SUDBURY
INTEGRATED NICKEL
OPERATIONS

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2020 WSN Battery Electric Vehicle (BEV) Symposium

BEV Specification Development History and Intent

Presented by Steve Holmik and Alain Landry, Glencore Sudbury INO

February 12, 2020

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Sudbury Operations

Overview

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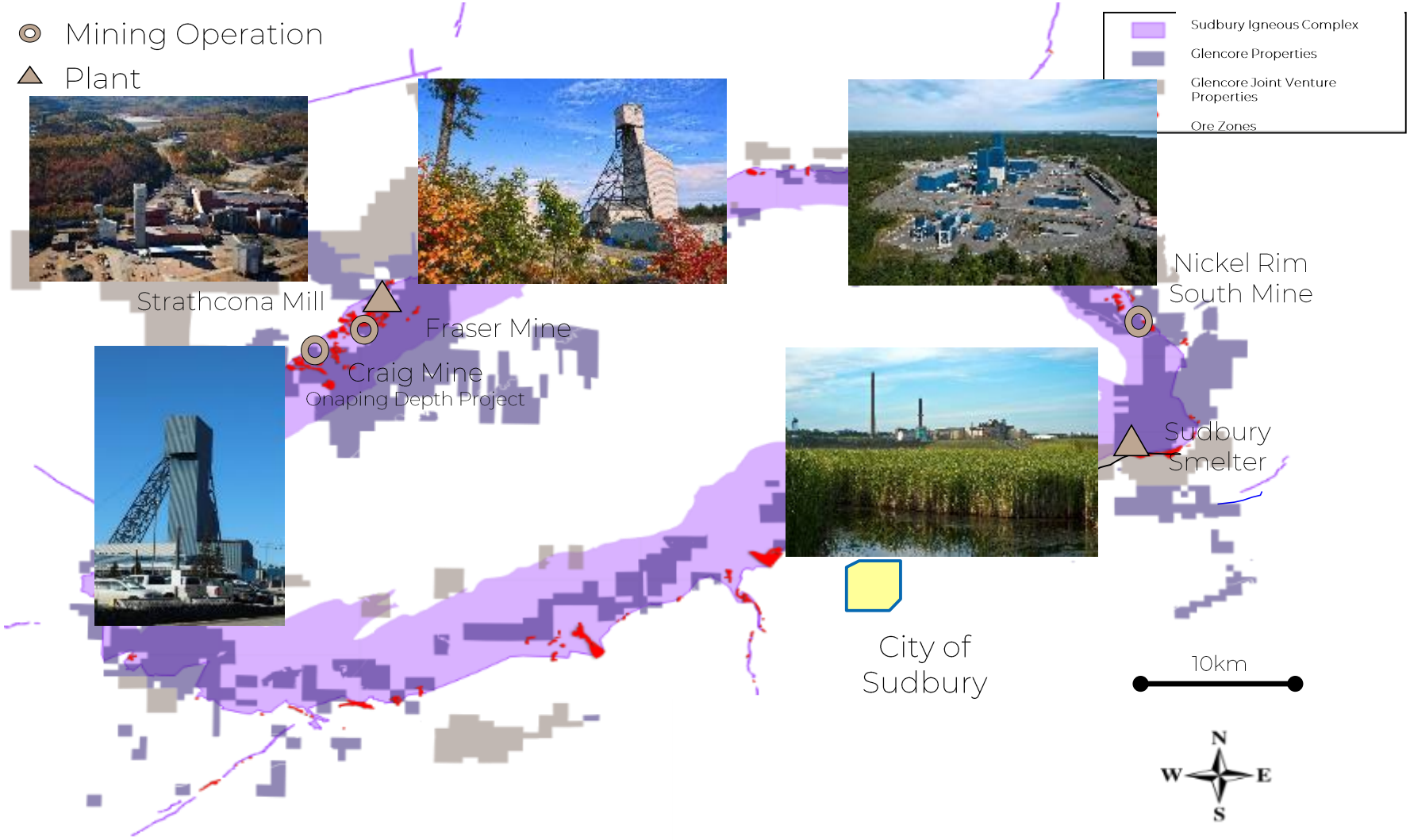
Sudbury Integrated Nickel Operations



