



 Natural Resources Canada Ressources naturelles Canada


DEEP Light-Duty Vehicle Project

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Natural Resources Canada
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Project Outline

- Determine the relative contribution of light and heavy-duty vehicles to the underground diesel particulate emissions burden.
- Test sample fleet of real vehicles in production at an underground metal mine.
- Extrapolate particulate data from sample fleet to total mine fleet.

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Contributors

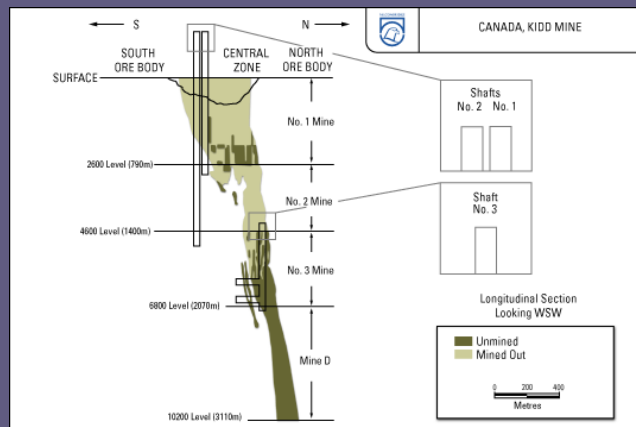
- Funded by the Diesel Emissions Evaluation Program (DEEP).
- Managed by CANMET-MMSL Natural Resources Canada.
- Falconbridge Limited, Kidd Mining Division.
 - Test site: Kidd Creek Mine

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Kidd Creek Mine



- Approx. 156 vehicles underground

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Project Sequence

- Identify 6 heavy-duty and 8 light duty vehicles that are representative of the mine fleet.
- Develop a diesel particulate matter (DPM) sampling system that will allow unobtrusive testing of vehicles in production.
- Test heavy-duty vehicles.
- Test light-duty vehicles.
- Extrapolate sample fleet DPM to 156 vehicle total mine fleet.

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Heavy vs. Light Duty

- Heavy-duty vehicles are defined for this study by duty cycle.
- Vehicles involved in production ore / waste handling are considered heavy-duty.
- All others are considered light-duty.

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Heavy-Duty (HD) Vehicles

- Generally higher horsepower engines.
- Mostly modern electronically-controlled engines.
- In use for a larger percentage of the shift.
 - Load Haul Dump (LHD) vehicles
 - Haulage Trucks

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Light Duty (LD) Vehicles

- Generally lower horsepower engines.
- Mostly mechanically controlled.
- Often used for transportation to workings but not in continuous shift operation.
 - Personnel transportation
 - Materials handling
 - Drilling / bolting / reclamation
 - Maintenance

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Sample Fleet Selection

- HD Vehicles
 - Toro 501D 8-yard LHD (2 tested)
 - Toro 400D 6-yard LHD
 - Wagner ST-3.5 yard LHD
 - EJC 430 Haulage Truck (2 tested)
- All HD engines are Detroit Diesel electronically controlled.

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Sample Fleet Selection

- LD Vehicles
 - Pickup Trucks (1 Ford, 1 Dodge, 1 Chev).
 - Kubota 5030 tractor (2 tested)
 - Driftec Shotcrete Sprayer
 - Getman Scissorlift
 - Getman Boom Truck

