Diesel Particulate Journey – Vale Base Metals

MDEC - Mine Vehicle Powertrain Conference Workshop

C Allen
4Oct2023

Photo: Vale

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Health Safety Environment

Culture of continuous improvement

Health and Safety

- **HomeSafe** – More than safety → Well-being in the workplace
- Safety is a prerequisite for production
- Organizations must ensure activities do not cause harm to employees or their communities

Environment

- Strategies in place to reduce pollution, impact to the environment, loss of bio-diversity and promote sustainable practices
- Care for our employees and communities
- Good environment = Good health

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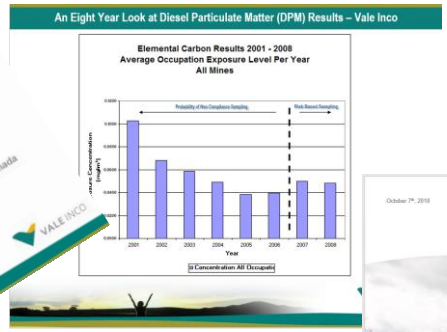
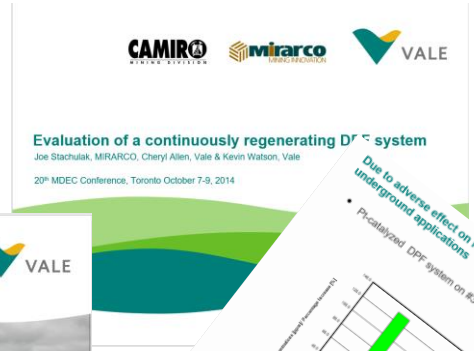
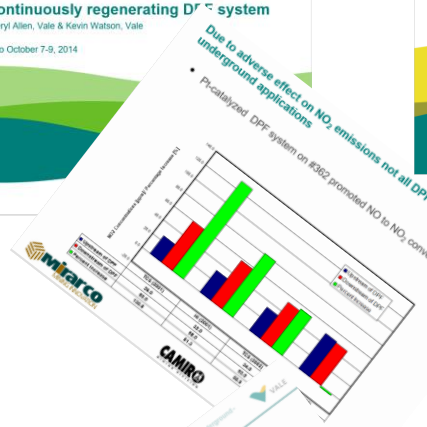
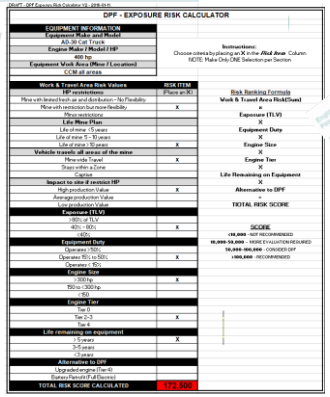
Research - Early Years









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Journey

Why a Program to Install DPFs?