Sudbury Integrated Nickel Operations (Sudbury INO)

Nickel Rim South Mine

2018 Production (tonnes):
1,299,590 ore mined

Fraser Mine

2018 Production (tonnes):
702,631 ore mined

Strathcona Mill

2018 Production (tonnes):
2,010,354 ore milled
22,806 Ni in concentrate
38,831 Cu in concentrate

Sudbury Smelter

2018 Production (tonnes):
77,234 Ni in matte
19,239 Cu in matte

Technology and Innovation

Our Future Mines

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SUDBURY INO 2022

ADAPTING FOR A DEEP MINING FUTURE WHILE ACHIEVING OPERATIONAL EXCELLENCE

PILLARS OF OUR STRATEGY

OUR LICENSE TO OPERATE

Manage our HSEC objectives & regulatory challenges and continue the journey towards zero harm.

OUR PEOPLE

Focused on our priorities and developing the skills to achieve them.

OUR ABILITY TO ADAPT

We need to innovate and utilize new technologies to secure our future.

EXCELLENCE IN OUR OPERATIONS

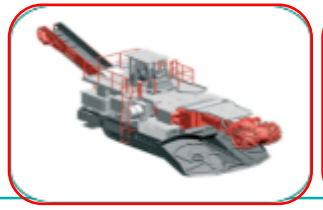
Deliver and exceed expectations to achieve the performance required for deep mining.

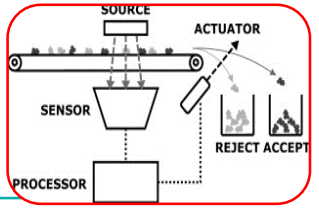
BUILDING OUR FUTURE

Achieve full approval, build two mines and the Process Gas Project on an aggressive timeline and on budget.

Our Future Mines
Sustainably Designing for Depth

Zero Emission	Real Time Information	Maximized Asset Utilization	Safe, Efficient Mining	Industry Collaboration	Minimize Waste Generation
Diesel-less	Real-time Digital Smart	Continuous Automated Operations	Mine Designed for Depth	Agile Ecosystem	Concentrate along the path
Completely Electric Mines	Fully integrated digital operations management	Leveraging Step Change in Mining Technology	Engineering out Deep Mining Challenges	Working with our peers to develop solutions	Reduce our environmental footprint





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Craig Mine - Onaping Depth Project
Battery Electric - Benefits

100% battery electric operated mobile fleet

- Energy efficiency
- Ventilation savings (lower flow)
- Cooling system savings
- Improved health benefits
- Increased opportunity to improve production profile

Craig Mine - Onaping Depth Project
Battery Electric - Benefits

Eliminated:

- Return Air Ventilation Ramp
- Fresh Air Raise
- (3) Ventilation Fans
- (5) Ore Passes (replaced w/ battery electric haul trucks regenerating power down ramp

Annual GHG emissions reductions (metric tonnes CO_2-equivalent/yr)* :

- Diesel: 17,130 tCO_2e/yr
- Reduction: 44%
- Battery: 9,620 tCO_2e/yr

** Energy Design review*

	Diesel		Battery Electric
Ventilation	300 m^3/s	-40% →	180 m^3/s
Shaft Diameter	6.5 m	-23% →	5.0 m
RAR Diameter	5.0 m	-24% →	3.8 m
Refrigeration	BAC = 19.2 MWr CSC = 25.3 MWr	-31% →	BAC = 13.3 MWr CSC = 17.5 MWr
Ventilation Fan Power	10,900 kWe	-44% →	6,100 kWe
Peak Refrigeration	3,300 kWe	-30% →	2,300 kWe
Total Power	14,200 kWe	-41% →	8,400 kWe

Battery Electric Vehicle

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History

2015 – 2016. Feasibility study for Onaping Depth (Glencore)

- Comparisons between diesel & use of BEV equipment.
- Advantages of BEV v's Diesel determined.

