Emergency Response to Underground Battery Fires

Workplace Safety North™

workplacesafetynorth.ca/minerescue

Battery Use in Ontario Mines

- Battery and electric-powered vehicles in use in Ontario since the 1950s
- Locomotives, scoops, LHDs, haul trucks, drills, bolters, personnel carriers, Re-chargeables and Electrical Storage
- Lead acid or wet cell battery technology used exclusively until development of newer, lighter batteries with higher density energy outputs
- Emerging Technology – Lithium and other metal-based electrolyte batteries are extremely popular & have advantages over traditional power sources for underground mining methods

Battery Use in Ontario Mines

- Government regulations imposed tighter limits on diesel and blasting emission in underground mines
- Reducing carbon emissions are now a key driver for many mining companies to achieve carbon neutrality. This puts battery power in demand to replace fossil fuel internal combustion engine (ICE) equipment
- Mines are more expansive. Battery power is becoming a necessity for mining activities in deep/remote areas with ventilation challenges

Battery Types in Ontario Mines

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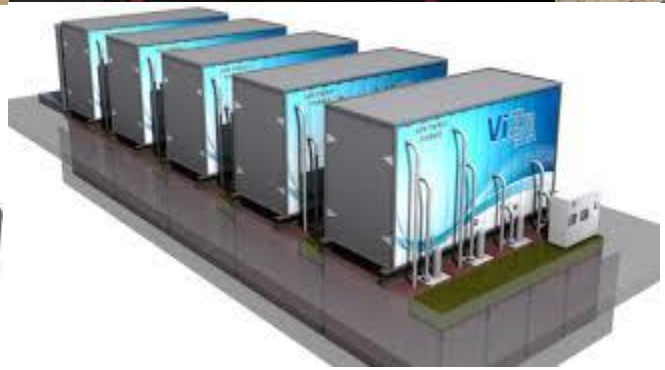



Current Emergency Response Capabilities in Ontario Mines

- Minimum response: Five-member team with a second team as backup and third team on standby

- All underground fires are considered as IDLH (Immediately Dangerous to Life and Health). All members will field test and don a Drager BG4 apparatus (rebreather) with 4-hour capability with a limit of 2-hour team operation

- MX6 Ibrid – set to detect three gases – with carbon monoxide, oxygen and methane sensors

Current Emergency Response Capabilities in Ontario Mines

- Kestrel Weather Meter for identifying potential and actual heat zones
- Mine radio communications to surface, Bell, VOIP or Femco Pager phones
- PPE includes Hi-viz Class 3 fire retardant coveralls, normal work attire, gloves and safety footwear

OMR Emergency Response Equipment

- Fire hose and nozzle
- Various multi-purpose handheld fire extinguishers and equipment fire suppression systems
- Low and high expansion foam systems

OMR Emergency Response Equipment

- Compressed Air Foam Systems (CAFs) portable and stationary
- Thermal Imaging Camera (TIC)
- Barricade and/or isolation materials

OMR Tactics

- Isolate all sources of electrical power in vicinity
- Fire attack dependent on ventilation flow, intensity of heat, smoke and limited access for approach
- Determine involvement of pneumatic tires, batteries or other unpredictable hazards. Use of TIC