Current State

- Diesel exhaust is a hazard
- Diesel particulate (DP) is a respirable dust

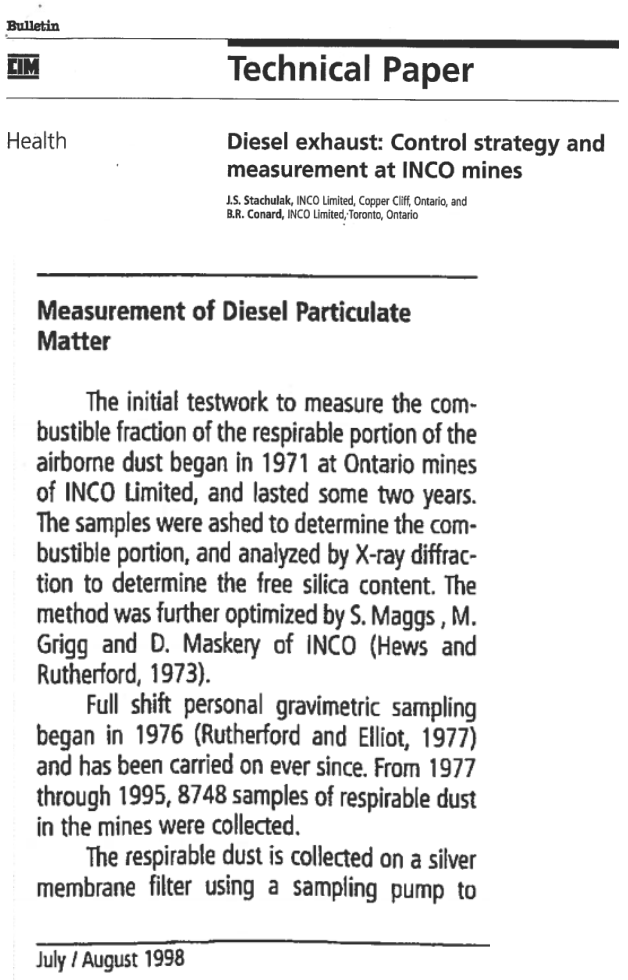
Future State

- Significant reduction and\or elimination of exhaust emissions in the workplace

Solutions

- Reduce emissions at the source
- Equipment maintenance, quality fuel and lubricants
- Dilution of contaminant by ventilation systems
- Substitution

Diesel Particulate Filters (DPF) are an engineering control that can reduce the DP mass as well as number count before reaching the mine atmosphere



Bulletin

EIM

Technical Paper

Health

Diesel exhaust: Control strategy and measurement at INCO mines

J.S. Stachulak, INCO Limited, Copper Cliff, Ontario, and
B.R. Conard, INCO Limited, Toronto, Ontario

Measurement of Diesel Particulate Matter

The initial testwork to measure the combustible fraction of the respirable portion of the airborne dust began in 1971 at Ontario mines of INCO Limited, and lasted some two years. The samples were ashed to determine the combustible portion, and analyzed by X-ray diffraction to determine the free silica content. The method was further optimized by S. Maggs , M. Grigg and D. Maskery of INCO (Hews and Rutherford, 1973).

Full shift personal gravimetric sampling began in 1976 (Rutherford and Elliot, 1977) and has been carried on ever since. From 1977 through 1995, 8748 samples of respirable dust in the mines were collected.

The respirable dust is collected on a silver membrane filter using a sampling pump to

Journey

Ontario MLITSD proposes OEL for DPM reduce to 160 µg/m^3 Total Carbon from 400 µg/m^3 (came into effect January 1, 2012)

- Introduction of Battery Electric Vehicles (BEV)
- Introduction of Diesel Particulate Filters (DPF)
- Ventilation improvements or efficiencies to reduce/reuse of air
- HEPA filtration for enclosed operator compartments
- Respiratory Protection (last resort)

Ontario MLRC proposes OEL for DPM reduce to 120 µg/m^3 Elemental Carbon (came into effect September 1, 2023)