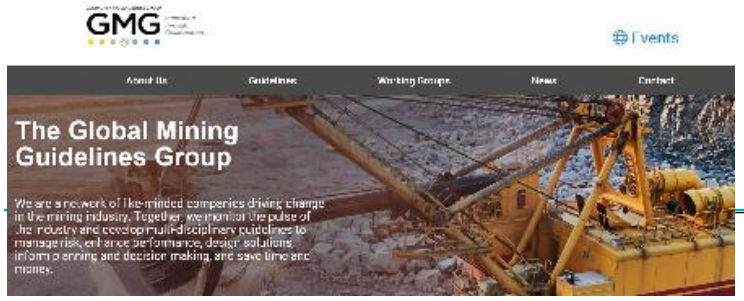
- Air quality, Heat, Cost, Noise, vibration etc.
  - Study returned that BEV equipment was the only way that the project & full mine operations could go ahead.
- 2016. Little to no information, history, guidelines or specifications for use in U\G mines
  - Neither nationally available or globally for BEV equipment use in U\G mining operations.
  - The BEV market for the U\G industry was in its infancy with very few units built or in use.
  - However, the automotive (Bus) industry gaining traction with BEV vehicle use & infrastructure requirements.

- EG. Tesla – (Field of Dreams) Build it and they will come

History *…continued*

- 2016. Initial focus was to determine how best to provide the "Charging (Fuel)" required to support a potential BEV fleet U\G.
  - BEV charging philosophy document created by Craig Harris for Glencore's RFBQ to assist in Onaping Depth feasibility study. The intent of this document was to encourage standardization of charging philosophy and connectors throughout the industry. SIMPLIFIED
  - Charging a mining EV needs to be as simple, convenient and safe as refueling a piece of diesel equipment.

- 2016-2017. 1st edition of GMSG "Recommended practices for Battery Electric Vehicles in Underground Mining" released.
  - This guideline was developed with input from Craig Harris's "Charging Philosophy" document, Canadian Mining Innovation Council, various industry stakeholders and various sectors including Mining, OEM's, Regulatory bodies etc. 1st edition released to industry in 2017.



History *…continued*

- 2018. 2nd edition of the now GMG "Recommended practices for Battery Electric Vehicles in Underground Mining" released to industry in late 2018.
  - Revisions include new material and content organization.
  - These guidelines are a great resource for operations wishing to enter into the U\G BEV world, however, did not address the standards & specifications to which the BEV equipment shall meet. It was deliberately structured this way by the GMG as not to stifle innovation and in recognition that there are many solutions to many different circumstances.

- 2018-current. Glencore & Vale realized that there is an opportunity to jointly help guide the industry & OEM's to a common BEV specification.
  - The focus was on safety and commonality of specifications. There are only limited Canadian or global specifications to which the BEV equipment, or components, are required to comply to, however is still in its infancy.

Intent

The intent of this specification is to:

- Ensure that BEV equipment complies to, at a minimum, Canadian Standards or to allow the use of other standards if deemed better.

- Ensure that OEM's are building units to a common standard that complies to the specification that has been developed with input from various end users & OEM's.
  - This will only help with the acceptance of BEV's into the mining industry as the end user can rest assured that what they are purchasing is safe for the mining environment.
  - Include preventions from real world learnings.
  - Should help reduce costs as OEM's now have a standard platform to work to and not a specific requirement by each end user.

Overview of Glencore BEV Specification

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- ✓ OPERATOR INTERFACE REQUIREMENTS
- ✓ HV DC INSULATION MONITORING SYSTEM
- ✓ ELECTRICAL SYSTEM CONSTRUCTION
- ✓ SERVICING AND ISOLATION REQUIREMENTS
- ✓ BATTERY ENCLOSURE REQUIREMENTS
- ✓ STANDARDS, APPROVALS AND DOCUMENTATION

Operator Interface Requirements

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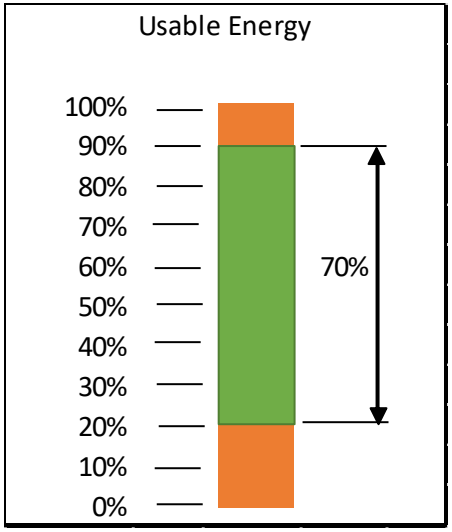
Operator Interface and Alarms

1. The BEV operator interface is the point of human-machine information and is critical to safe BEV operation. The operator interface (display in operator's cab) shall visually display information about the battery condition, faults and usable SOC to the operator at all times during the normal course of operations.