OMR Tactics

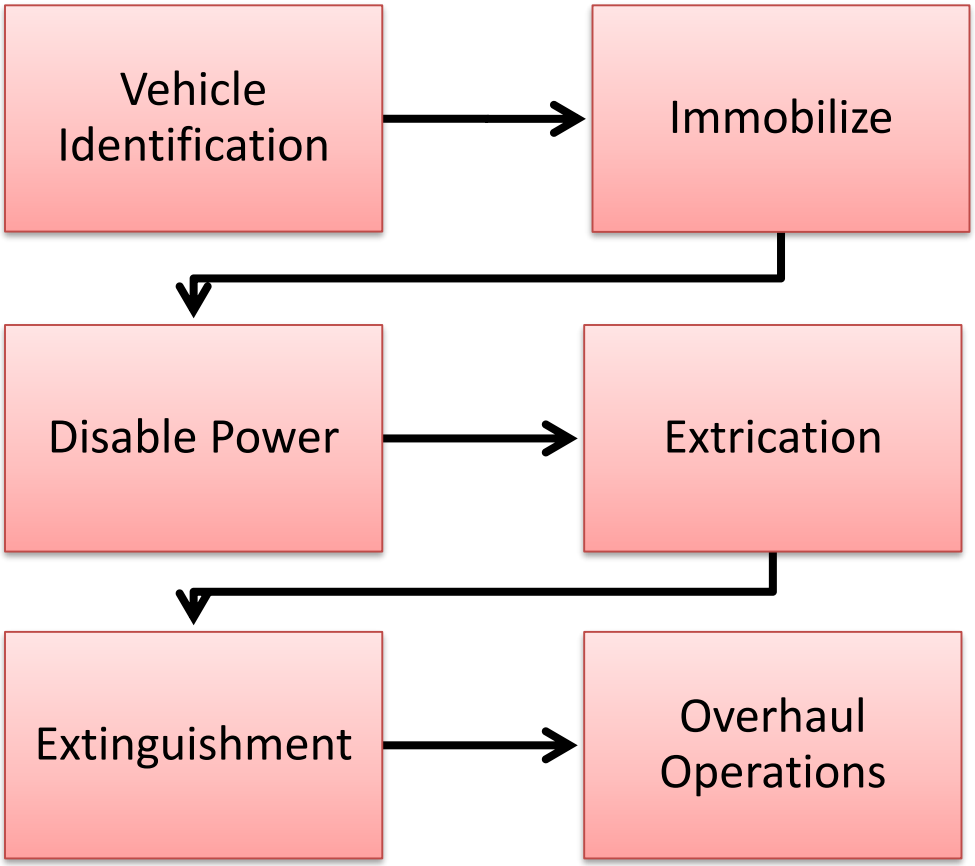
- Team may retreat to cooling area or work in intervals
- Direct Extinguishment – use fire hose/nozzle, multi-purpose extinguisher, PROpak foam dispenser, CAFs, AAAF low expansion or equipment suppression systems
- Indirect Extinguishment – High expansion foam generator or seal/isolate when there is no risk of life to workers or team

Causes of Battery Fires

Causes of Battery Fires

- External damage, misuse or inadequate maintenance
- Over-discharging, overcharging or charging cycles outside of OEM's recommendations
- Defects or internal short circuit leading to thermal runaway and potential exothermic reaction from inside the battery
- External heating from vehicle, fire and other heat sources
- Malfunctioning charging systems, smart cards, ground fault redundancies or cooling systems

Current NFPA Best Practices Responding to EVB Fires [1]



Identification

- Scene Sizeup – quickly identify vehicle as ICE engine or battery powered
- Depends on training, familiarization, awareness, labeling, instrumentation and warning signage
- Location of battery modules within the vehicle

Immobilization

- Perform normal immobilization procedures such as wheel chocks, parking brake, stabilizing unsecure position and loads
- Electric vehicles or equipment may be “hibernating” . Normal ICE sights and sounds not evident with battery powered. Avoid contact with any controls, trams or accelerators

Disabling Power Components

- Automatic shutdown of the high voltage system feeds from battery power modules. Switching off any master, key or disconnect according to manufacturer design
- Removing the manual disconnect. However, this was listed as not being a primary method for first responders to disable the vehicles high voltage circuits, as there are a variety of manual disconnect designs and locations

Disabling Power Components

- It may take up to 10 minutes for some systems to dissipate their energy
- Firefighters assigned the task of disabling the high voltage system via the main should consider wearing Class 0/1000v high voltage safety gloves with outer leather covers
- Disconnect power to any charger or charging system if the vehicle or battery is plugged in

STRANDED ENERGY!

Aside from thermal imaging of affected surfaces, responders lack the means to effectively monitor the battery's progression towards ignition or re-ignition due to the STRANDED ENERGY (stored energy) inside the battery(s)

Extrication

- Damaged high voltage battery may emit corrosive, toxic, and flammable fumes
- Responders should use ventilation techniques to protect the occupants of the vehicle and prevent the buildup of flammable vapours
- Avoid inadvertent contact with all high voltage cabling and high voltage components

Suppression and Extinguishment

- Defensive Attack recommended in the event high voltage battery becomes involved in fire and there are no exposures
- Allowing the battery to burn itself out has shown to an effective means to handle the situation

Suppression and Extinguishment

- Since the battery is sealed direct application of water may be all but impossible
- Continue to control fire around the battery and allow the battery pack to burn itself out
- If the battery pack needs to be extinguished copious amounts of water must be applied to the battery case to cool adjacent cells and electrolyte below ignition temperatures
- Electrolyte in most high voltage battery cells is flammable

