehicles:

- Operation of the industrial vehicles is only allowed for trained drivers.
- Only use approved industrial vehicles with sufficient load bearing capacity.
- Never transport material directly above people or over the areas they occupy.
- Only work past industrial vehicles when the vehicle driver has signalled that they have acknowledged you.

Hazards During Storage

WARNING Incorrect storage of the battery system components can lead to their tipping or falling down and can lead to severe injuries or even death and considerable material damage.

WARNING Incorrect long term storage of the battery system components in hot environment or in direct sunlight can lead to significant material damage and may even result in battery fire.

To prevent hazards, personal and material damage or limited function when commissioning the battery system or components must be stored as follows:

- To prevent harm in case of a battery fire, the storage area must be locked and only accessible to authorized personnel.
- Secure the battery system against tipping.
- Protect components against mechanical damage.
- To protect against mechanical damage the unit shall not be stored on the floor directly without suitable supports (e.g. pallet).
- The storage area must be approved for storing dangerous goods.
- The storage area must be protected against unauthorized access.

Hazards During Packing, Shipping and Dispatch

The packing protects the battery system components from transport damage and other damage up until assembly. It must only be removed just before assembly. Before connecting the battery system, the packing must be checked for external damages.

DANGER Handling operating a damaged battery system is dangerous and can lead to severe injury or death. A damaged battery system is not allowed to be connected or operated.

In case that a battery system has to be shipped, the following instructions have to be considered:

- Damaged batteries have to be evaluated individually in terms of secure transport. Contact the battery manufacturer in case of doubt.
- The battery must be protected from heat during transport and storage.

Temperature / °C	Time Period
Under -20	
-20...+25	
+25...+35	
+35...+45	
above	



Battery Transportation and Handling

Transportation of Dangerous Goods

TDG Bulletin Transporting Batteries

Dangerous Goods Shipping Document

MacLean

Canada

https://tc.canada.ca/sites/default/files/migrated/bulletin_transporting_batteries.pdf

- Transportation of lithium ion batteries are considered "dangerous goods" and fall under TDG regulations when outside of a vehicle and require special classifications
- A rechargeable lithium-ion battery falls under UN3480 and Class 9 designation
- Labelling affixed to battery shipments
- Other documentation for shipping and SDS information also included



Note: This is a high-level overview, additional details available upon request.

https://tc.canada.ca/sites/default/files/migrated/bulletin_transporting_batteries.pdf

Emergency Response – Towing Procedure

MB

Title:	Battery Electric Vehicle (BEV) Towing Procedure
Number:	MB-GEN3205
Part Number(s) Affected:	1070616, 1133010, 1220820, 1233901
Machine Model(s) Affected:	MacLean EV Series™ Vehicles
Parts Manual Section:	Drive Train
PPR References:	37069
ECN References:	N/A
PSB References:	PSB20-014EN
Revision:	B
Creation Date:	23-Sept-2020
Revision Date:	13-Jan-2021

1.0 Scope:

The purpose of this Maintenance Bulletin (MB) is to provide a detailed explanation for the steps to safely tow a MacLean Engineering EV Series™ vehicle.

This document is supplied as a service. The information provided was known to be up to date at time of printing. If any discrepancies occur, please contact MacLean Engineering as soon as possible. Up to date information will be sent where possible.



THE FOLLOWING PROCEDURE MUST ONLY BE PERFORMED BY TRAINED AND QUALIFIED MAINTENANCE PERSONNEL. FAILURE TO COMPLY MAY RESULT IN SERIOUS DAMAGE TO THE VEHICLE AND/OR DEATH TO PERSONNEL.



ALWAYS FOLLOW ALL MINE SITE AND/OR GOVERNMENTAL RULES AND REGULATIONS REGARDING VEHICLE TOWING.