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Journey

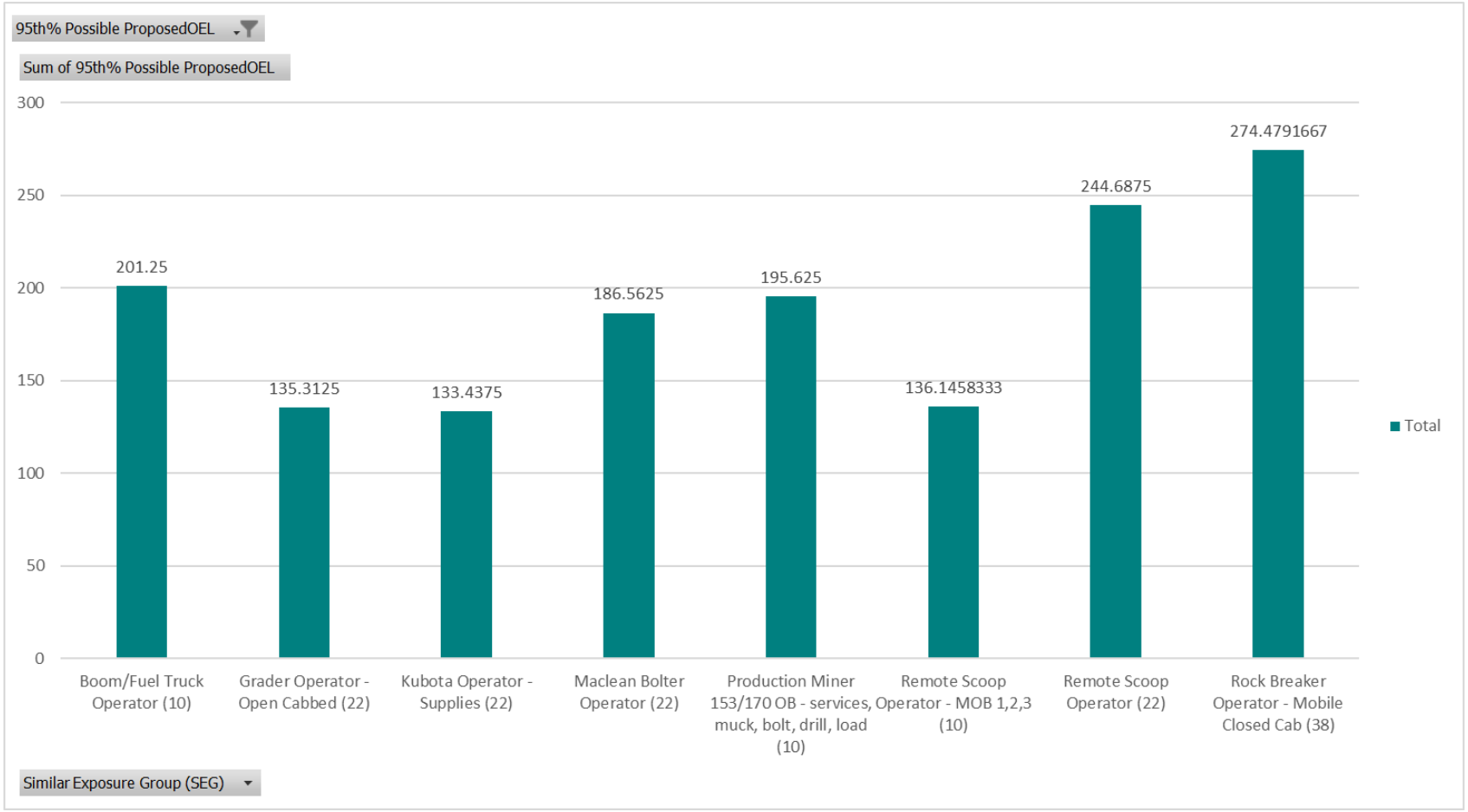
Impact to Vale Base Metals Ontario operations at notice of change to 120 µg/m^3 EC

- Mines primarily impacted
- Increase monitoring demand to evaluate who is at risk and validation of control effectiveness
- 10-15% of work groups would be a risk of exposure, compared to 1 work group at 400 µg/m^3 TC
- 8-12% of all diesel particulate samples collected would , without controls, exceed the proposed limit
- Respiratory protection will become mandatory for jobs/tasks/areas deemed at risk and become primary control to prevent exposure.

Strategy

Equipment to focus on:

- LHD Scoop Trams
- Diesel Haulage Trucks
- Equipment in main haulage ways with open operator compartments



