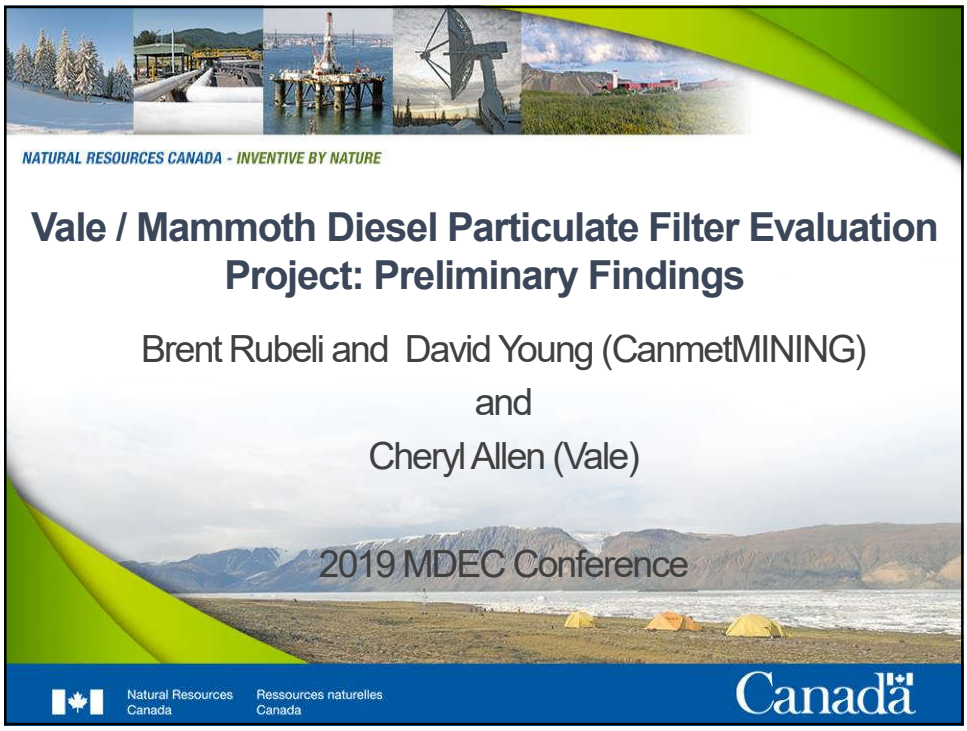
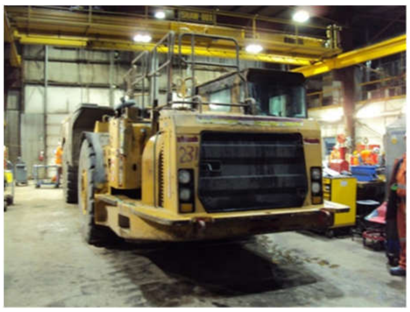


Introduction

- Vale is trialling a passive regeneration-type diesel particulate filter (DPF) manufactured by Mammoth equipment on a Caterpillar AD30 haulage truck #231.
- CanmetMINING was contracted to provide an independent assessment of the in-use performance of the DPF.
  - Surface workshop test – ECOM gas analyzer and smoke dot test.
  - Underground in-use test – SEMTECH PEMS gas analyzer.

Vehicle and DPF System

- Test vehicle: Caterpillar AD30 Unit #231
- DPF: Mammoth DPF System #78183



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Workshop Steady-State Tests

- CanmetMINING performed a series of steady-state emissions tests using an ECOM EN portable gas analyzer.
- These tests are similar to Vale’s internal test program.