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DPM Sampling System

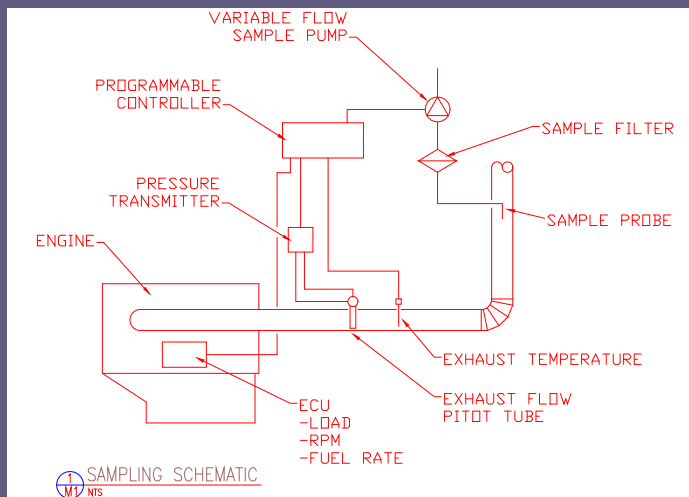
- System collects diesel particulate matter on a sample filter.
- System must draw a sample of exhaust at a flow rate that is proportional to the engine exhaust flow.
- System must adjust sampling rate to follow the transient operation of the vehicle.
- System must not interfere with the vehicle's production work.

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DPM System Schematic

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DPM Sampling System

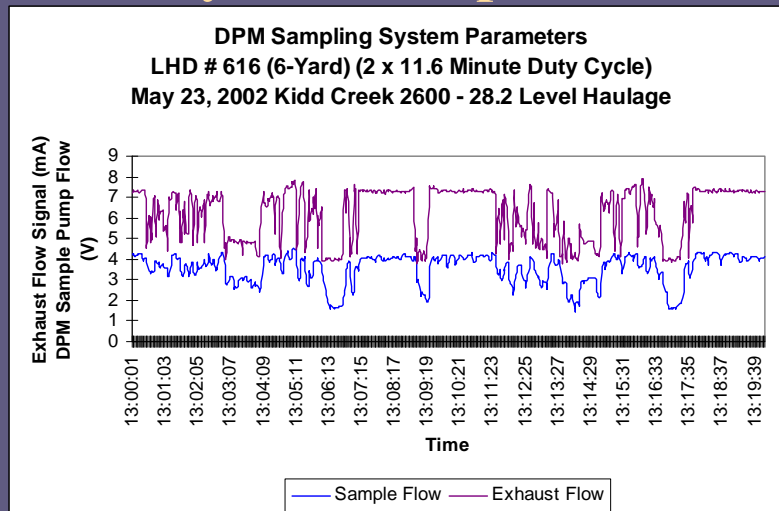
- Interchangeable pitot tubes allow the system to test a wide range of vehicles.
- System has a fast response time.
- Tested in the laboratory on diesel engines similar to those tested underground.
- Calibrated against laboratory DPM sampling system.

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System Response



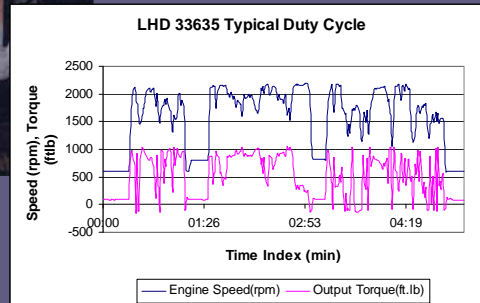
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HD Vehicle Testing

- Toro 501D LHD, 285 HP, 11.1 L Series 60

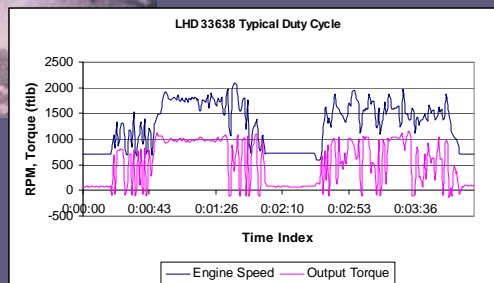


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- Toro 501D LHD, 285 HP, Remote Operation

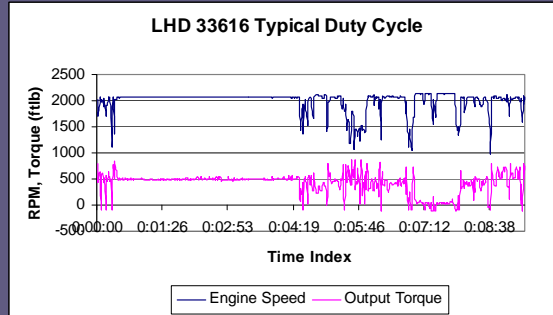


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- Toro 400D LHD, 250 HP, 8.5 L Series 50