Strategy

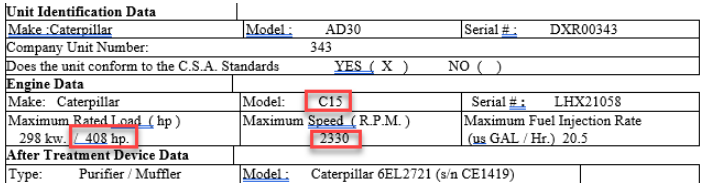
2020/2021 Planning

- Initial planning in 2020 to communicate to the business, budgeting process and filter selections
- Budget request of $1.96M to procure and install 61 filters
- 6 and 8 yd scoops and large trucks with capacity >30T
- Mine and equipment type prioritized by Occupational Exposure Monitoring data
- In 2020, approximately 600 pieces of equipment selected for DPFs post initial filter installations
- 2022, Q1,2 of 2023 mines begin to install DPFs on prioritized prime movers

Implementation

Preparation for 2023

- Occupational Health Hygienists baseline – 5 years of data prior to 2023
  - Target SEG exposures post 2022/23 DPF installs
  - Assess priority for next stage of DPF installs and implement other controls as required
  - Continue to monitor control effectiveness
- Continue and progress with adding DPF and monitoring
- Investigate DPF solutions for cool running engines, short run times, 0-3 tier rating engines
- Mobile Fleet records audit
  - Engine data details updated with exact engine variation vs generic



Unit Identification Data		
Make : Caterpillar	Model : AD30	Serial # : DXR00343
Company Unit Number: 343		
Does the unit conform to the C.S.A. Standards YES (X) NO ( )		
Engine Data		
Make: Caterpillar	Model: C15	Serial # : LHX21058
Maximum Rated Load (hp) 298 kw. / 408 hp.	Maximum Speed (R.P.M.) 2330	Maximum Fuel Injection Rate (us GAL / Hr.) 20.5
After Treatment Device Data		
Type: Purifier / Muffler	Model : Caterpillar 6EL2721 (s/n CE1419)	

  - Prioritize engines requiring > 100cfm/bhp (0.06 cms/kw) to assign new vent rates and label equipment
  - Update vent rates for all CSA certified mobile equipment

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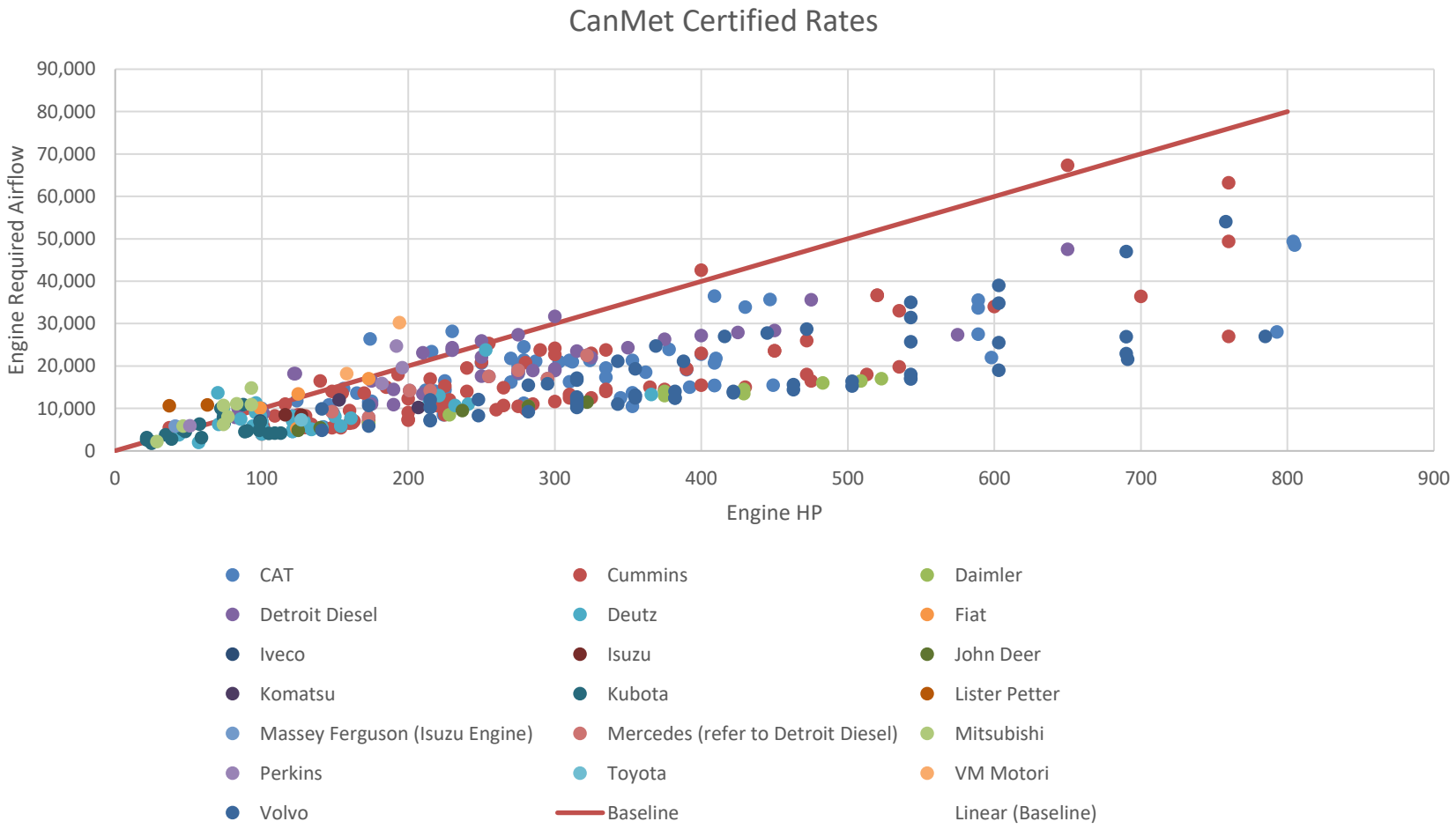
Implementation – Assign CSA Rates