BEV TOWING PROCEDURE

PROCEDURE

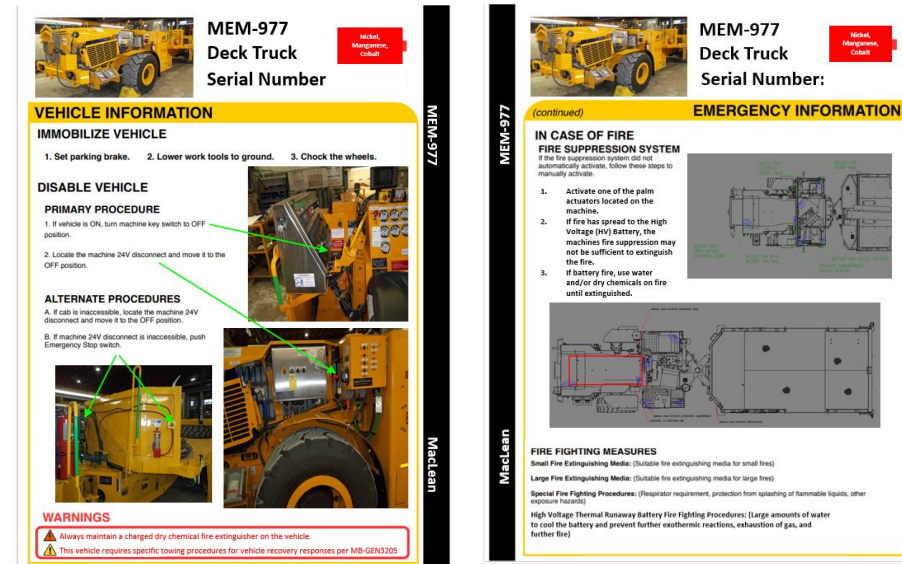
1. PLACE WHEEL CHOCKS ON BOTH SIDES OF MACHINE TIRE
2. ENSURE HVDC PANEL DISCONNECT SWITCH IS IN THE 'OFF' POSITION
3. ENSURE 24VDC BATTERY DISCONNECT SWITCH IS IN THE 'OFF' POSITION
4. CONNECT THE TOWING STRAPS TO THE FRONT BUMPER TOW POINTS OF THE BEV
5. REMOVE THE HYDRAULIC HOSE LABELED 'TK05' OR 'TK45' FROM THE 'T' OR 'TK' PORT ON THE BRAKE MANIFOLD
6. CONNECT A HYDRAULIC HAND PUMP TO THE 'T' OR 'TK' PORT
7. APPLY A PRESSURE OF 300 TO 500 (MAX) PSI IN ORDER TO RELEASE THE BRAKES
8. TIGHTEN ANY SLACK IN THE TOW STRAPS AND REMOVE THE WHEEL CHOCKS FROM THE WHEEL. THE BEV MAY MOVE AT THIS TIME
9. TOW THE DISABLED BEV AS REQUIRED WITHOUT EXCEEDING 6KM/H, FOLLOWING MINE SITE PROCEDURE. ABOVE 6KM/H MAY CAUSE DAMAGE TO THE TRACTION MOTOR AND MOTOR CONTROL UNIT
10. WHEN YOU ARE FINISHED TOWING THE BEV, PLACE WHEEL CHOCKS ON BOTH SIDES OF MACHINE TIRE
11. DISCONNECT THE HAND PUMP FROM PORT 'T' OR 'TK' ON THE BRAKE MANIFOLD
12. RECONNECT THE HYDRAULIC HOSE THAT WAS REMOVED IN STEP 5 AND CLOSE THE BRAKE MANIFOLD COMPARTMENT DOOR
13. REPAIR ORIGINAL FAULT AND CHECK FOR ANY OTHER ACTIVE FAULTS.
14. REPAIR/TROUBLESHOOT AS NEEDED.

1233901

Emergency Response Cards – Vehicle Information

- MacLean in collaboration with our customers have devolved Emergency Response Cards to be used by the control group in an underground emergency as a resource.

- As part of our MacLean BEV safety training, these Emergency Response Cards are provided to all customers with BEVs.



MEM-977 Deck Truck
Serial Number: Nickel, Manganese, Cobalt

VEHICLE INFORMATION

IMMOBILIZE VEHICLE

1. Set parking brake.
2. Lower work tools to ground.
3. Chock the wheels.

DISABLE VEHICLE

PRIMARY PROCEDURE

1. If vehicle is ON, turn machine key switch to OFF position.
2. Locate the machine 24V disconnect and move it to the OFF position.

ALTERNATE PROCEDURES

A. If cab is inaccessible, locate the machine 24V disconnect and move it to the OFF position.

B. If machine 24V disconnect is inaccessible, push Emergency Stop switch.

WARNINGS

- Always maintain a charged dry chemical fire extinguisher on the vehicle.
- This vehicle requires specific towing procedures for vehicle recovery responses per MB-GEN3205

EMERGENCY INFORMATION

IN CASE OF FIRE

FIRE SUPPRESSION SYSTEM

If the fire suppression system did not automatically activate, follow these steps to manually activate:

1. Activate one of the palm actuators located on the machine.
2. If fire has spread to the High Voltage (HV) Battery, the machine's fire suppression may not be sufficient to extinguish the fire.
3. If battery fire, use water and/or dry chemicals on fire until extinguished.