VALE #231 AD30
MAMMOTH DPF @ CCM

				VALE PASS FAIL CRITERIA				100		700		50		750	
				Smoke Dot Test		T.GAS TEMP (°F)		CO (ppm)		NO (ppm)		NO2 (ppm)		NOx (ppm)	
DESCRIPTION	DATE	UNIT HRS.	DPF HRS.	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
OEM	7-Apr	12,108				884	793	197	27	511	529	16	21	527	550
MAMMOTH DPF INSTALLED	8-Apr	12,146				878	781	161	44	535	578	18	11	553	589
FIRST BI-WEEKLY TEST	27-Apr	12,220	54			851	799	221	65	540	608	14	9	554	617
TEST 3	28-May	12,308	142			864	550	209	20	464	496	13	8	477	504
TEST 4	31-May	12,401	235			787	630	258	22	408	446	29	9	437	455
TEST 5	18-Jun	12,404	238			849	736	193	24	247	312	11	11	258	323
TEST 6	22-Jun	12,473	307			858	739	285	30	509	527	9	5	518	532
TEST 7 - Faulty #6 injector	6-Jul	12,585	419			808	655	283	20	383	[illegible]	14	18	397	[illegible]
TEST 8	9-Jul	12,599	433.3			852	709	409	35	457	503	32	5	489	508
TEST 9	25-Jul	12,626	460			929	749	307	131	360	305	4	0	364	305
TEST 10	18-Sep	12,711	545			973	813	353	41	532	445	10	6	542	451
TEST 11	19-Oct	12,823	657			832	672	275	24	482	504	29	11	511	515
TEST 12	7-Nov	12,973	806.5			907	723	332	24	447	476	20	7	467	483
AVERAGE						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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Steady-State Test Results

- Gases and Smoke

ECOM Emissions Test Data						
	Stall		Low Idle		High Idle	
Gas	Before DPF	After DPF	Before DPF	After DPF	Before DPF	After DPF
CO	235	27	65	38	243	96
NO	471	476	272	310	401	434
NO_2	21	27	37	10	61	19
NOx	492	503	309	320	462	453
Smoke	9	3				

Pre-DPF (engine out) and post-DPF (tailpipe) smoke, CO, NO, and NO_2 concentrations are very close to the average values measured by Vale's program. There is a discrepancy in the post-DPF NO_2 concentrations. NO_2 is very sensitive to water so it is suggested that the Vale ECOM be checked for adequate water removal.

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Underground In-Use Tests

- Installed the SEMTECH on-board emissions analyzer on the truck deck. Connected to the engine ECU datalink.
- Emissions measured pre- and post-DPF during normal haul operations. Gases and particulate mass (DPM) emissions.

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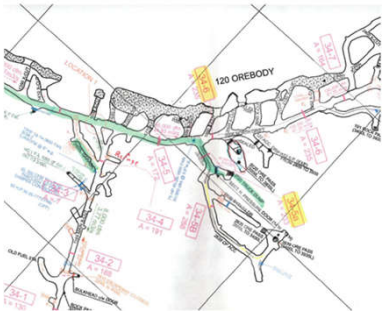
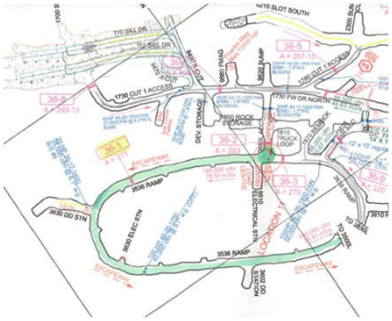
Haul Cycle

- The truck was side-loaded by LHD on 3650 level and then hauled up to the 2020 ore pass on 3400 level.
- Our station was in 3400 shop where we checked filters and sample probes.



3400 Level (2020 Ore Pass)



3650 Level Loading

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Sampling

- The vehicle completed eight haul cycles over two days where emissions were monitored.
- Samples were taken for gases and DPM pre- and post-DPF simultaneously.

			Sampling Locations		
	Run Number	Elapsed Time (min)	Gas Probe	DPM Probe	DPM Filter
Day 2	1	48	Pre DPF	Post DPF	EC/OC1
	2	40	Post DPF	Pre DPF	VM-07
	3	35	Pre DPF	Post DPF	VM-08
	4	35	Post DPF	Pre DPF	EC/OC2
Day 3	5	41	Pre DPF	Post DPF	EC/OC3
	6	38	Post DPF	Pre DPF	VM-06
	7	34	Pre DPF	Post DPF	VM-04
	8	39	Post DPF	Pre DPF	EC/OC4

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Underground Test Results

- Diesel Particulate Matter (DPM filtration)

