Battery vs. Diesel Underground LHDs

Direct Comparison of Heat Generation

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MINING DIESEL mdec EMISSIONS COUNCIL

Jay Armburger and Chris McGuire

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Outline

- Study Motivation
- Test Description
- Results
  - Heat Output
  - Energy Cost
- Conclusions

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Study Motivation

Compare efficiencies of Battery-Electric & Diesel powertrains by capturing actual application data in an underground test environment

- Trend towards battery-electric mobile equipment in underground mining
- Driven by improvements in workplace air quality and ventilation requirements
  - Reduced contaminant generation (CO, NOx, DPM)
  - Reduced temperatures and humidity
  - Reduced noise and vibration
- Additional benefits including reduced ventilation CAPEX & OPEX, and reduced mobile equipment cost per tonne of ore

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Battery vs Diesel

- Battery vehicle powertrains are more efficient than an equivalent diesel combustion engine powertrain
  - Battery : 95% efficient
  - Diesel : 33% efficient

  } Battery vehicles are ~3x more efficient
  ⇒ Theoretically 3x less heat production
- Other differences & inefficiencies are not as easy to estimate

➢ Perform side-by-side testing of identical size-class (CAT® R1300) battery and diesel LHDs, quantify actual heat difference

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Test Procedure

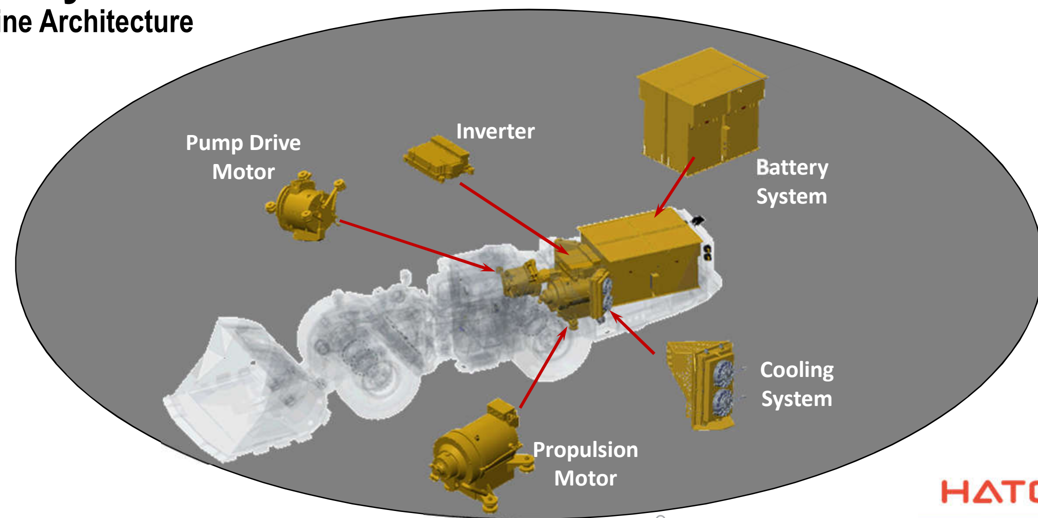
- Similar diesel and battery scoops performed identical simulated mucking cycles
- Test carried out over two days in an available heading of a Glencore mine in Sudbury
  - Three runs completed by battery scoop (recharge between each run)
  - Two runs completed by diesel scoop (exit heading for equivalent recharge time)

Equipment Comparison

	Diesel Scoop	Battery Scoop
Model	Cat R1300G - HLJB01555	Cat R1300 Battery Test Bed
Engine Rated Size	123 kW	123 kW equivalent
Battery	n/a	Fast Charge, Liquid Cooled
Load	7,500 kg steel	7,500 kg steel
Travel Distance	107 m	107 m
Hydraulic Pump	Mechanical linkage to engine RPM	Independent Motor (responds to demand)
Output Torque Control	Mechanical torque converter	Motor output control

Battery Electric LHD

Machine Architecture



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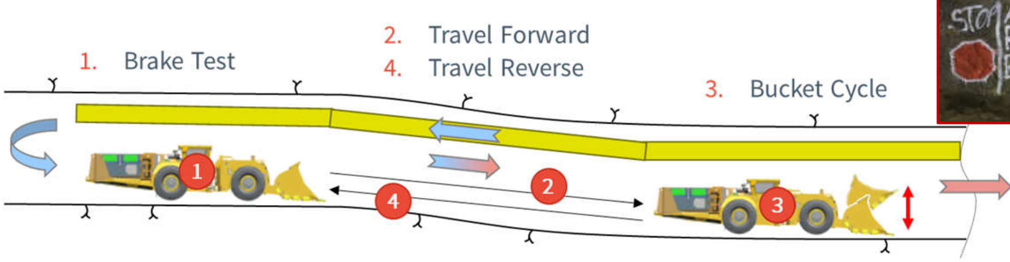
Simulated Mucking Cycle



1. Perform brake test (simulate driving bucket into muck pile)
2. Travel forward
3. Stop and perform bucket cycle (lift and lower)
4. Travel reverse back to brake test location

- Repeated for 30 Cycle Runs

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Measurements

- Total energy input to LHDs:
  - Onboard data monitoring of battery voltage/current output
  - Total diesel fuel consumption
- Heat input to ventilation airstream
  - Data loggers recording temperature, pressure and humidity
  - Measured fresh air in supply duct and exhaust air in drift