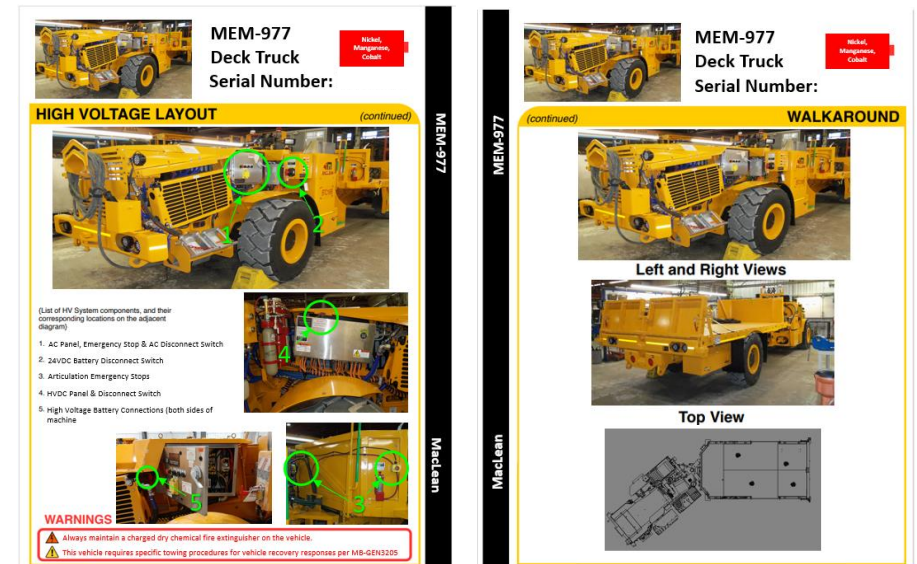
FIRE FIGHTING MEASURES

Small Fire Extinguishing Media: (Suitable fire extinguishing media for small fires)

Large Fire Extinguishing Media: (Suitable fire extinguishing media for large fires)

Special Fire Fighting Procedures: (Respirator requirement, protection from splashing of flammable liquids, other exposure hazards)

High Voltage Thermal Runaway Battery Fire Fighting Procedures: (Large amounts of water to cool the battery and prevent further exothermic reactions, exhaustion of gas, and further fire)



MEM-977 Deck Truck
Serial Number: Nickel, Manganese, Cobalt

HIGH VOLTAGE LAYOUT

(continued)

(List of HV System components, and their corresponding locations on the advance diagram)

1. AC Panel, Emergency Stop & AC Disconnect Switch
2. 24VDC Battery Disconnect Switch
3. Articulation Emergency Stops
4. HVDC Panel & Disconnect Switch
5. High Voltage Battery Connections (both sides of machine)

WARNINGS

- Always maintain a charged dry chemical fire extinguisher on the vehicle.
- This vehicle requires specific towing procedures for vehicle recovery responses per MB-GEN3205

WALKAROUND

(continued)

Left and Right Views

Top View



Note: This is a high-level overview, additional details available upon request.

BEV Service Layers – Trade Qualifications

Qualified Personnel:



Mechanic: A licensed/certified mechanic authorized by site.

- 421A - *Heavy Duty Equipment Technician*
- 310S - *Automotive Service Technician*
- 310T - *Truck and Coach Technician*



Electrician: A licensed/certified electrician authorized by site.

- 309A - *Electrician – Construction and Maintenance*
- 442A - *Industrial Electrician*



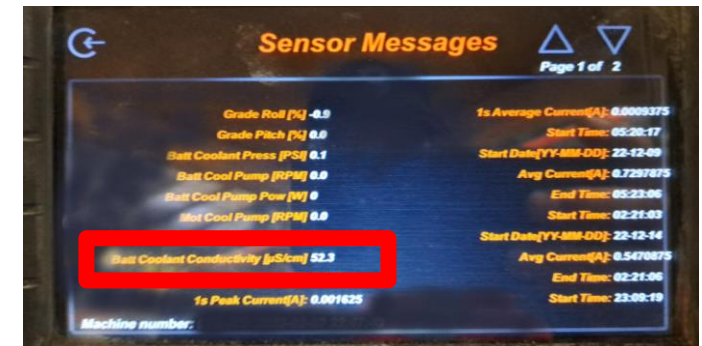
MacLean Only: Only a MacLean Employee can complete the task.



