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Development of an On-Board Diesel Particulate Sampling System with Proportional Flow Control

Brent Rubeli
Natural Resources Canada
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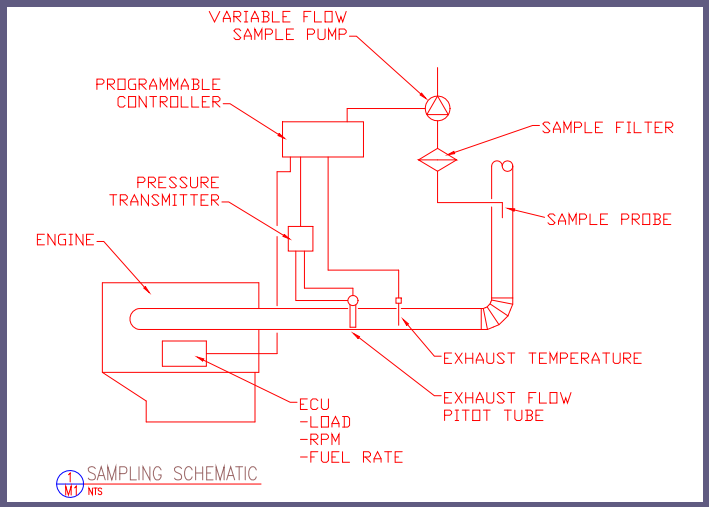
Project Drivers

- Laboratory engine testing provides DPM data from well-defined, standard test cycles.
- Often data is available only for new engines.
- Test cycles often do not reflect in-mine operation of the vehicle.
- There is a need to determine actual DPM mass emission rates for real vehicles in production operation underground.

System Concept

- On-board vehicle operation for unobtrusive sampling of DPM mass while the vehicle is performing its normal duties.
- Exhaust sample probe and heated lines leading to heated sample box.
- Direct measurement of exhaust flow allows determination of DPM concentration.
- Programmable controller for fast pump commands.
- Pump sample flow tracks engine exhaust flow for real time proportional sampling.
- Filter loading correction.

System Schematic



Proportional Sampling

- Define ID of sampling probe and match to ID of exhaust pipe .
- Open end probe directed into exhaust flow.
- Control sample pump flow such that velocity of gas in sample probe is the same as exhaust gas velocity.
- Define parameters for electronic control.

Sampling Parameters

Diesel Engine Data										
Engine	**DDECS 60**									
Power	325	HP		**Ideal Airflow**			**Actual Airflow**			
Bore	5.12	in		Max. Flow	1818.85	lb/hr	Max. Flow	4547.13	lb/hr	
Stroke	5.47	in								
Cyl.	6			**Volumetric Efficiency (est.)**			**Fuel Flow**			
Displ.	675.72	cu.in		Rated	250	%	Rated	117.65	lb/hr	
Rated	2100	rpm		Max Torque		%				
Fuel Flow	9.9	gal/hr		Idle		%	**Exhaust Flow**			
BSFC	0.362	lb/HPhr					Max. Flow	4664.78	lb/hr	
Sampling Spool										
Spool Dia.	5	in		**Required Flow For Isokinetic Sampling**						
Probe Dia.	0.152	in		Flow Rate	4.31	lb/hr				
Area Ratio	0.000924				0.97	CFM				
					30.79	**L/min**				
Environmental Conditions										
Temp.	25	C		**DPM In Exhaust Gas:**			**Filter Dimensions**			
Humidity	50	%		Estimated	25	mg/m3	Diameter	37	mm	
Bar Press.	760	mmHg					Area	10.7521	cm2	
Air Dens.	0.07383	lb/ft3		**Soot Deposition Rate**			**Filter Face Velocity**			
Correct.	1.11745			Loading	**0.77**	**mg/min**	Velocity	**47.73**	**cm/sec**	