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Test Metrics

	Battery Scoop	Diesel Scoop
Length/Run	1.23 hrs	1.24 hrs
Number of Cycles/Run	26, 28, 30	28, 30
Number of Runs	3	2
Average Speed – Forward	8 km/h	10 km/h
Average Speed – Reverse	6 km/h	7 km/h
Average Airflow in Drift	13.4 m^3/s (28.3 kcfm)	13.4 m^3/s (28.3 kcfm)*

*Minimum airflow per Ontario regulations 7.4 m^3/s (15.6 kcfm)
→ Test reflects 80% more flow than required by regulations

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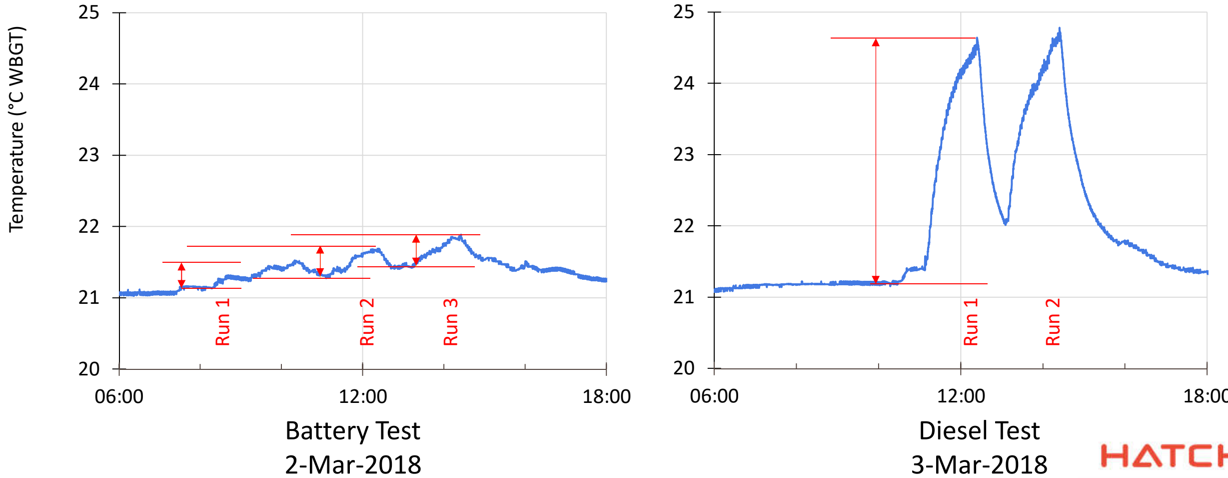
Measured Temperatures

WBGT defined as 0.7 x $T_{wet\ bulb}$ + 0.3 x $T_{dry\ bulb}$

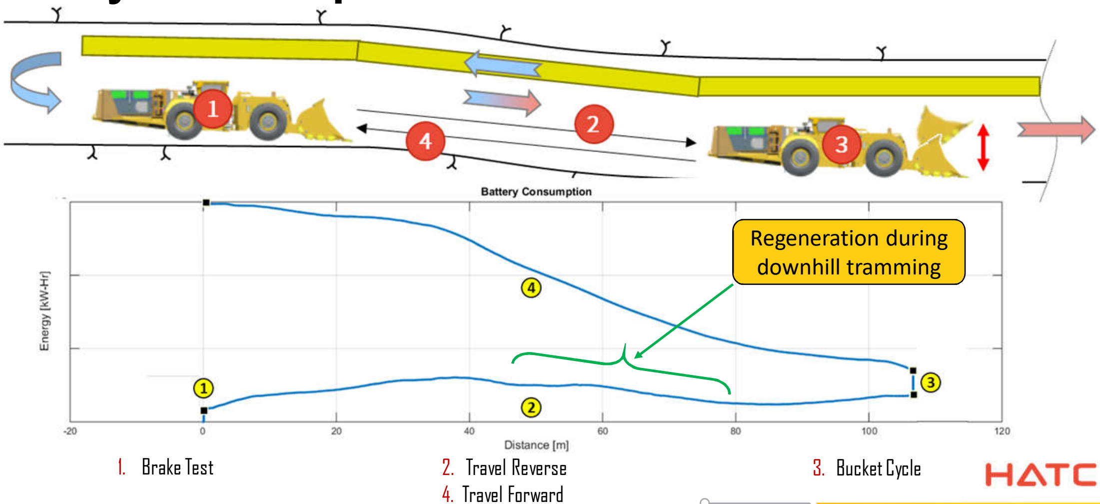


Heat Output

	Battery LHD	Diesel LHD	Ratio Diesel/Battery
Theoretical Heat Output Based On Drivetrain Efficiencies			3
Measured Total Energy Input	36 kW_T (net of regeneration)	355 kW_T	10
Measured Air Enthalpy Increase	20 – 45 kW_T	300 – 325 kW_T	7 – 8
Measured Air Temperature Increase	0.4 °C WBGT	3.0 °C WBGT	7.5

WBGT defined as 0.7 x $T_{wet\ bulb}$ + 0.3 x $T_{dry\ bulb}$

Battery Consumption Profile



Energy Cost Comparison

	Battery Scoop	Diesel Scoop
Average Electrical / Diesel Output per Run	43 kWh (net of regeneration)	50L Diesel
Unit Cost *Typical values for Sudbury mine*	$0.085/kWh	$0.75/L
Energy Cost per Run	$3.66	$37.50

- Observed 10-fold reduction in expected fuel costs for equivalent duty

Conclusions

- Battery vehicles can reduce heat output by more than predicted by drivetrain efficiency alone
- Ventilation benefits include reduced volume & cost for similar workplace conditions, or increased production capability for same air volume & cost
- Observed energy cost 10x less for battery LHD with equivalent duty cycle
- Further testing recommended to generalize these findings

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