Ventilation Requirements

In general ventilation is required in order to provide workers and diesel engines a source of fresh air to dilute and clear away contaminants in the mining process.

These include the following:
- Toxic equipment exhaust gases (CO, CO2, NOx, Hydrocarbons etc.)
- Diesel Particulate matter (DPM)
- Heat
- Dust (silica)
- Blasting fumes (CO, NO2 etc.)
- Other gases (SO2, ammonia, Radon)

Current legislation in Ontario is 0.06 m3/s for each kW of power of the diesel engine in underground mines.
Ventilation Requirements

What would ventilation requirements look like if there was no diesel equipment?

We would need to ventilate for air quality.

These would include the following:

- Heat
- Dust (silica)
- Blasting fumes (CO, NO2 etc.)
- Other gases (SO2, ammonia, Radon)

In deeper mines like Onaping Depth the driver for ventilation will become heat.

Efficiency of Diesel Engines

- Diesel engines are typically 44% efficient (producing work) and the other ~56% of diesel fuel is converted to heat

  ~29 kW exhaust gas heat   8 kW charge air cooling

  ~100 kW fuel energy in   44 kW work output

  ~15 kW Heat to cooling   ~4 kW Engine friction
Efficiency of Electric Motors

- Electric motors are typically ~93% efficient.

~100 kW Elec energy in → 93 kW work output

~7 kW Heat

HEAT LOSSES FROM DIESEL AND BATTERY LOADERS:

- Diesel Engine Peak efficiency
- 8% Charge Air Cooling
- 25% Exhaust Gases
- 15% Heat to Coolant
- 4% Engine Friction
- 4% Torque Converter n=0.9
- 2% Gear Box n=0.95
- 3% Axles n=0.92
- 64% Diesel Fuel Energy

- Battery Energy
- 7% Battery Heat n=0.93
- 3% Power Electronics n=0.97
- 7% Electric Motor Losses n=0.93
- 4% Drop Box n=0.95
- 3% Axles n=0.92

n = 35% To wheels and rolling resistance

n = 73% To wheels and rolling resistance
Power Regeneration

• The battery electric systems offers the ability of the electrical motors to be used for regenerative braking especially when going down ramp.

• Regenerative braking converts the kinetic energy from braking back into the batteries rather than dissipating it off as heat.

• This makes battery significantly more efficient than diesel especially when hauling in a down ramp application.

Reduced Ventilation Cost

There is some reduction in ventilation cost to consider

• Reduction in number and/or size of ventilation raises

• Reduction in number of fans

• Reduction in heat generation due to auto-compression of ventilation air forced underground

• Smaller drift size

• Reduction in size of air cooling plant required on surface

• Increased humidity due to burning of diesel fuel

• For the same amount of work done you generate approximately 6-7 times less heat using battery electric over diesel
Onaping Depth Project
Prefeasibility Study 2016

Battery Electric Equipment Opportunity

Onaping No. 1 Shaft
- 6000L Truck Dump
- 4500L Crusher
- 4700L Loading Pocket

Onaping No. 2 Shaft
- 5700L Ore Bin
- 3800L Waste Bin
- 4200L green - Phase 1 (access)
- 3810L yellow - Phase 2 (ore/waste handling system + mine infrastructure)
- 3960L purple – Phase 3 (mine development & production ramp-up to 60%)
- 3930L black – existing infrastructure

Service Shaft
- 5000L
- 4000L Tram
- 2555L
- 1200L
- 2605L loading pocket

Production Shaft
- 1150L Tram Drift (4 x 5.2m)
- 315 RA Ramp (5.0m x 5.4m)
- 56 Exhaust Fan

Exhaust Fan
- 325 Bulk Air Cooler (BAC) = 23.7 MWr
- 302 Condensing Spray Chamber (CSC) = 32.5 MWr
- 2635L shaft bottom
- 2515L
- 2405L
- 1915L

Ventilation Flow = 300 m³/s
Bulk Air Cooler (BAC) = 23.7 MW
Condensing Spray Chamber (CSC) = 32.6 MW
Ventilation Fan Power = 10,500 kW
Refrigeration Power = 7,100 kW
Total = 17,600 kW

Production Levels:
- 5.0 m x 5.4 m ramp/drifts
- 54" vent ducts
- (5) Ore Passes

5.0 m dia. Exhaust Raise

- green - Phase 1 (access)
- yellow - Phase 2 (ore/waste handling system + mine infrastructure)
- purple - Phase 3 (mine development & production ramp-up to 60%)
- black - existing infrastructure
Why Battery Electric Mining Vehicles?

**Improved Vehicle Characteristics**
- No emissions
- Improved Performance
- Less Noise
- Simpler Machinery
- Less Wear and Tear
- Less Maintenance

**Benefit to Mining**
- **Health Benefits**
  - Less pollutants / particulates
  - Quieter
- **Less Ventilation**
  - Reduce Size & Number of Ventilation Openings
  - Reduce size of refrigeration plant
  - Less heating of mine air in winter (if required)
- **Overall Lower Energy Usage and Cost**
- **Improved Productivity**
  - Subjective at present – but mostly due to health benefits
Why Battery Electric Mining Vehicles?

Estimated CAPEX savings:
- Vent & Cooling Infrastructure: $24M
- Shaft Size: $5M
- Drift Size: $12M
- Total CAPEX: $41M

CAPEX additions:
- Mobile Equipment Premium: $21M (current assumption 140% of diesel fleet)
- Charging Infrastructure: $5M
- Total CAPEX additions: $26M

Estimated OPEX savings:
- Fan & Refrigeration Power Cost: $7.3M/year
- Natural Gas Cost: $0.3M/year
- Operating/Maintenance Cost: $0.3M/year
- Total OPEX savings: $7.9M/year

Note: One 3000HP Fan Running Continually = Approximately 5000 MWh/Quarter
Concerns and Challenges

**Vehicles**
- Lower Energy Density
- Slower Refueling Time
- Capital Cost of Equipment
- Availability of Equipment

**Challenges to Mining**
- Duty vs Battery Charge Cycle.
  - Shift Design around Equipment Capabilities and Limitations
  - Cultural change. Need to break “addiction” to convenience of fossil fuels.
- Infrastructure and Logistics
  - Parking
  - Charging

Path Forward and Challenges:

- Confirmation of vent flow and heat load requirements at Feasibility Study Level

- OEM technology development roadmap

- Equipment Cost

- Hauling up ramp still has challenges at this time

- **Mine infrastructure to support full mine battery electric fleet**
  - Charging stations for battery change out?
  - Quick change
  - Large scale infrastructure to support 80+ units
  - On-board battery charging?
  - Flexibility, reduced infrastructure
  - Charge time
Thank you