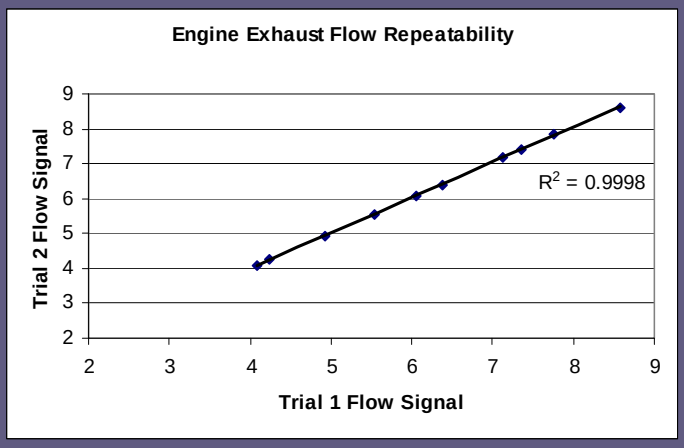
Laboratory Testing

- Validation of sampling system at CANMET diesel testing facility.
- Flow measurement with ASME venturis, Sierra 620S mass flow sensor, AVL 734 fuel meter.
- DPM sampling Sierra BG-2 Micro-dilution tunnel.
- Operation of laboratory engines over various speed and load points for a wide range of exhaust flows.
- Detroit Diesel 11.1L Series 60, Kubota V3300T.

System Validation Steps

- Calibration of exhaust flow sensors.
- Program sampling system for isokinetic flow DPM mass collection.
- Verification of DPM mass collection.
- Determination of system response time.
- Field trials.

Lab Engine Repeatability



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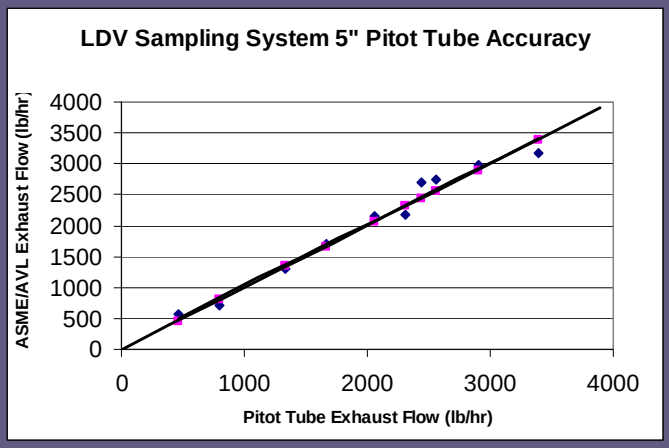
Exhaust Flow Calibration



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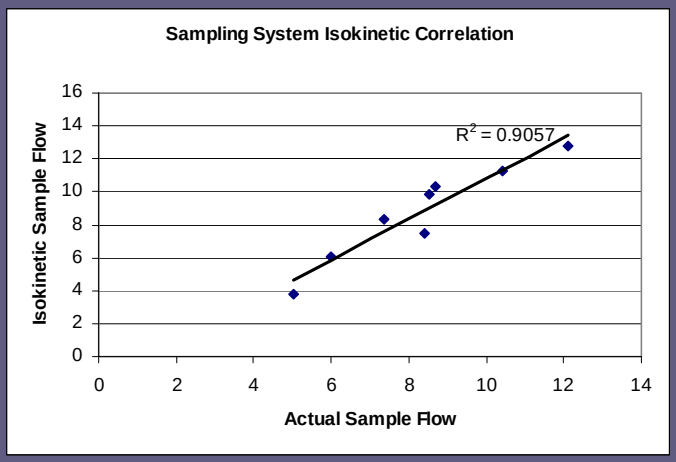
Sampling Command

- Flow signal as input to programmable controller.
- Controller makes required corrections and scaling for proportional flow.
- Output command signals desired flow to variable flow hi-volume sample pump.
- Actual sample pump flow measured by flow meter.