- 116 pieces of equipment > 100 cfm/bhp
  - 93% < 110%
  - 7% > 110%

Engine Data Challenges

Engine Manufacturer: **Caterpillar**

Engine Model: **C15 (AD30), PN# 273 7265, Tier 3;**
C15[1] (R3000H) PN# 416 2215, Arrg# 385 0232, Tier 3;
C15[2] (R2900G) PN# 416 2215, Arrg# 385 0232, Tier 3

Governing Standard: **CSA M424.2-90 (Non-Gassy Mines)**

Certificate Number	Engine Rating and Fuel Rate at Sea Level	Fuel Sulphur Fuel - ppm	Ventilation Prescriptio	
			CFM	m^3/s
1184	409 HP (305 kW) @ 1800 RPM,151.8 lb/hr	0.05	36,500	17.23
		0.10	38,600	18.22
		0.20	42,800	20.22

Engine Manufacturer: **Caterpillar**

Engine Model: **C15 (AD30) PN# 319-7503, Arrg# 377-5438,**
C15[1](R2900G) PN# 390-9211, Arrg# 375-7224, and
C15[2](R3000H) PN# 390-9211, Arrg# 367-3100

Governing Standard: **CSA M424.2-90 (Non-Gassy Mines)**

Certificate Number	Engine Rating and Fuel Rate at Sea Level	Fuel Sulphur Fuel - ppm	Ventilation Prescription	
			CFM	m^3/s
1206	409 HP (305kW) @ 1800 RPM, 144.6 lb/h	0.05	20,700	9.77
		0.10	22,600	10.67
		0.20	26,500	12.51
		0.25	28,700	13.54
		0.50	41,100	19.40
			49,700+	23.46+

if permitted by the appropriate regulatory authority.

Engine Manufacturer: **Caterpillar**

Engine Model: **C15 (AD30 Truck), PN #444 7113**

Required accessories: **pDPF PN #395 0217, and ultra-low sulphur fuel (15 ppm)**

Governing Standard: **CSA M424.2-90 (Non-Gassy Mines)**

Certificate Number	Engine Rating and Fuel Rate at Sea Level	Fuel Sulphur Fuel - ppm	Ventilation Prescription	
			CFM	m^3/s
1266X	409 HP (305 kW) @ 1800 RPM, 144.6 lb/h	15	15,400	7.27
			20,900+	9.86+

+ These ventilation rates are recommended by CanmetMINING where some of the gases govern ventilation rates rather than the EQI criterion.