Overhaul Operations/Post-Incident

- Stranded Energy (Stored Energy). Always assume the battery and associated components are energized and fully charged
- Notify an authorized service center or vehicle manufacturer representative (dealer) as soon as possible as there may be additional steps they can take to secure and discharge the HV battery
- Do not store a severely damaged vehicle with a lithium-ion battery inside a structure or within 50 feet of any structure or vehicle
- Vehicle should be monitored for leaking fluids, sparks, smoke, flames, gurgling or bubbling sounds from the HV battery, and if detected, assume the HV battery is burning and follow above guidance to extinguish the fire

Hazards to Mine Rescue Teams

- Stranded Energy – Electrical hazards from battery modules, high voltage output and live charging circuits
- Attempted cooling efforts can expose teams to high voltage (water is a primary conductor)
- In some instances water and/or foam will increase intensity of fire with possible explosive hazards
- Unfamiliarity with early stages of thermal runaway
- Contact with hazardous combustible electrolyte
- Mine Rescue teams are not equipped with full structural PPE (Bunker Gear) and may be exposed to intense heat and projectiles

Hazards to Mine Rescue Teams

- Ventilation limitations within the confined underground environment – heat, smoke and hazardous gasses present in the downstream flows or trapped in poorly vented levels and drifts. Lack of water or water pressure
- Battery in close proximity to other EVB's, conveyors, mining equipment, electrical and other mine Infrastructure or combustible material
- EVB's located in remote or expansive mining locations increasing response times.
- Other respiratory and contact (skin) hazards. (hydrogen flouride, sodium chloride, other airborne metallics, oxides of carbon, nickel, lithium, copper and cobalt battery steam, sulphuric acid, etc . . .)
- Battery locations and "bomb proof" encasement difficult to access with suppression agents
- Damaged cooling systems can leak, burn or hinder access to cool, monitor or extinguish battery

Incident #1
Rechargeable Battery Fire

App. 30 plus rechargeable lithium batteries were thought to be stored in the area

Signs of intense heat and melted metal and copper



It was determined that between shifts, the battery charging operation failed, and a fire started on the top shelf, which burned through to the second shelf containing the batteries. Subsequently, the batteries and burning shelving material fell to the ground. The lithium batteries served as the fuel, which ignited an isolated high-heat fire

Incident #2
Thermal Runaway Lead Acid Battery Incident

Incident # 4
Lithium Ion Battery Fire

Incident # 5
Multi-Electric Mine Utility Vehicle Fire

Examples of MSDS Information

SECTION 5 - FIREFIGHTING MEASURES

Flash Point	Not Applicable	Flammable Limits in Air % by Volume (When Charging)	Hydrogen (H_2) Lower 4.1% Upper 74.2%	Extinguisher Media	Class ABC, CO_2, Halon
Auto-Ignition Temperature	Polypropylene 675°F				
Special Fire Fighting Procedures	Lead/acid batteries do not burn, or burn with difficulty. Do not use water on fires where molten metal is present. Extinguish fire with agent suitable for surrounding combustible materials. Cool exterior of battery if exposed to fire to prevent rupture. The acid mist and vapors generated by heat or fire are corrosive. Use NIOSH approved self-contained breathing apparatus (SCBA) and full protective equipment operated in positive-pressure mode.				
Unusual Fire and Explosion Hazards	Hydrogen gas and sulfuric acid vapors are generated upon overcharge and polypropylene case failure. Ventilate charging areas as per ACGIH Industrial Ventilation: A Manual of Recommended Practice. Hydrogen gas may be flammable or explosive when mixed with air, oxygen, and chlorine. Avoid open flames/sparks/other sources of ignition near battery. To avoid risk of fire or explosion, keep sparks or other sources of ignition away from batteries and do not allow metallic materials to simultaneously contact negative and positive terminals of cells and batteries. SULFURIC ACID REACTS VIOLENTLY WITH WATER/ORGANICS.				

SECTION 6 - ACCIDENTAL RELEASE MEASURES

Procedures for Cleanup: Avoid contact with any spilled materials. Contain spill, isolate hazard area, and deny entry. Limit site access to emergency responders. Neutralize with sodium bicarbonate, soda ash, lime or other neutralizing agent. Place battery in suitable container for disposal. Dispose of contaminated materials in accordance with applicable local, state, and federal regulations. Sodium bicarbonate, soda ash, sand, lime or other neutralizing agent should be kept on-site for spill remediation.
Personal Precautions: Acid resistant gloves, aprons, boots, and protective clothing. ANSI approved chemical splash goggles w/face shield recommended. Ventilate enclosed areas.
Environmental Precautions: Lead and its compounds and sulfuric acid can pose a severe threat to the environment. Contamination of water, soil and air should be prevented.

