Underground mining: Alternative to diesel-powered Load-Haul-Dump vehicles (LHD)

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Abstract

Ventilation will always be a challenge in underground mining. With ore bodies being present deeper under the ground, the cost of installing and operating fans, heating and cooling will grow significantly. In other areas, mines are being reopened but have to exploit the ore body using infrastructures already in place, making sometimes ventilation management impossible. The requirement for ventilation is mostly driven by regulation, and the industry expects the constraint will increase as the health hazards related to diesel particulate matter (DPM) in underground space are brought to the knowledge of everyone. While Tier 4 diesel engines are starting to be available on LHDs, they are becoming increasingly complex and require much more maintenance than before. GE is bringing forward it's knowhow in battery-powered vehicle in coal mining to the hard rock industry through a battery powered LHD. The advantages are multiples, sometimes quantitative (ventilation savings, maintenance savings) and sometimes priceless (health).

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Presentation overview

- Diesel particulate matter (DPM)
- Heat
- Ventilation
- Solution

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Diesel particulate matter (DPM)

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Knowledge on DPM is improving

MDEC 2010
NIOSH Observations
(…) Underground miners can be exposed to over 100 times the typical environmental concentration of diesel exhaust and over 10 times that of other workplace exposures.

http://mdec.ca/2010/S3P3_willick.pdf

National Cancer Institute
(…) The researchers observed increased risk for lung cancer death with increasing levels of exposure to diesel exhaust. Risks among heavily exposed workers were about three times greater than risk among workers with low exposure to diesel exhaust.
*They also reported that non-smokers with the high levels of diesel exposure were **seven times more likely to die from lung cancer** than non-smokers in the lowest exposure category.*

http://www.cancer.gov/newscenter/newsfromnci/2012/DieselMinersQandA

World Health Organization - WHO
June 13th, 2012: reclassification of diesel particulate from a "suspected carcinogen" to a "known carcinogen"

http://www.globalpost.com/dispatch/news/health/120613/diesel-engine-exhaust-fumes-cancer-carcinogenic-carcinogen-who

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Knowledge on DPM is improving

CDC 2010 - Aerosols emitted in u/g mine air by diesel engine fueled with biodiesel

By Bugarski AD & al.

Biodiesel reduces DPM, but increases NO_x

http://www.cdc.gov/niosh/mining/UserFiles/works/pdfs/oeium.pdf

CDC 2012 - Newmont Leeville after treatment highlights, by Troy Terrillion

1. EBMP is essential for DPM compliance.
2. There is no "Silver Bullet" to DPM reduction.
3. Must have corporate "buy in" for success.
4. Maintenance must be key stakeholder.
5. Temperature profiling
6. Keep good records(IE duty cycle, design, material)
7. Use available resources (Data, MSHA, NIOSH)
8. Attending conferences beneficial
9. Use quality components for measurements. (ECOM)
10. CJ4 Oil requirement

http://www.cdc.gov/niosh/mining/userfiles/workshops/dieselaerosols2012/terrillionmvs2012aftertreatmenttech.pdf
http://www.smenet.org/docs/meetings/papers/MineVent2012/vent2012p13.pdf

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Solutions are not easy

Tier4 – a world of compromise

- *DPM vs NOx*
- *Urea injection*
- *Increase in technical challenges, maintenance*
- *Expensive solution (EGR, Platinum / Palladium catalyst in SCRs)*
- *Adds heat through exothermic process of catalyst and regeneration*
- *Passive or active regeneration*
- *Why such a discrepancy between surface and underground mining?*
- *Technical conflict with underground coal mining environment*

http://www.cdc.gov/niosh/mining/userfiles/workshops/dieselaerosols2012/tremaine-mvs2012enginetechnology.pdf
http://www.resourcesandenergy.nsw.gov.au/__data/assets/pdf_file/0010/461278/B8-Furniss-and-George-Lin_Caterpillar-CAT-Engine-Overview-Coal-Applications-2013.pdf

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Regulation

Québec
Regulation respecting occupational health and safety in mines
Chapter S-2.1, r.14
Article 100.1
- *Certificate of homologation MMSL-CANMET*
- *US 30CFR, MSHA*
- *5.5m³ per min per kw (144 CFM per HP), down to possibly 1.9m³ per min per kw (50CFM per HP) with proper performance and certification*

Ontario
OSHA in mines
Regulation 854
Article 183.1 (3)
- *0.06m³ per sec per kw (94.8 CFM per HP)*

Court case in Canada

Claude Fortin
December 17, 2012
- Claude Fortin developed lung cancer despite healthy lifestyle
- Superior court upheld previous decision by CLP
- Occupational disease
- **Following regulation is not enough to protect workers**

http://blogueslonnord.lovery.ca/en/mining-companies-and-occupational-disease-regulatory-standards-are-not-the-test/