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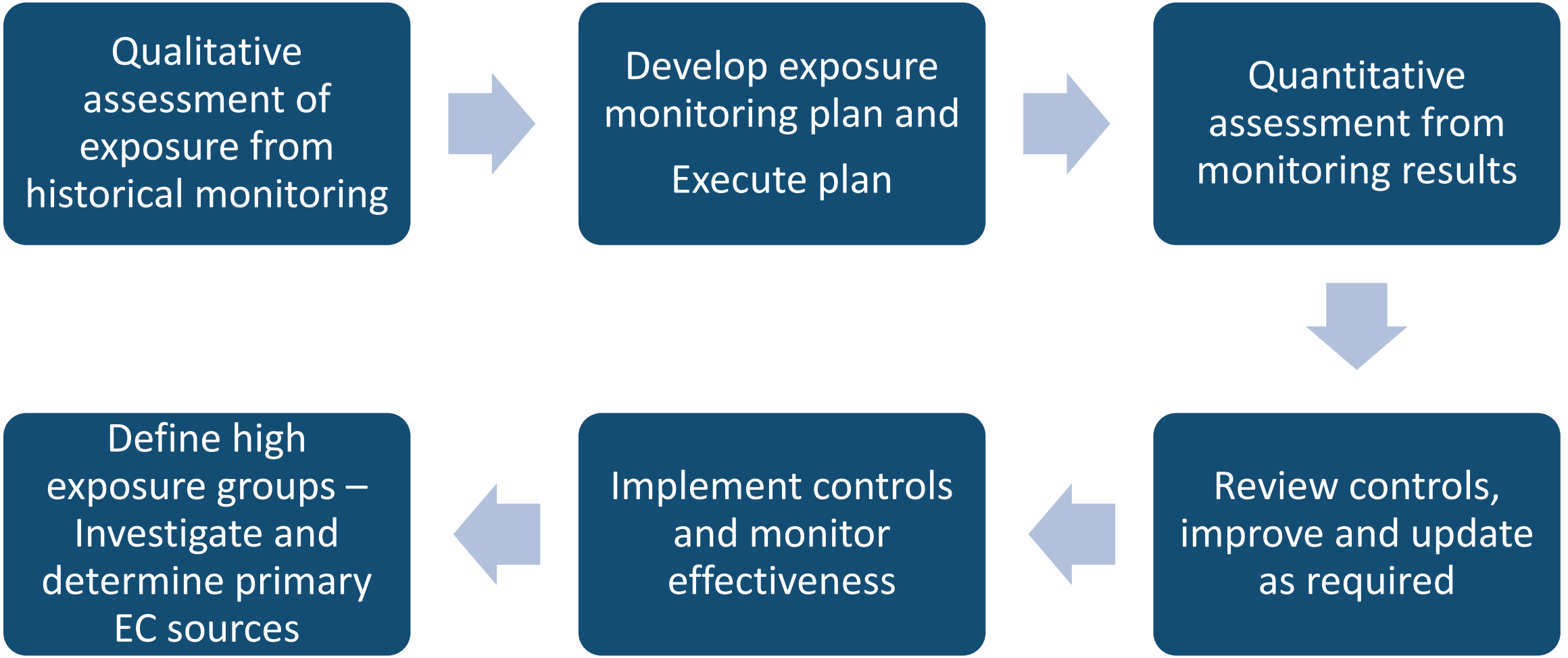
Occupational Health – Sampling Process