SECTION 7 - HANDLING AND STORAGE

Precautions to be Taken in Handling and Storage	Store away from reactive materials, open flames and sources of ignition. Combustion or overcharging may create or liberate toxic and hazardous gases and liquids including hydrogen, sulfuric acid mist, sulfur dioxide, sulfur trioxide, stibine, arsine and sulfuric acid. Store batteries in cool, dry well-ventilated area. Do not short circuit battery terminals, or remove vent caps during storage or recharging. Protect battery from physical damage and adverse weather conditions. Avoid contact with internal components.
Other Precautions	GOOD PERSONAL HYGIENE AND WORK PRACTICES ARE MANDATORY. Refrain from eating, drinking or smoking in work areas. Thoroughly wash h… …othing before reuse. Emptied batteries contain hazardous …

SECTION 8 - EXPOSURE CONTROLS AND PERSONAL PROTECTION

5. Fire Fighting Measures

Suitable fire extinguishing agents:	CO_2 or dry powder extinguishing agents
Unsuitable fire extinguishing agents:	Water, if the battery voltage is above 120 V
Special protective equipment:	Protective goggles, respiratory protective equipment, acid protective equipment, acid-proof clothing in case of larger stationary battery plants or where larger quantities are stored.

5 – FIRE-FIGHTING MEASURES

Fire and fume hazard: Except LFP series batteries, LCP and LMP batteries can leak and/or spout vaporized or decomposed and combustible electrolyte fumes in case of exposure above 150 ° C resulting from inappropriate use, abuse, or from the environment. Possible formation of hydrogen fluoride (HF) and phosphorous oxides during fire. LiPF 6 salt contained in the electrolyte releases hydrogen fluoride (HF) in contact with water.

Extinguishing media: spray the battery with water or put the smoking battery into basin at once.

Can be used : ..... Type D extinguishers , Co2, Dry chemical or Foam extinguishers

Special hazards : Following cell overheating due to external source or due to improper use, electrolyte leakage or battery container rupture may occur and release inner component/material in the environment.

Eye contact : The electrolyte solution contained in the battery is irritant to ocular tissues.

Skin contact: The electrolyte solution contained in the battery causes skin irritation.

Ingestion: The ingestion of electrolyte solution causes tissue damage to throat and gastro/respiratory tract.

Inhalation : Contents of a leaking or ruptures battery can cause respiratory tract, mucus, membrane irritation and edema.

Special protection: Use self-contained breathing apparatus to avoid breathing irritant fumes.

Wear protective clothing and equipment to prevent body contact with electrolyte solution.

Indication of immediate medical attention and special treatment needed: Not available.

Section 5 - Fire Fighting Measures

Suitable extinguishing media:

Use extinguishing agent suitable for local conditions and the surrounding environment . Such as dry powder , CO_2.

Unsuitable extinguishing media:

No further relevant information available.

Specific Hazards arising from the chemical:

Special hazards arising from the substance or mixture

Battery may burst and release hazardous decomposition products when exposed to a fire situation. Lithium ion batteries contain flammable electrolyte that may vent, ignite and produce sparks when subjected to high temperature(>150℃(302℉)), when damaged or abused (e.g. mechanical damage or electrical overcharging); may burn rapidly with flare-burning effect; may ignite other batteries in clothes proximity.

Specific protective actions for fire-fighters:

Protective equipment: Wear self-contained respirator. Wear fully protective impervious suit.

Section 6 - Accidental Release Measures

Flammability: Not available.

Extinguishing media

Suitable extinguishing agents

Use extinguishing agent suitable for local conditions and the surrounding environment . Such as dry powder , CO_2.

Special hazards arising from the substance or mixture

Battery may burst and release hazardous decomposition products when exposed to a fire situation. Lithium ion batteries contain flammable electrolyte that may vent, ignite and produce sparks when subjected to high temperature(>150℃(302℉)), when damaged or abused (e.g. mechanical damage or electrical overcharging); may burn rapidly with flare-burning effect; may ignite other batteries in clothes proximity.

Advice for firefighters

Protective equipment: Wear self-contained respirator. Wear fully protective impervious suit.

5. Fire-fighting measures

Keep public away from danger area. Keep upwind and use self-contained breathing apparatus.