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Heat

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Heat in underground mines

Ventilation - *Agnico-Eagle LaRonde extension case study*

Depth up to 3,000m (level 311)

Heat stress
- *3 underground cooling plants (146, 170, 262, 278)*
- *Mobile equipment (200 units)*
- *Rockmass : thermal gradient 10.6°C/km*

Cooling solution
- *4,000 tons on surface*
- *2,000 tons on level 170*
- *5,000 tons on level 262*
- *Total of 11,000 tons*
- *Temperature at level 262 during summer time: 15°C*

Massive infrastructure
- *28ft diameter raise for exhaust*
- *Underground booster fan of 6,000HP (194)*

http://quebecmines.mrn.gouv.qc.ca/programme/pdf/st08_05_para_conf_fr.pdf

Ventilation – *Rio Tinto Resolution Copper*

*(...) There, a mile underground, where rock temperatures reach **80°C**, we are preparing to mine one of the largest copper ore bodies ever found. (...)*

Rio Tinto - Resolution Copper

http://www.riotinto.com/copper/resolution-4682.aspx

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Heat - compromises

Deep mining temperature

(…) The exposure of working personnel to these higher temperatures must be monitored and managed in an effort to maintain safe working conditions. Some ways to manage these conditions include ***shorter shifts*** *or* ***more frequent rests*** *in a temperature-controlled environment to reduce exposure, and/or* ***increasing local ventilation and cooling****. (…)*

Sandy Watson from Stantec – Mining Magazine May 2014

http://www.stantec.com/content/dam/stantec/files/PDFAssets/2014/Digging%20a%20little%20deeper%20-%20Mining%20Magazin%20May%202014.pdf

(…) None of the subjects could complete the 2-hour simulated mining work task at a WBT of 32 °C. (…)

G. Kenney & al. – HEAT STRESS IN CANADIAN DEEP MECHANIZED MINES: LABORATORY SIMULATION OF TYPICAL MINING TASKS PERFORMED IN VARYING ENVIRONMENTS, 2009

http://www.lboro.ac.uk/microsites/lds/EEC/ICEE/hexlsearch/09proceedings/ICEE13-Proceedings.pdf

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Ventilation

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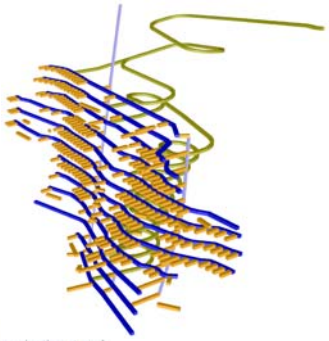
Ventilation on demand

Cost saving with VoD

According to Cheryl Allen from Vale, savings at Coleman mine using VoD can be in the order of 12%-20% of ventilation power spending

http://www.bestech.com/Downloads/Whitepapers/VOD%20Impact%20CIM_Montreal-CHERYL%20ALLEN-2011-04-21.pdf



"(...)80 pieces of underground machinery(...)"

"Once fully operational, the system is projected to comprise 60 to 80 fans and about 15 air flow regulators, and will generate estimated annual savings of $1.6 - $2.5 million over conventional ventilation systems."

Goldcorp Éléonore mine

http://www.goldcorp.com/English/blog/Articles-Details/2014/A-Breath-of-Fresh-Air-this-Earth-Day/default.aspx

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Ventilation still required

Looking at other factors than engine mechanical kW

WMC 2013, J.D. Stinette and E. De Souza

- *Reducing ventilation math based on Tier 4*
- *Increase because of heat (deeper mines, Tier 4 engines with active regeneration)*
- *0.028m³/s/kW suggested (44.2 CFM/HP) for Tier 4 engines, based on PI, CO_2 and NO_x*
- *Mineral dust*

*(...) mine airflow requirements **are unlikely to decrease by 90% as a result of** the 90% reduction in emissions associated with **Tier IV diesel engines**. (...)*

http://www.mvsengineering.com/files/Publications/wmc2013Paper694.pdf

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Reality check

- For deep underground mining, a lot of heat can come off the rock, cooling and ventilation will be required
- Heat generated by diesel machinery (approx. 25% system efficiency!)
- DPM is difficult to control, complex technology and tight procedure required, regulation can't keep up
- Some efforts to capture DPM, resulting in more smaller particles have been proven to be even more dangerous to human health than no treatment at all.