Operator Interface, Alarms and Controls

2. *Visible and audible alarm signals shall be part of the cabin operator interface, visible alarm for minor faults and visible & audible alarm for severe faults. Ie standardization of alarms – according to criticality.*

3. *Operator interface shall display usable energy available in battery in the form of a fuel gauge and be represented as a percentage. Example: If the lower safe battery discharge limit is 20% of total battery energy then the "Fuel Gauge" should display 0% energy remaining to the operator. Same shall apply to the upper limit, if the battery is limited to charge to 90% of total battery capacity the "Fuel Gauge shall display 100% charged.*



4. *Operator shall receive 2 levels of low SOC visual alarms prior to machine going into de-rated mode*
   - *First level : A constant visual alarm that will be initiated when the battery SOC reaches 10% of usable energy remaining*
   - *Second level: A flashing visual alarm that will be initiated when the battery SOC reaches 5% of usable energy remaining.*

Operator Interface, Alarms and Controls

5. *In addition to the display of usable energy, the display shall also display the amount of usable energy remaining (Range) in kWh with 0 kWh representing lower safe discharge limit*.

6. *In cases of equipment that may be used to transport explosives, the equipment shall be capable of de-rating the speed from maximum programmed speed to 10 km/h as legislated by law. This should be activated automatically when explosives light (beacon) is turned on*.

7. *Shall display if charging cable is connected*

8. *Where an over speed condition may cause damage to components or speed in excess of maximum allowable – max ramp test speed:*

    - *The operator shall be warned when approaching that condition.*
    - *If the operator exceeds max allowable speed, the machine shall slow down.*
    - *If the over speed condition persists, the vehicle shall be brought to a controlled stop.*

9. *There must be a means to prevent freewheeling of vehicle when traveling down ramp if loss of regenerative braking occurs when the battery is fully charged. For example, use of brake resistors, speed de-rating, or other methods. Manual or automatic application of service brake as the only means to control speed is not acceptable.*

HV DC Insulation Monitoring System

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Onboard HV DC Insulation Monitoring System

1. The BEV must include a HV DC insulation monitoring system to constantly monitor and visually alert personnel to a HV insulation fault to vehicle frame.

2. The HV insulation monitoring system shall perform a self-test upon start-up through the control system or BMS. If this is not possible, then a pushbutton that simulates an insulation fault condition shall be provided.

Electrical System Construction

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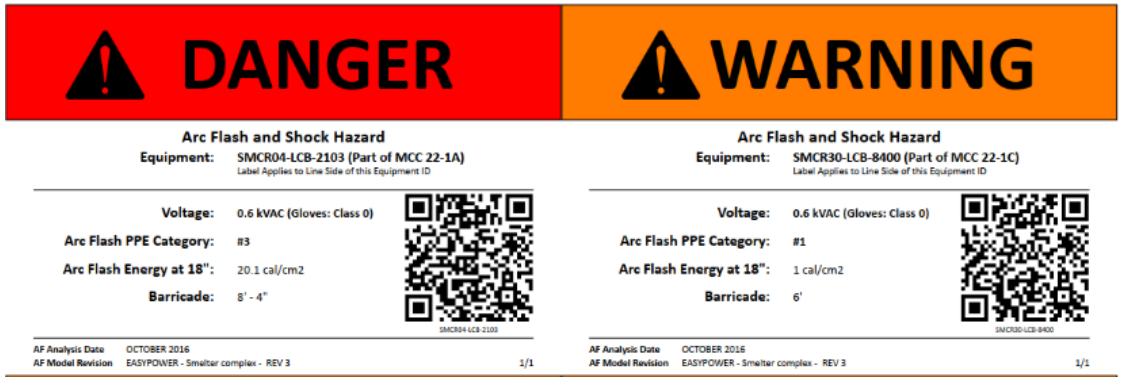
Electrical System Construction

1. The BEV must be designed to minimize the possibility of electric shock and arc flash. Where there is the possibility of arc flash.