Notify Police and Fire Department as soon as possible.

Tab .1 - Recommended Extinguishing Media

Extinguishing media	Recommended in	Effectiveness
Standard extinguisher according to the source of fire	Presence of external fire surrounding the battery	Undetermined
Fire extinguisher Class D, CO_2, Halogenated Hydrocarbon, Water in large amount	Emission of smoke and small flames from the battery	Medium, extinguish the fire and reduce time to reach inert state of the battery
Fire Extinguishers Class D, Dry Powder, Sodium Carbonate	Very unlikely event of leakage of metallic Sodium outside the battery**	High, neutralization of metal sodium

*** When a severe occurrence takes place the metallic sodium inside the cells reacts internally with the cathode material with heat development and no fire. Only a disrupting mechanical damage with generation of a large breach in the outer double steel container and simultaneously rupture of some cell cases can provide chances for a leak of a small amount of metallic sodium directly exposed to the environment and possibly the development of some flames but no risk of explosion.*

Such mechanical damage can be excluded during normal operation of the battery in the industrial stationary applications.

Interim Protocols for Mine Rescue Personnel Responding to Battery Fires

1. Training and awareness to Identify EVB's during initial information gathering stage of incident
2. Access to battery product MSDS and manufacturer contact information for specific firefighting considerations
3. Early detection of battery thermal runaway – knowing when to use cooling suppression techniques
4. Retreat to defensive position in the event of high voltage battery becomes involved in fire and there is no worker exposure. Allowing the battery to burn itself out
5. Embed electrician within the 5-member team – recognition of ALL potential electrical hazards, disconnects, charging circuits and STRANDED ENERGY
6. Company and Mine Rescue personnel to avoid downstream contamination

Future Considerations

"It's just a case of the fire service playing catch-up to the modern world."

NFPA Journal 2018 Juan Diaz, chief of the Mountain View Fire Department

"There are currently no ways for responders to determine how much energy remains in a damaged battery, and no way to drain that energy to reduce the threat. The battery industry is working to improve safeguards so that thermal runaway and stranded energy are no longer issues"

NFPA Journal 2018 Don Karner, the founder of Electric Applications Incorporated

Advancing Market Demand

With so many players emerging with the latest and greatest battery technology, government standards and regulations have yet to catch up as it relates to use in Ontario mines. . .

Considerations for Responding Mine Rescue Teams

1. Develop strategic storage and charging depots to avoid propagation in case of battery fires
2. Develop MSDS data base for easy access for Mine Rescue teams, Briefing Officer and Control Groups
3. Mine electrical trades people trained as Mine Rescue Volunteers

Considerations for Responding Mine Rescue Teams

4. Investigate appropriate PPE for initial response to battery fires. This may be MSDS and site specific to protect responders from high voltage, extreme heat and toxic fumes
5. Investigate extra gas detection and sensors. This would also be site specific and is in use in some mines already
6. Timely removal of stored “recycled or damaged” batteries
7. Share incident investigation and “near miss” information to begin building our expertise to develop strategies for safe handling of battery fires

Thank You!

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Source Material

Best Practices for Emergency Response to Incidents Involving Electric Vehicles Battery Hazards:
A Report on Full-Scale Testing Results
Fire Prot*ection Research Foundation © June 2013*

A Review on the Thermal Hazards of the Lithium-Ion
Battery and the Corresponding Countermeasures
MDPI 2012

Handbook of Training in Mine Rescue and Recovery Operations
Workplace Safety North © 2015

What firefighters need to know about electric car batteries
Author: Chief Robert R. Rielage, CFO, EFO, FIFireE, FireRescue 1 Copyright © 2020 Lexipol.

BU-304a: Safety Concerns with Li-ion
Battery University 2011

Electric/Hybrid Vehicle Safety Training for Emergency Responders
Author: Andrew Klock - **Fire Prot*ection Research Foundation © May 2013***

A Review on the Thermal Hazards of the Lithium-Ion Battery and the Corresponding Countermeasures

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Current Status of Health and Safety Issues of Sodium/Metal Chloride (Zebra) Batteries

National Renewable Energy Laboratory
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CRM 9/19/2019 FIRE – Southern Ontario – CGC Vehicle Fire – Dan Rulli

CRM 12/6/2018 FIRE – Red Lake District – RLGM Fire – Grant Saunders

CRM 11/16/2018 FIRE – Southern Ontario – CGC Battery Fire – Dan Rulli

Stranded Energy

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