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Solutions

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GE's Fairchild Workhorse Family

Full Line of Multi-Purpose Vehicles

*Low Seam **Workhorse** Scoop*
(Minimum Seam Height = 36")

*Standard **Workhorse** Scoop*
(Minimum Seam Height = 56")

***Workhorse** Shield Hauler*

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Available in Diesel, DC or AC propulsion

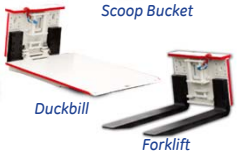
Common Uses

- Roadway Cleanup
- Equipment Transport
- Coal Hauling
- Maintaining/Repairing Other Equipment
- Rock Dusting
- Shield Hauling (Longwall)
- Forklift

Multiple Attachment Available

Maintenance Bucket

Scoop Bucket



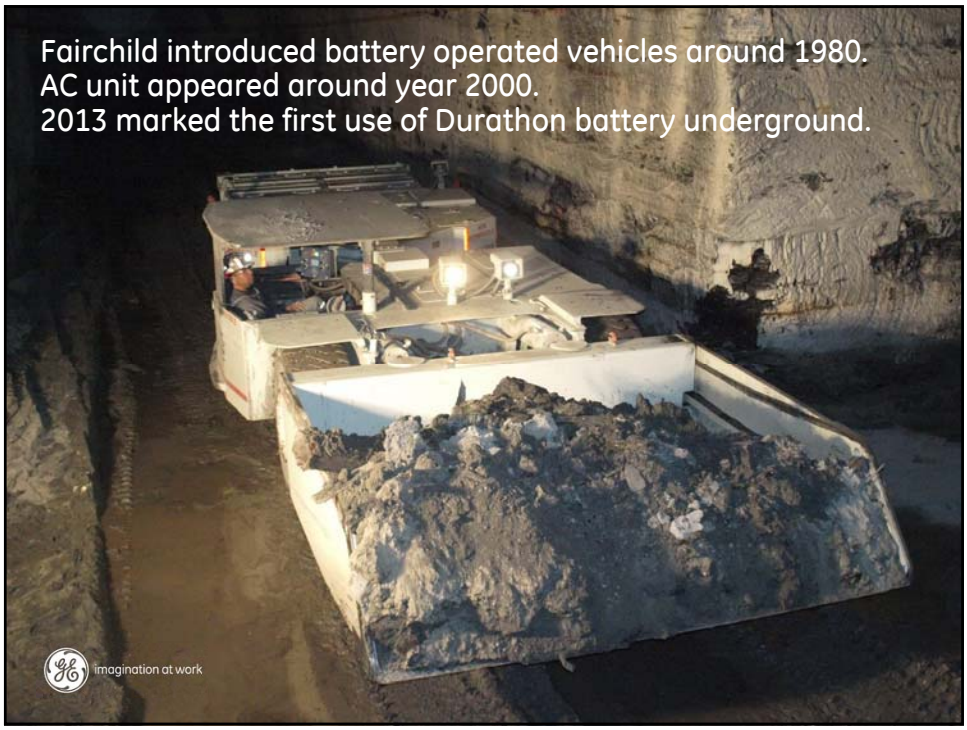
Duckbill

Pressure Washer

Forklift

17
GE Mining Equipment – Battery-operated LHD - MDEC 2014
1/26/2015

Fairchild introduced battery operated vehicles around 1980.
AC unit appeared around year 2000.
2013 marked the first use of Durathon battery underground.



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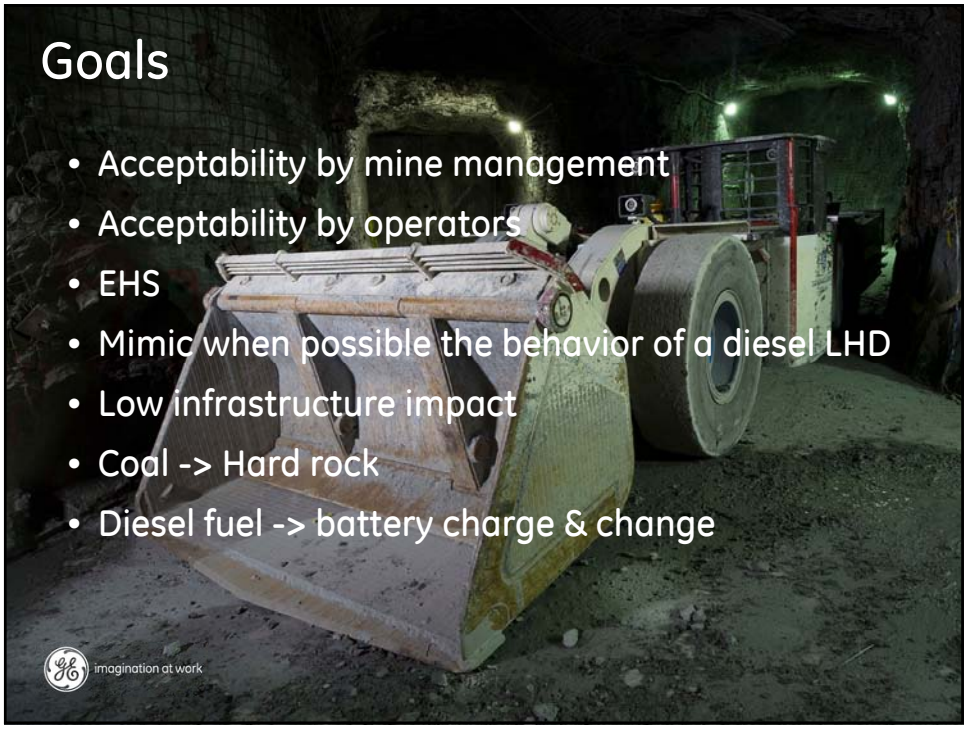

