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## In-Use Emissions Verification Testing for Diesel Engines in Underground Mining Operations

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## Introduction

- The CSA M424.1 and M424.2 standards prescribe the quantity of ventilation required for effective dilution of emissions while an engine is operating underground.
- These tests are performed on a new engine in a test laboratory before it is introduced into service.

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graph LR; A[Testing] --> B[Certification]
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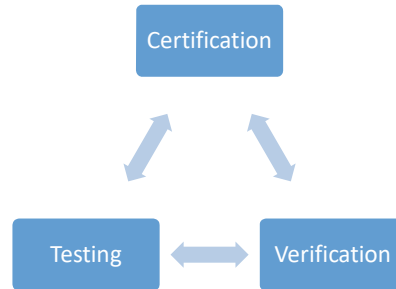
- *But what happens after service introduction?*
- Provincial jurisdictions require periodic workshop emissions testing against legislated limits.
- Mines often set their own limits based on experience.

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## Introduction

- The methods are effective in identifying gross emitters and engines that are in need of maintenance but;
- A CSA-prescribed ventilation rate will only provide protection if the engine continues to operate close to certification levels.
- *How would this be done?*



- An in-use verification component added to the CSA M424 would close the loop and better inform new approval testing.


## Approval Testing

- Engine manufacturer submits an application to CanmetMINING along with a sample engine and all aftertreatment system components.
- CanmetMINING performs the certification test according to the CSA standard. If the engine passes, a ventilation rate prescription is calculated and published on the website.


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 <sup>3</sup> /s
—	409 HP (305kW) @ 1800 RPM, 144.6 lb/h	500	20,700	9.77

## CSA Test Modes

- Based on ISO8178 with additional modes.
- Special tests for aftertreatment.
  - Measure engine parameters, CO, CO<sub>2</sub>, NO, NO<sub>2</sub>, O<sub>2</sub>, DPM.
  - Calculate ventilation rate.
  - Emissions are known for each of the 18 modes.
  - *How could we determine if these emissions are being maintained in service?*





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## In-Use Verification – EPA Model

- The US EPA operates a verification program when in-use vehicles are tested for performance against certification.
- Engines are tested over the full operating range and emissions must not exceed 1.25 times the certification values in the NTE zone.





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## In-Use Verification – Mining Trials

- An in-mine trial was conducted to evaluate the feasibility of verification using a previously certified engine.
- Phase 1: Steady State
  - Workshop-type stationary engine stall test.
  - Portable gas analyzers.
  - Target: low and high idle, stall at rated power.
- Phase 2: Transient Cycle
  - In-service test during shift.
  - No specific targets but post-test speed and load analysis will identify if any of the 18 modes were achieved and how often.

## Phase 1: Stationary Testing

- Workshop test at low idle, high idle and converter stall.

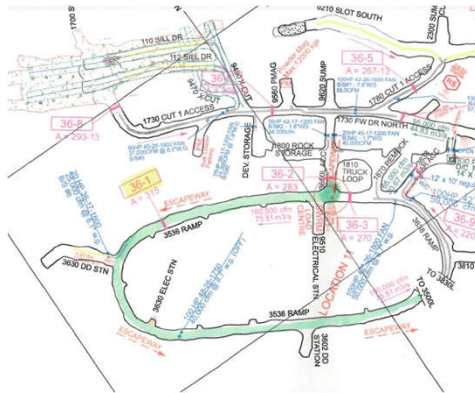


STEADY-STATE NTE FACTORS			
MODE	CO	NO	NO <sub>2</sub>
Stall	0.60	1.20	0.44
Low Idle	0.73	1.17	1.28
Hi Idle	1.40	0.95	1.22

- *How do we evaluate against the certification test?*
- All emissions/modes except two were in the 1.25 window.

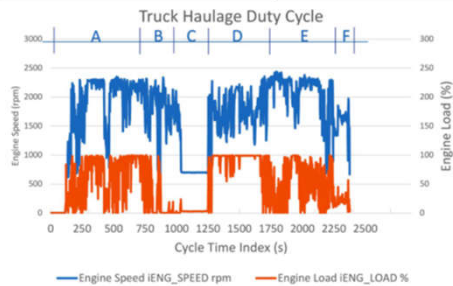
## Phase 2: Transient Cycle

- Underground test using on-board emissions equipment in real-time.



## Transient Cycle Analysis

- Haul truck duty cycle.
- Did we achieve any of the certification modes? Yes.



- A – Trimming empty on the level to ramp
- B – Descending the ramp empty
- C – Waiting at idle during ore loading
- D – Ascending the ramp
- E – Trimming loaded ore to dump point
- F – Dumping ore to crusher

		SPEED (RPM)					
		1800	1600	1400	1200	700	2330
Load (%)	100	–	–	–	✓	Idle	Idle
	75	✓	✓	✓	–	–	–
	50	✓	✓	✓	–	–	–
	10	✓	✓	✓	✓	–	–

## Transient Cycle Analysis

- Of the test modes achieved, how many were within the NTE window for emissions?

		SPEED (RPM)					
		1800	1600	1400	1200	700	2330
Load (%)	100	–	–	–	4.3	2.18	0.88
	75	0.67	1	1.74	–	–	–
	50	4.05	2.5	0.94	–	–	–
	10	0.82	0.81	0.93	1.63	–	–

- What does this mean?
- The engine could meet the certification emissions test levels just over half the time. *Is the criteria correct?*
- Some of the certification test modes were not achieved in service. *Are they relevant?*

## Discussion

- In-use verification of mining vehicles against certification tests is technically feasible.
- But this was just a single trial of one vehicle.
- The NTE zone needs to be better defined as well as verification test acceptance criteria like ambient conditions.
- If this becomes part of a CSA standard test, how will we respond to exceedances?*
- Do the CSA M424 test modes need review? Would a transient test cycle be more appropriate?*

## Comments / Questions?

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