Occupational Health - Identification

Tailpipe Testing

- Malfunctioning DPF
- Damaged exhaust system
- Maintenance required

DPFs – Scoops & Haul Trucks

- Significant EC reduction for SEGs
- 1 mine – 14 SEGs at risk reduced to 3 SEGs

Defining Source of Exposure

- Address tasks generating exposures
- Reduce number of impacted workers

Occupational Health - Analysis

3 EC Samples per SEG

- Statistically analyzed to 95th percentile
- Prioritize investigating high GSD or likely to exceed exposures

Investigate

- Tailpipe test with DPM analyzer
- Cabin seals, filters window position
- Vent flow & quality
- Monitor worn correctly

Defining Source of Exposure

- Address tasks generating exposures
- Reduce number of impacted workers

Occupational Health - Controls

High Exposure Isolated, Controls Implemented

- Reduce exposure through JHA
- Reduction of activities in area
- Ventilation increase
- Equipment maintenance repairs
- Engine swaps
- Task based respiratory protection

Planning, Funding, Procurement of Future Controls

- Further vent changes and or upgrades
- Upgrade to cleaner engines
- Upgrade to Tier 4F equipment
- Further DPF installations
- Trials on after treatment controls

External Service Providers

- Communication, expectations & compliance
- Evaluation
- Maintenance
- Controls implemented

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Occupational Health – SEG Examples

SEG and Task Examples of EC Exposure

- Remote scoop operator
  - operating scoop outside of cab
  - *source*: scoop
- Kubota operator
  - Open cab slow moving equipment
  - *Source*: kubota and other equipment operating in close proximity “up wind”
- Bolter operator bolting on diesel
  - Open cab
  - *Source*: Bolter operating on diesel
- Open cab boom truck operator
  - Open cab
  - *Source*: boom truck and other equipment operating in close proximity “up wind”
- Wet and dry shotcreters
  - Operating equipment close to exhaust pipe
  - *Source*: equipment used for shotcreting (Kubota, transmixer, etc…)
- Diamond driller
  - Operating on electric (no emissions generated by task)
  - *Source*: other equipment operating in close proximity “up wind” or drilling near return air raise

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Ventilation – Mobile Diesel Equipment

- Ontario has options to assign vent rates to diesel equipment

    1. If engine has CSA M424.2:2022 or earlier certification rates, those rates apply
    2. Equipment without certification requires 100 cfm/bhp (0.06 cms/kw)
    3. Equipment in 1 or 2 and retro-fitted with a DPF or similar device and not certified, company can establish vent rate if process is done in consultation with JHSC, follows good engineering practice, testing performed.

- There is no guarantee that vent rates for an area will decrease and may increase due to other considerations.

- Air volume determination, regardless of jurisdiction, region, country, follow the same design principles