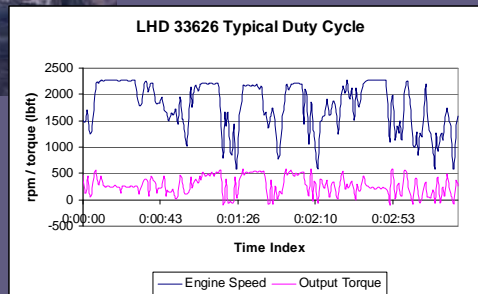
Vehicle	Duty Cycle Description	DPM (mg/m3)	DPM Mass (g)	Run Time(min)	DPM Mass Rate(g/hr)
Scoop 616 6-yd	4800 to 3000 (traffic)	15.90	7.54	36	12.56
	3000 to 2800	14.72	7.98	37	12.94
	Turned on vent fan	29.29	4.15	19	13.11
	Mucking 28-2 to 2600	26.47	3.71	11	20.23
	Mucking 28-2 to 2600	23.88	3.44	10	20.64
	Mucking 28-2 to 2600	21.08	3.36	12	16.80
	Mucking 28-2 to 2600	22.86	3.27	11	17.83
	Mucking 28-2 to 2600	24.55	3.43	10	20.60
	Mucking 28-2 to 2600	25.01	3.33	10	19.98
	No muck	20.12	3.00	10	17.98

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- Wagner ST-3.5 LHD, 180 HP, 4.65 L, Series 71

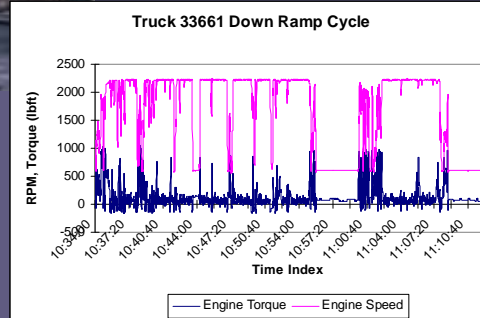


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● EJC430 Haul Truck, 300 HP, 11.1 L, Series 60

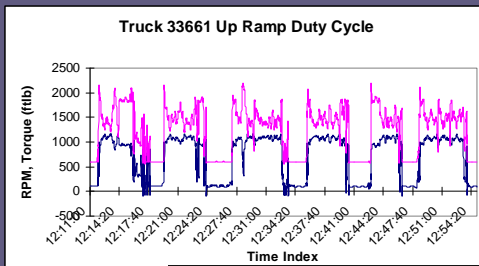


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● EJC430 Haul Truck, 300 HP, 11.1 L, Series 60



Vehicle	Duty Cycle Description	DPM (mg/m3)	DPM Mass (g)	Run Time(min)	DPM Mass Rate(g/hr)
Truck 661	4600S to 6400	28.13	14.68	24	36.71
	6400 to 6900	25.10	5.74	12	28.70
	Idle on 6900	12.77	0.36	5	4.33
	6900 to 7400	25.11	9.38	19	29.63
	7400 to 7200	18.51	3.79	8	28.43
	7200 to 7000	10.34	1.43	6	14.26
	7000 to 6900	11.30	2.46	8	18.46
	6900 to 6600	11.18	1.77	6	17.70
	6600 to 6400	3.68	0.66	7	5.62
	6400 to 6200	2.59	0.47	8	3.49
	6200 to 5800	7.89	1.68	8	12.60
	5800 to 5600	5.91	1.08	8	8.08
	5600 to 5400	5.57	0.73	5	8.70
	5400 to 5200	4.61	0.89	7	7.64
	5200 to 5100	10.09	1.93	9	12.85
	5100 to 4600S	9.37	3.40	12	17.01