Low Conductive Coolant Improve Battery Design

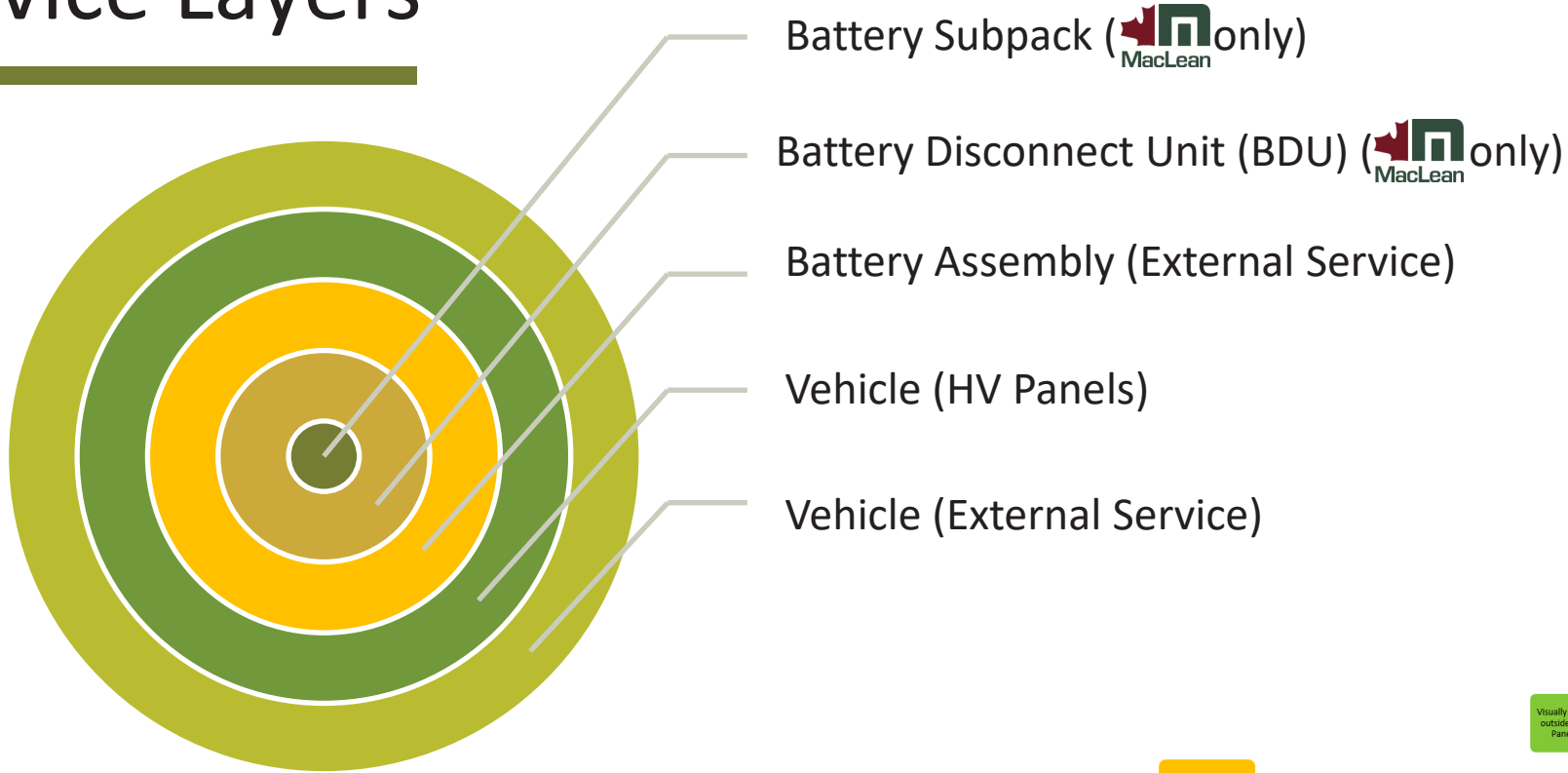
Implementation of low conductive coolants minimize the risk of internal arcing within liquid cooled BEV batteries.