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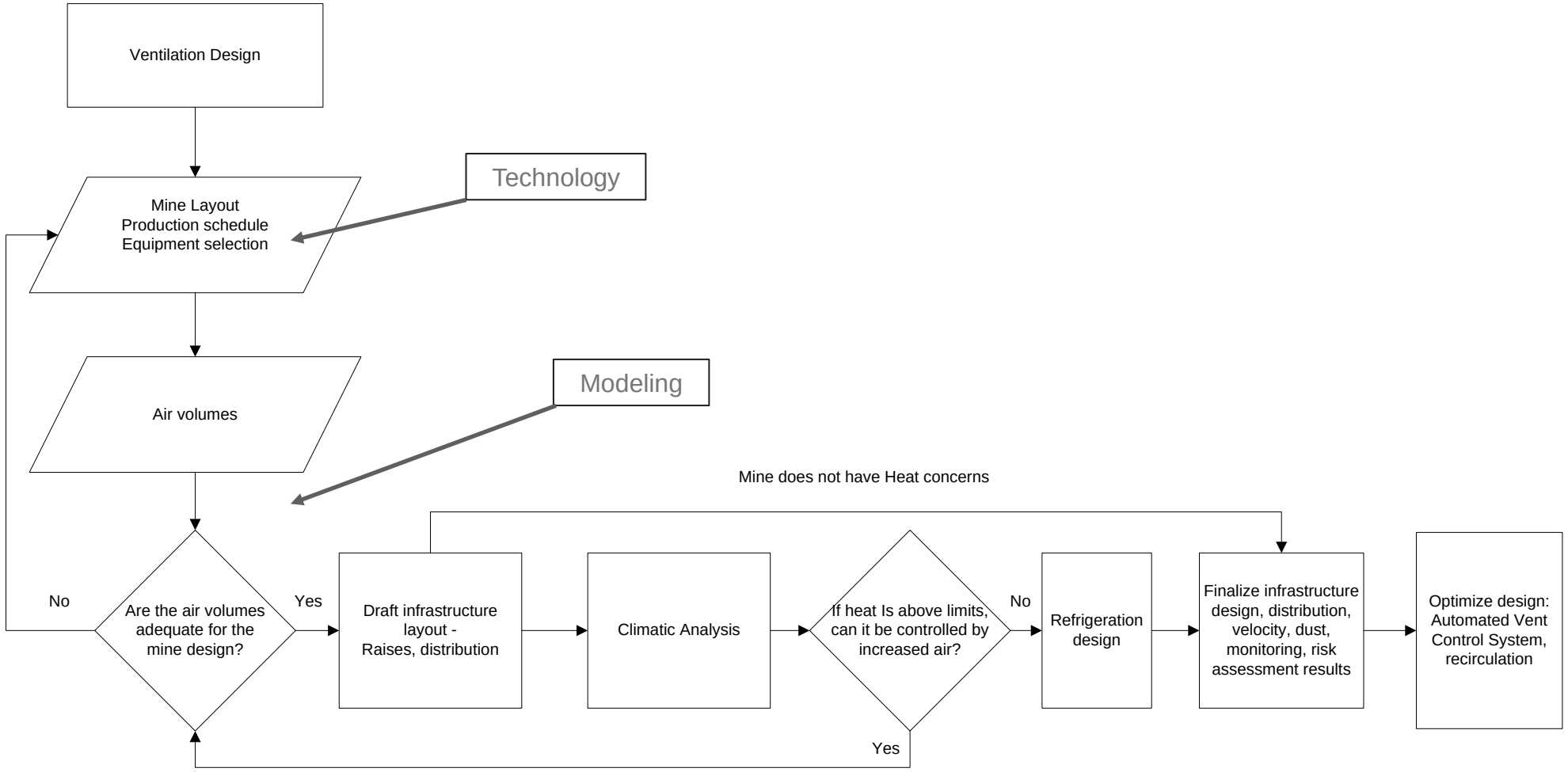
Introduction - Ventilation Design & Modeling



Ventilation – Design Air Volumes

- Mine ventilation design rates must include calculations and understanding of:
  - Certified or established equipment vent rates in a continuous course of air
  - Dust created by the mining activity or occurring naturally
  - Heat in respective areas of a mine
- There is no guarantee that vent rates for an area will decrease and may increase due to any one of the above considerations.
- Engineering design based on the mine plan will drive the planned vent rates and field measurements will impact either the vent rate or allowed mining activity.

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Ventilation – Vehicle Air volume

- Good engineering practice will be required to establish an equipment air volume. Ideas to consider:
  - Compare an “equivalent” engine w/DPF that is certified, the 100 cfm/bhp,
  - Trend engine gas and DPM emissions from regular PMs, apply resultant contaminant dilution air volume.
  - 3rd party in-field testing using approved monitoring equipment
  - Real-time or TWA data collection in test area with proposed vent rate to verify.
  - Develop a data base of non-certified DPF fitted engine vent rates (documentation of process)
- Any or combinations of above may be required.

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Conclusion

- Mining is required for products that support the world
- Our purpose will not change
    1. designing and managing,
    2. air is required underground,
    3. employee well-being and care for the environment
- In driving for solutions, challenges will always be present
- The journey of change and improvement is a continuous loop

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Thank you


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