Natural Resources Canada | Ressources naturelles Canada

The Fuelcell Mining Vehicles Development Program: An Update

Marc C. Bétournay

Mining Diesel Emissions Conference
October 29, 2002

1 CANMET MINING AND MINERAL SCIENCES LABORATORIES Canada

Immediate Issues and Opportunities

- Health
  - air quality
  - regulatory directions
  - need to establish a long-term solution to diesel exhaust

✓ fuelcells offer a total solution, reducing heat and noise generation as well as eliminating all emissions

2 CANMET MINING AND MINERAL SCIENCES LABORATORIES Canada

Issues and Opportunities (cont'd)

- GHG
  - industry is committed to reducing GHG's
  - ~3000 diesel emitting vehicles in Canadian underground metal mines (47% light duty; 38% LHD's; 15% trucks)
  - Canadian metal mining extraction (underground and open pit) produces 3.7 MT CO_2/year

✓ 1.0 MT/year of CO_2 would be eliminated

3 CANMET MINING AND MINERAL SCIENCES LABORATORIES Canada

Issues and Opportunities (cont'd)

- Operating Costs
  - diesel equipment, maintenance, downtime, automation
  - ventilation costs (40% of underground metal minesite electrical consumption)

✓ reduction of > 35% in ventilation, natural gas (~12% in site electrical and energy bill, 0.3-1.0 $M/year)

✓ lower maintenance costs, higher reliability

✓ increase in productivity from vehicle availability, performance

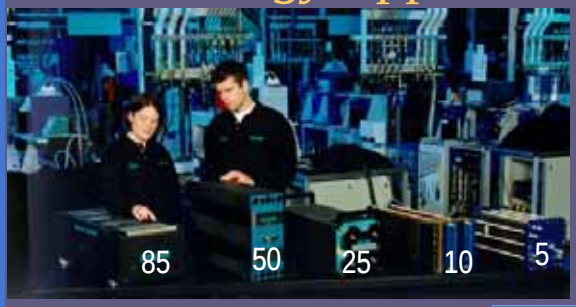
✓ automation, tele-remote operation improved

4 CANMET MINING AND MINERAL SCIENCES LABORATORIES Canada

Technology - Current Applications

- space missions
- submarines
- city buses
- large power plants
- residential

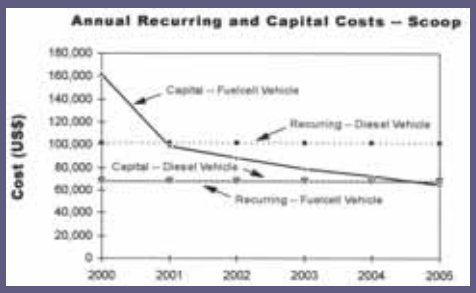
Technology Applications (cont'd)

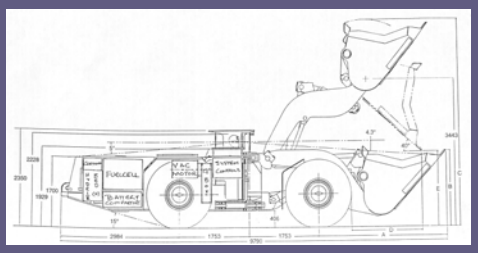


POWER RANGE	
• Mine loco	15- 50 kW
• LHD	150-300 kW
• Truck	300-500 kW
• Light duty	50-100 kW

Fuelcell Technology Status

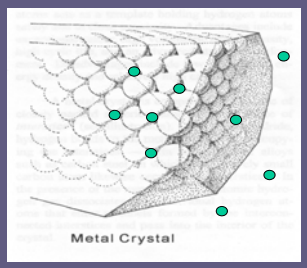
- Ready for mining/industrial application
- Robust enough for mining
- Capital intensive (cost dropping) but low in operating costs
- Fuelcells and diesel costs for running mining vehicles are the same





Fuelcell Technology Status (cont'd)

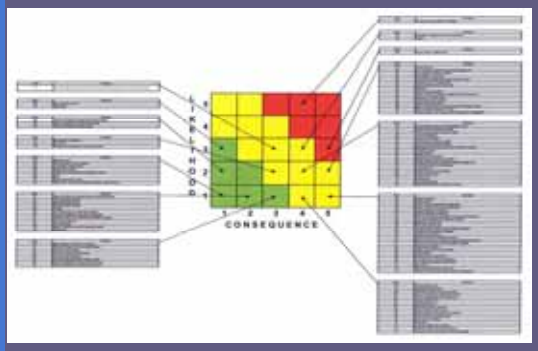
- Hydrogen will be stored in low pressure, low flammability medium - metal hydride powder



- Free hydrogen in system/fuelcells very small
- Safety risk: at or lower than diesel

Risk Evaluation (locomotive)

2 high risks
85 moderate risks
33 low risks



ISSUES

Power plant
- •controller
- •connections
- •software
- •maintenance/procedures

Mine
- •dust, gasses
- •rock falls
- •fires
- •sparking/ignition
- •impacts

External
- •operator error/vandalism
- •transportation/damage
- •refueling/station
- •freeze-ups
- •lightning