- Early BEV battery internal design increased the risks of internal arcing.
- MacLean and some of our Partners introduced low conductive coolants into there specifications and standards to reduce inherent risks of a breech of coolant.
- Improvements in internal battery design further reduce risks of arcing.
- Commercial grade diesel engine coolants have a conductivity range of **~3000-5000 $\mu\text{S}/\text{cm}$** .
- Low Conductive Coolants have a conductivity range of **~1-20 $\mu\text{S}/\text{cm}$** .
- *Electrical conductivity is measured in $\mu\text{S}/\text{cm}$ (micro-siemens per centimeter).*

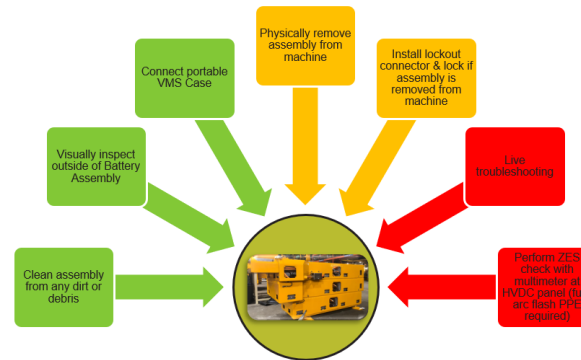
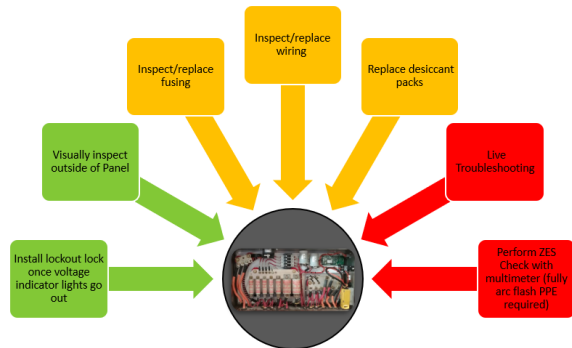


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BEV Service Layers



No ZES Check with Multimeter Required	
After ZES Check with multimeter	
Before/During ZES Check with multimeter	



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Commissioning Documents – BEV Specific



1. Pre-Energized Inspection and Testing
2. Stationary Energized Inspection and Testing
3. Mobile Energized Inspection and Testing

Rev Date: October 27, 2023		Pre/Post Energizing Commissioning Report							
System and Elements		Item #	Name	Description	Reference Document or Other Instructions	Expected Result	Actual Result	Comments or Attachments	Pass/Fail
A - Vehicle and Drive System	1	Review Commissioning Report and Associated Inspection Documents	The purpose of this check is to verify that the previous work completed using the typical field commissioning report has been done correctly.	Field Commissioning Report for specific S/N	All required checks should be completed and no deficiencies found				
	2	Pre-Op Check (Visual only without 24V or 750VDC Battery Power Energized)	The purpose of this check is to verify that the BEV meets the designated pre-op checks before proceeding to further steps that will require the vehicle to be energized	MB-GEN3136 (977) MB-LE1319	All required checks should be completed and no deficiencies found				
	3	Verify Coolant Conductivity Level	The purpose of this check is to verify that the conductivity level of the TMS coolant is within acceptable levels.	1. Using handheld conductivity meter, either take a coolant sample or open the coolant reservoir and take a coolant sample. 2. Using the handheld meter, take a reading of the conductivity of the coolant sample. Record this number to verify later.	Conductivity level of the sample should be under the recommended values (300 micro siemens is the warning level, 500 micro siemens is the alarm level)				
	4	Verify Fuses Inside HVDC Panel	The purpose of this check is to verify that the fuses located inside the HVDC panel are both in the correct position, are the correct brand, and are the correct size.	1. Open HVDC Panel and using fuse ID lamacoid and the applicable electrical drawing together, verify: - Fuse location is correct - Fuse size is correct - All fuses are an appropriate brand/style 2. Close HVDC panel	All fuses in the HVDC panel should match what is shown on the fuse ID lamacoid. All fuses should have correct labeling and markings.				
	5	Verify Fuses Inside AC Panel	The purpose of this check is to verify that the fuses located inside the AC panel are both in the correct position, are the correct brand, and are the correct size.	1. Open AC Panel and using fuse labels attached above the individual fuses and the applicable electrical drawing together, verify: - Fuse location is correct - Fuse size is correct - All fuses are an appropriate brand/style 2. Close AC panel	All fuses in the HVDC panel should match what is shown on the fuse ID lamacoid. All fuses should have correct labeling and markings.				
	6	Verify Drive/System Parameters along with OCM software version. (Do Energized)	The purpose of this check is to verify that all software items have been updated to the newest versions.	1. Verify correct software and parameters with engineering. 2. Download the correct versions onto your laptop.	Technician should have all the correct files loaded on their laptop.				
	7	All Panels Have All Required Labels	The purpose of this check is to verify that all panels have the required labelling on them.	1. Visually inspect the front every panel and verify that all required labelling and/or name plates are present.	All panels should have all required labels. These may include the following: - Arc Flash Labels - Voltage Labels - Name Plate Labels				
	8	All Panels/Junction Boxes Are Sealed	The purpose of this check is to verify that all panels/junction boxes on the machine are equipped with a working cover that requires tool access, and that that cover is in place and functioning.	1. Locate each panel or enclosure on the machine. 2. Verify that the tool required access to that panel or enclosure is functioning properly and is in place.	All panels or enclosures should have either locking lid that requires tool access to open or lid clamps that are all functioning properly and in place.				
B - Battery System	1	Pre-Op Check (Visual only without 24V or 750VDC Battery Power Energized)	The purpose of this check is to verify that the battery meets the designated pre-op checks before proceeding to further steps that will require the vehicle to be energized	MB-GEN3136 (977) MB-LE1319	All required checks should be completed and no deficiencies found				
	2	Record Battery Assembly Serial Number	The purpose of this check is to record the HV Battery Assembly serial number.	Visually locate the battery assembly serial number and record it.	Recorded numbers should be provided to engineering for record keeping.				