2. An arc flash analysis of the machine's HV system is to be completed and appropriate labels to be placed on panels indicate the arc flash rating that will be accessed during maintenance tasks.



3. Enclosures and/or components not in enclosures (such as motors, chargers, invertors etc.) shall be rated IP66 as a minimum, with preference given to IP69K, to allow pressure washing.

Electrical System Construction *…continued*

3. All BEV electrical enclosures and components must be corrosion resistant. Specialty enclosures or components that are not manufactured as corrosion resistant shall be treated with some form of corrosion resistant material to prevent corrosion.

4. Enclosures that must be located below the axle line of the machine, or that can be reasonably expected to be submerged during normal operation, shall be rated to withstand immersion with an IP67 or greater rating along with corrosion resistance.

3. Low and high voltage systems shall be in separate enclosures where possible. This is to allow HDEM mechanics to be able to work on low voltage vehicle systems.

4. Clear and prominent labelling if the enclosure houses stored energy such as batteries, capacitors or other devices, that do not de-energize within 10 seconds when the BEV high voltage disconnect is switched off. There must be visible confirmation that the energy has been dissipated.

5. HV DC cables must have an orange jacket.

Electrical System Construction *…continued*

8. All electrical enclosures shall be properly labelled. Minimum requirements for labelling include:
   - All voltages within the enclosure
   - Arc flash rating
   - Unique enclosure identification which aligns with the electrical diagrams/schematics
   - Description of the enclosure's purpose/function

9. Any areas that cannot be washed down with a pressure washer to be properly labeled and outlined in the operator and maintenance manual.

Servicing and Isolation Requirements

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Accessibility and Service

1. Engineered lifting points shall be provided for heavy components and located to minimize interference with other components when lifting for removal or installation.

2. Enclosures where access is required for maintenance personnel; barriers, partitions, and covers shall be provided and arranged such that testing and troubleshooting can be safely conducted.

3. Disconnects shall be accessible from ground level.

4. Enclosures requiring frequent access are to be accessible from ground level when practical.

5. Hot surface protection is to be provided to guard against fire or injury to personnel on components such as, but not limited to, brake resistors.

6. Any components that must be isolated before welding must be identified and a procedure provided in the maintenance manual.

Isolation of High Voltage DC (HV DC) System

1. The equipment is to be designed to minimize the number of mechanical HV DC disconnect switches required to isolate the energy and shall be easily accessible from ground level.

2. The mechanical HV DC disconnect switch/switches shall be capable of accepting a personal padlock(s) or multi lock device.

3. The HV disconnect system shall comply with CSA Z460.

4. When opened, the HV DC disconnect shall:

   Physically disconnect all sources of HV DC electrical energy from the battery to the rest of the machine.
   Temporary storage devices, such as capacitors, should be designed to discharge stored energy within 10 seconds. If energy is not dissipated within 10 secs after the HV DC disconnect switch is opened, a procedure must be provided and a label clearly and prominently installed warning of this condition. A permanent meter or light indicating that the capacitance has been dissipated shall be installed.

5. A visual means (such as a permanent meter or indicator light) must be in place to clearly identify that the HV DC mechanical disconnect switch has been opened and that energy isolation has been achieved. A manual hand held meter measurement shall not be required.

Battery System Safety/Enclosure/ Charging

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Battery / Stored Energy Enclosures

Battery / Stored Energy Enclosures

1. Each battery on board the machine shall have a means of isolation such that the battery can be safely removed from the vehicle.

2. When disconnected, the battery and vehicle connection points shall be touch-safe.

3. Battery enclosure cable connection point shall have physical protection from damage when being maneuvered.

4. The Battery enclosure must be constructed and/or positioned such that effects from a collision or punctures are mitigated.