9 CANMET MINING AND MINERAL SCIENCES LABORATORIES Canada

Participants

Champions: Fuelcell Propulsion Institute, CANMET MMSL

- Mining companies
  - INCO
  - Noranda
  - Placer Dome
  - Newmont
- U.S. National Mining Association
- U.S. Bituminous Coal Mining Association
- Provincial Chief Inspectors of Mines
- U.S. Mine Safety and Health Administration (MSHA)
- Mining equipment manufacturers
  - Caterpillar Elphinstone
  - R.A. Warren Equipment
- Technology developers
  - H-Power
  - Nuvera
  - Sandia National Labs
  - Westinghouse-Savannah River
- HATCH
- CANMET Energy Technology
- U.S. Department of Energy

10 CANMET MINING AND MINERAL SCIENCES LABORATORIES Canada

PROJECTS OF FPI

Locomotive for metal mining

Loader for metal mining

Shuttle car for coal mining

Locomotive for surface railways

11 CANMET MINING AND MINERAL SCIENCES LABORATORIES Canada

Completed Projects

Impact of underground environments on fuelcells 2001-02

CANMET MMSL, FPI, INCO, Ontario MOL, H-Power, Sandia

$80k value (task shared)

- dust and gas effects on the generation of electricity and on fuelcell materials
- shock and vibration effects on stack integrity

12 CANMET MINING AND MINERAL SCIENCES LABORATORIES Canada

Completed Projects (cont'd)

Environmental impact

Aux. vent.

Muck pile

CANMET MINING AND MINERAL SCIENCES LABORATORIES

Canada

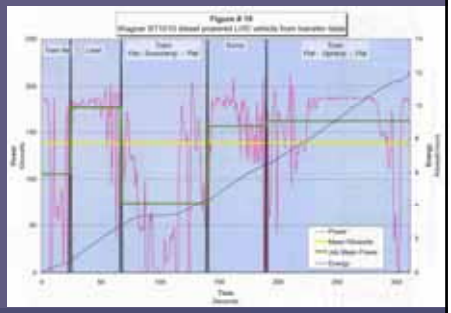
Completed Projects (cont'd)

Duty cycles

CANMET MMSL, FPI, Joy, Placer Dome, Cambior, Noranda, Peabody Coal

$70k value (U.S. DOE funding)

- Basis for fuelcell powerplant design
- Energy used during duty cycles, routes of production vehicles:
  - mine locomotive
  - LHD
  - coal mine shuttle car



CANMET MINING AND MINERAL SCIENCES LABORATORIES

Canada

Completed Projects (cont'd)

Locomotive 2000-02

12 partners

$2.4M value (U.S. DOE, NRCan ETP funding; task shared)

- Evaluate reliability, response, practicality, productivity and safety aspects in representative underground conditions
- Compare to conventional battery locomotive for same tests
- Familiarization for stakeholders
- Laying groundwork for other vehicle development
- Regulatory tests performed
- Full field tests performed at 2 minesites

15

CANMET MINING AND MINERAL SCIENCES LABORATORIES

Canada

Projects Underway

Underground loader

CANMET MMSL, FPI, Newmont, Noranda, Placer Dome, Ontario MOL, CSST Quebec, U.S. MSHA, Caterpillar Elphinstone, University of Nevada, Stuart Energy Systems, Southwest Research Institute, Westinghouse Savannah River, HATCH

$7M value (U.S. DOE, NRCan ETP, industry funding; task shared)

- **Phase 1 2001-2003**
- **mine safe refueling system**
- **electrolysis plant site test**
- **cost benefit analysis**
- **preliminary design, powertrain**

16

CANMET MINING AND MINERAL SCIENCES LABORATORIES

Canada

Timeline

2000-2004	Demonstrator projects finished
2002-2004	Establishing hydrogen production and delivery protocols
2005 →	Retrofit of diesel equipment
2006-2007	Partial fleet dedication to fuelcells
2008 →	New fuelcell vehicles generation designed and manufactured
2009 →	Major fleet changeover

Future Mining Opportunities

- New Mining Approaches: Power
  - power when and where needed
  - fuelcell power plant size evolution
  - universal power for underground use
- New Mining Approaches: Extraction Technology
  - consideration of extraction approach based on technology
  - higher degree of tele-remote mining
  - continuous 24hrs/day
- High Impact Example:
  - narrow vein mining is becoming more mechanized
  - smaller vehicles can be considered

Summary

- Fuelcell technology is being applied to power mine production vehicles
- It addresses four important industry issues
  - improved health benefits
  - automation, higher productivity, lower mine costs
  - reductions in GHG's
  - reduction in energy consumption (electricity, natural gas, diesel)
- Participation/support from mining stakeholders
- Proof of concept projects underway
- Other conceptual applications and contributions to mining are being developed