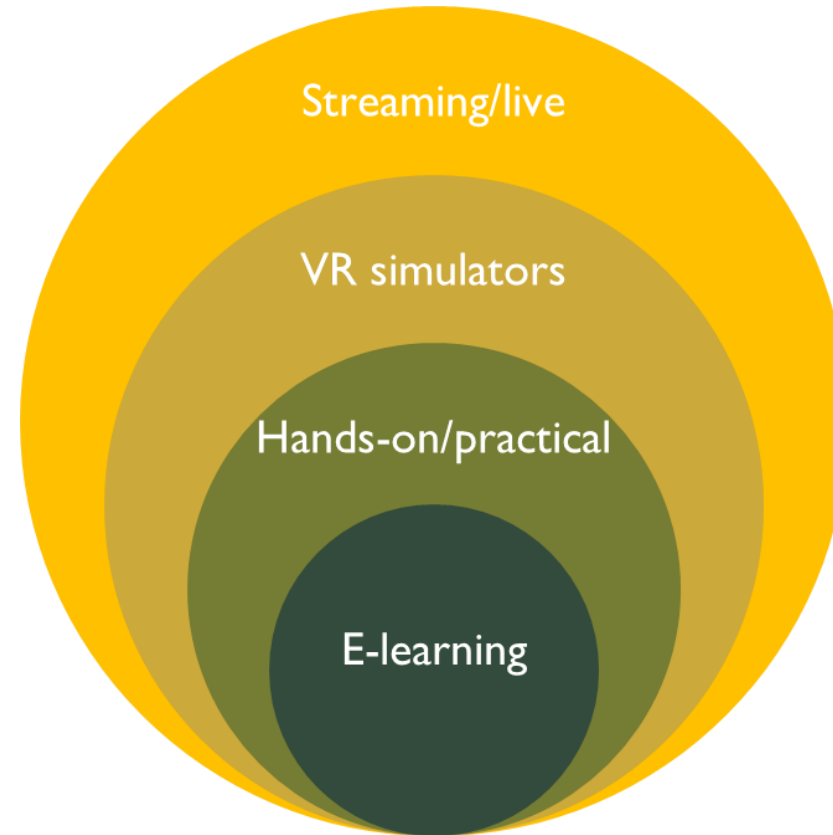
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MacLean Academy



Multiple E-Learning Courses Available:

- Operator, Mechanical & Electrical safety training
- Accessible, traceable, engaging
- Web-based for ease of access
- Built-in knowledge checks and final tests
- Provides set up to hands-on training and competency assessment in the field



In Summary..

- Safety systems continue to mature as more BEV machines are deployed.
- For BEV to continue being successful you need to:
 - Understanding of the potential risks and how to mitigate them.
 - Continuous improvement with the help of customers.
 - Training, Training, Training.
- Adoption of BEV technology in the mining industry is happening now, are you ready?





THANK YOU / MERCI / GRACIAS

Q&A + Contact Info

Please do reach out for any questions, requests for documentation or discussions on how this could work for your project/operation.

Alexander Lenz – alenz@macleanengineering.com

Ryan Proulx – rproulx@macleanengineering.com

<https://macleanengineering.com/ev-series/>