5. The Battery enclosure shall be designed to minimize the effects of a thermal event.

6. For equipment designed to operate under unprotected ground during remote control operation such as LHD's, remote blockholer and mobile remote rock breakers, protection above battery is required to protect against small falls of ground during remote control operation. This protection shall be equivalent to FOP's Level 2.

7. If any off gasses are produced by batteries during charging or discharging, sufficient venting to a safe location must be provided away from personnel and possible ignition sources.

HV connector protection

1. A means must be in place to minimize the risk of accidental contact with electrical energy when HV connectors are disconnected. This can include but not limited to:

   - Break first pilot signal to de-energize cable before disconnecting
   - Physical guard to prevent access to connectors when energized
   - Touch safe connectors

Charging interlocks and isolation

1. *BEV shall have an interlock that prevents movement (directional travel) of vehicles when charging cable is connected to the unit. Exceptions to this are equipment with 600v AC cable reels designed to move during normal working operations. Example, Bolters, Jumbo's, Production drills etc.*

2. A means shall be provided for isolating the charging connector from feeding the equipment with the main HV and LV disconnects locked out, such that the charging plug cannot be energized.

3. Onboard Charging Requirements:
   - BEV's with on board charger(s) shall be supplied with a 600 volts AC 3-phase 60 Hz charger using a standard SMS type Mine Ground Fault power connector with a ground check conductor customer supplied Startco SE-107 ground-fault/ground check monitor.
   - OEM is to install a zener diode (Startco SE-TA6) within the BEV in order to complete the ground-check circuit along with a matching SMS receptacle.

   .
4. Off board Charging Requirements:
   - The BEV off board receptacle must accept a SAE CCS Type 2 compatible plug, unless the OEM's design allows a higher charging rate than CCS Type 2 charging allows. Live parts of the connector should be protected with an automatic shutoff or appropriate ingress protection to prevent contact.

Standards, Approvals and Documentation

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Standards

Reference Documentation

The following documents were used in the development of this document or have instructions and procedures applicable to it. They shall be used in their most recent revision in those sections that apply.

- Ontario Electrical Safety Code
- 20180621_UG_Mining_BEV-GMG-WG-V02-r01 – GMG Recommended Practices for Battery Electric Vehicles in Underground Mining – Second Edition
- CSA M421-16 Use of electricity in mines
- CSA Z460 – Control of Hazardous Energy – Lockout and other Methods
- CSA Z432 – Safeguarding of Machinery
- CSA Z462 - Electrical Workplace Safety
- CSA Z463 - Guideline on Maintenance of Electrical Systems
- UL2580-2 - Batteries for use In Electric Vehicles Safety Standard
- M424.3-M90 Braking Performance - Rubber-Tired, Self-Propelled Underground Mining Machines
- OHSA R.R.O. 1990 Regulation 854 - Mines and Mining Plants.
- IME-20 – Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the use of Commercial Electric Detonators
- ISO3449_Earth-Moving Machinery - Falling Object Protective Structures- FOP's - Laboratory Test and Performance Requirements

Electrical Approvals

1. The complete BEV system, consisting of the electrical and charging systems, shall be designed using good engineering practices and designed using applicable standard with preference being North American standards where possible.

2. Where possible the electrical system and/or components should be certified by a certification body (CB) accredited by the Standards Council of Canada (SCC), such as CSA or ULC and must bear the certification mark or label of said CB.

3. As a minimum the AC side of the charger must be inspected and approved by the Electrical Safety Authority (ESA).

Documentation

Additional documents to be provided by supplier includes:

- Electrical drawings showing all voltages, cables and wire sizing, components, enclosures, and their associated labelling
- A procedure for handling stored electrical energy, i.e. capacitors which don't dissipate within 10 secs to be included in operational and maintenance manuals
- Recommended Maintenance Plans (PMs), schedule intervals and procedures for inspecting and maintaining BEVs and their components, including but not limited to carrier, BEV system, fire suppression, etc
- Daily pre-operational checklists
- Specific BEV firefighting procedures to train operations and maintenance personnel, and first responders (Mines Rescue)
- Locking and tagging procedure to achieve zero energy state to be included in operational and maintenance manuals
- Power on/ energized work procedures to be included in operational and maintenance manuals

Questions?

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