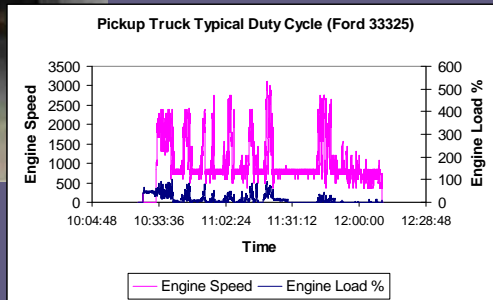
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LD Vehicle Testing

- Pickup Truck (typical) Ford Super Duty

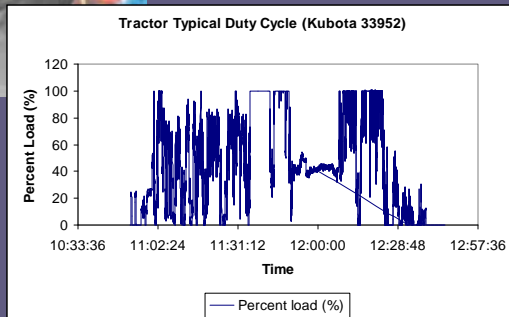


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- Kubota 5030 Tractor, 54 HP, 2.8 L

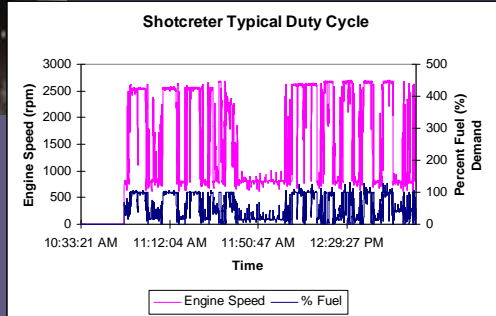


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- Driftec Shotcreter, 240 HP, 5.9 L QSB

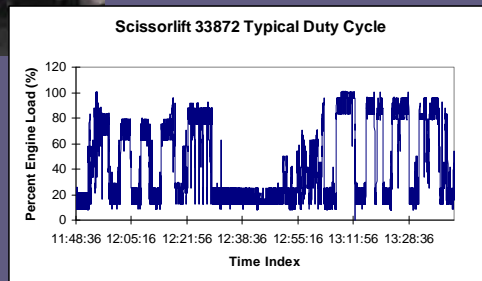


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- Getman Scissorlift, 110 HP, F5L413FRW

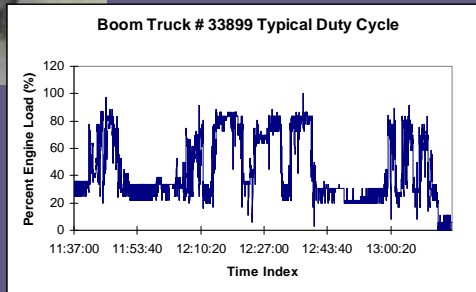


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- Getman Boom Truck, 82 HP, F6L912W



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Emission Summary

Vehicle	Total Mass (g)	DPM Rate (g/hr)
LHD 33635 8-yd	45.8	22.0
LHD 33616 6-yd	43.2	15.6
LHD 33626 3.5-yd	37.8	23.6
LHD 33638 8-yd	43.1	22.1
Truck 33661	50.4	19.9
Truck 33661 repeat	43.5	12.0
Chevrolet truck 33348	4.0	3.3
Ford truck 33325	2.6	1.6
Dodge truck 33336	4.3	3.1
Kubota Tractor 33966	24.5	22.7
Kubota Tractor 33952	16.2	13.3
Driftec Shotcreter 33973	12.4	6.3
Getman Scissorlift 33872	10.8	6.0
Getman Boom Truck 33899	19.5	12.9