GE Mining Equipment

LHD Vehicle Overview

The GE-Fairchild LHD-5-LB is 5.5 Ton (5 tonnes) LHD designed to work in underground soft and hard rock, room and pillar mining. It uses lead acid batteries coupled with an AC propulsion system. The LHD utilizes a battery swapping system that minimizes vehicle downtime and improves availability. It is designed with the flexibility to work in low seam mines with both permissible and non-permissible atmospheres.

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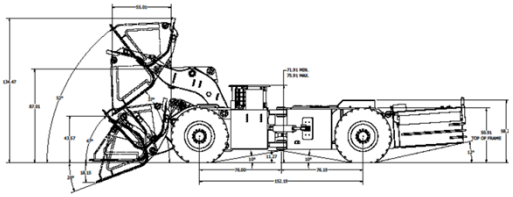
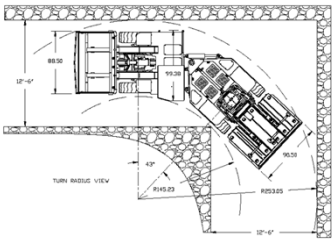
Main Dimensions & Capacities





- Total Length – 339.2 in (8610mm)
- Max Width – 99.4 in (2520mm) @ operator's cab
- Height w/ Canopy – 72.0 in (1820mm) MIN. / 76.0 in (1930mm) MAX.
- Turn Radius – outside - 253 in (6426mm)
  - inside 145 in (3683mm)
- Min Ground Clearance – 11.3 in (2870mm)

- Standard Bucket – 3 yd^3 (2.3m^3)
- Bucket Height Raised – 134.5 in (3410mm)
- Bucket Reach – 55.0 in (1390mm)
- Tramming Capacity – 11,000 lbs (4,990 kg)
- Breakout Force, Lift – 28,000 lbs (12,700 kg)
- Breakout Force, Tilt – 28,000 lbs (12,700kg)
- Vehicle Travel Speed Forward & Reverse (Loaded & Level) – 4.8 mph (7.7 km/h)
- Regenerative Breaking

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Battery, charger & infrastructure

Battery

- 3 - Lead acid batteries assemblies, 930 AH at 240V each

Charger

- 480V (130A) or 575V (110A) supply for battery charger
- Skid mounted, portable

Benefits

- Proven battery swap out system. Typical battery swap times of 15 minutes once at the charger.
- Typical battery charging time of 8hrs

Theoretical heat of an "old battery"

- Charger: 116kWh_{th} (8 hours span)
- Battery charging: 39kWh_{th} (8 hours span)
- Battery discharge: 17kWh_{th}
- Inverter, motors: 14kWh_{th}

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Battery advantages

Battery v. Diesel Benefits

Zero exhaust **emissions**... improved ventilation and human safety

Less fuel and oil delivery, lesser waste oil handling

Reduced maintenance costs

Increased **power/torque** through entire battery charge cycle

Side benefits

Reduction in cooling needs, possibility of reducing ventilation infrastructure requirement

Lighter load on procurement chain for fuel, spare parts or engine replacement

No urea, SCR or air filter management, no need for hot regeneration

Quiet operation of the vehicle

Battery powered equipment is a **safer**, **cleaner**, and **more efficient** alternative to diesel.

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Test results

- Acceptability by management, operators, EHS: Yes!
- Mimicking diesel LHD behavior: possible while retaining maximum efficiency
- Low infrastructure impact: Yes!
- Coal -> Hard rock: Well understood, normal development process
- Diesel fuel -> battery charge: Yes, more definition on work profile required
- Estimation of 10x less heat vs comparable diesel engine

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