Gravimetric DPM Samples (1.7 L/m sample flow)						
Filter	Location	Mass (mg)	Time (min)	Volume (m^3)	DPM (mg/m^3)	Reduction (%)
VM-07	Pre DPF	5.017	40	0.0680	73.8	N/A
VM-08	Post DPF	0.023	35	0.0595	0.4	99.5
VM-06	Pre DPF	4.064	38	0.0646	62.9	N/A
VM-04	Post DPF	0.052	34	0.0578	0.9	98.6

Filter	Location	Organic Carbon (mg/m^3)	Elemental Carbon (mg/m^3)	Total Carbon (mg/ m3)	Reduction (%)
EC/OC1	Post DPF	0.175	0.025	0.200	N/A
EC/OC2	Pre DPF	17.209	28.298	45.507	99.6
EC/OC3	Post DPF	0.085	0.098	0.183	N/A
EC/OC4	Pre DPF	14.560	25.396	39.955	99.3

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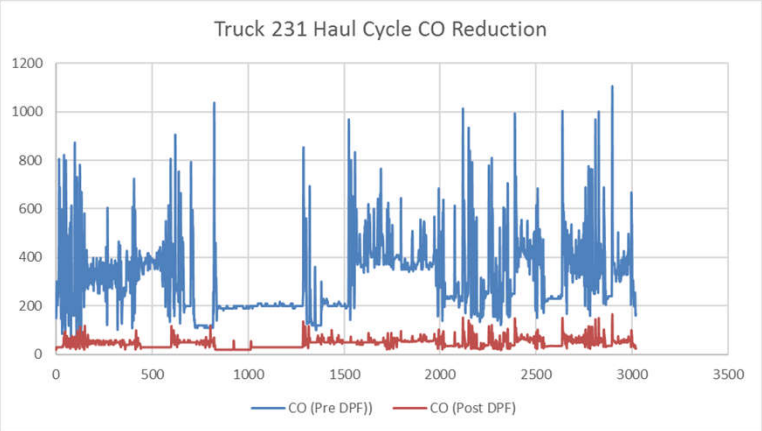
Underground Test Results

- Carbon Monoxide (catalyst performance)



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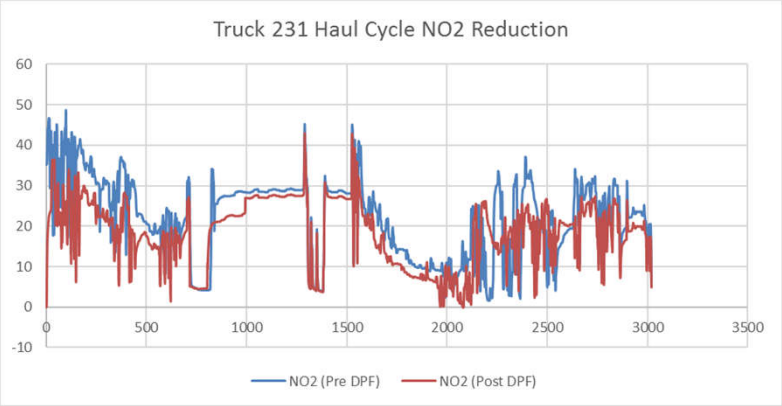
Underground Test Results

- Nitrogen Dioxide (NO_2 catalyst performance)



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Conclusions

- The stationary workshop tests conducted by CANMET are consistent with Vale's own internal data.
- The Mammoth DPF can achieve its claimed performance in-service by reducing the mass of particulate emissions by 98-99% without an increase in NO_2 emissions.
- In fact NO_2 emissions were reduced by 17% and CO emissions were reduced by 85% over the haulage cycle.
- The DPF system performance is consistent with other advanced catalyst systems known to CANMET.

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Recommendations

- This study was limited in scope and did not examine any effects on DPM particle size or unregulated emissions.
- The long-term durability of some advanced catalysts is unknown so it is recommended that Vale continue to monitor the emissions performance using their internal system.
- Some of the Vale internal NO_2 gas data was reading lower than CANMET's. Process and equipment calibration should be reviewed.

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Questions?