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Operator Exposure



- NIOSH 5040

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Operator Exposure

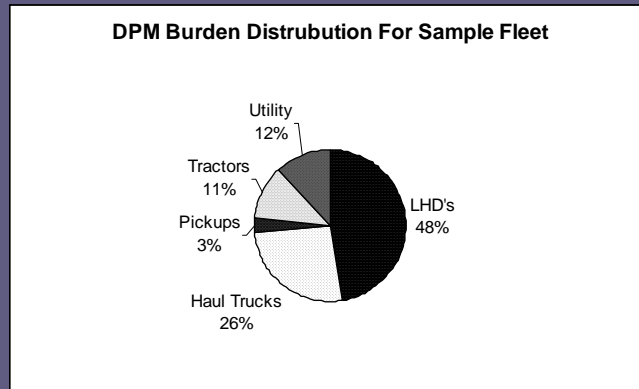
Operator's Vehicle	EC (mg/m ³)	OC (mg/m ³)	TC (mg/m ³)	EC/OC
LHD 33635 8-yd	0.094	0.098	0.191	0.96
LHD 33616 6-yd	0.137	0.282	0.419	0.49
LHD 33626 3.5-yd	0.229	0.173	0.401	1.32
LHD 33638 8-yd	0.088	0.122	0.210	0.72
Truck 33661	0.184	0.161	0.345	1.14
Truck 33661 repeat	0.180	0.159	0.339	1.13
Chevrolet truck 33348	0.206	0.170	0.376	1.21
Ford truck 33325	0.089	0.061	0.150	1.47
Dodge truck 33336	0.129	0.064	0.193	2.01
Kubota Tractor 33966	0.287	0.262	0.549	1.09
Kubota Tractor 33952	0.247	0.144	0.391	1.72
Driftec Shotcreter 33973	0.087	0.053	0.140	1.63
Getman Scissorlift 33872	0.100	0.057	0.157	1.75
Getman Boom Truck 33899	0.112	0.074	0.186	1.52

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Sample Fleet DPM



- DPM Burden from 14 vehicle sample fleet

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Extrapolation to Mine Fleet

- Extrapolate DPM data from 14 vehicle sample fleet to 156 vehicles Kidd Mine fleet.
- Model fleet composed solely of vehicles that were tested.
- Operating hours per year as determined by Kidd Mine maintenance records.

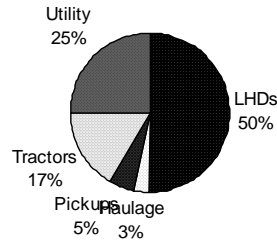
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Kidd Mine Model Fleet

Total Kidd Creek Mine Model Fleet DPM Burden



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Kidd Mine Model Fleet

Vehicle Type	Number	DPM rate (g/hr)	Utilization (hr/yr)	DPM Burden (kg/yr)
8 yd LHD	10	22.05	2583	569.55
6 yd LHD	3	15.62	1880	88.07
3.5 yd LHD	7	23.63	1583	261.85
30t Trucks	2	15.95	1600	51.04
Chevrolet pickups	33	3.32	698	76.53
Ford pickups	1	1.56	698	1.09
Dodge pickups	8	3.07	698	17.13
Tractors	18	18.00	942	305.21
Shotcreters	25	6.35	651	103.33
Scissorlifts	24	6.03	686	99.34
Boom trucks	25	12.88	779	250.82

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Conclusions

- Due to their increasing numbers and poorer emissions quality, LD vehicles are a significant contributor to the underground DPM burden.
- LHD's are the largest single group contributor to the DPM burden followed by utility vehicles and tractors.

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Recommendations

- Apply DPM control strategies to all 8-yard LHD vehicles.
- Apply DPM control strategies to the Kubota tractor fleet.
- Gradually implement DPM control technologies to utility vehicle fleet perhaps starting with the most common (old) engine: Deutz F6L912W.

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Future Work

- Creation of a model of DPM emissions throughout the Kidd Mine.
- Integration of the DPM model with the mine ventilation model to predict zones of potential high DPM concentration.
- Optimize ventilation to reduce these concentrated areas.

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