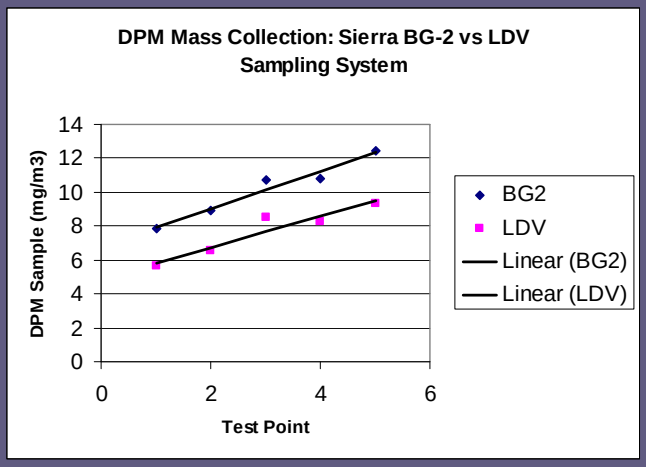
Isokinetic Flow Validation



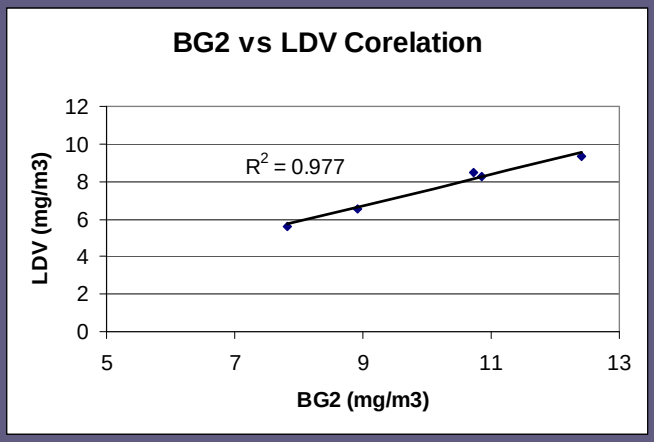
DPM Mass Collection

- Sierra BG-2 Micro-dilution system.
- Used for engine certification to ISO 8178.
- Diluted sample collection on 90mm filters.
- LDV sampling system: undiluted tailpipe exhaust collection on 37mm filters.
- Difficult to compare diluted to undiluted system.

DPM Mass Collection



DPM Mass Correlation



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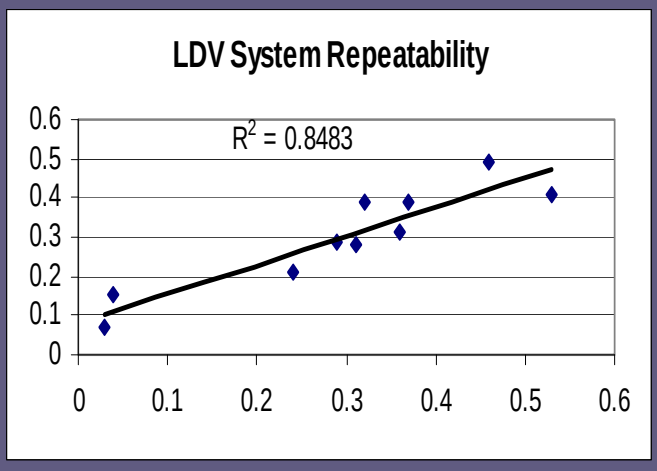
Repeatability



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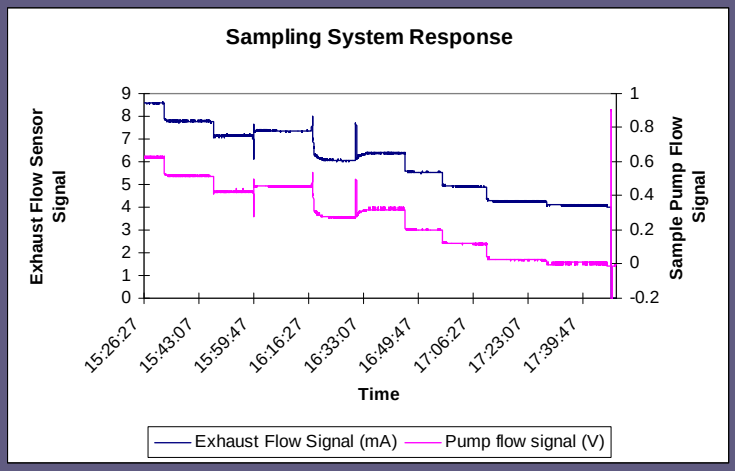
Response Time



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Validation Criteria Met?

- 2", 2.5", 3", 4" and 5" pitot tubes calibrated for a wide range of engines and flows.
- Near-isokinetic or proportional sampling achieved through electronic control.
- Absolute DPM mass equivalency not achieved, but correlation is good.
- Repeatable.
- Response time fast enough to follow transient exhaust flows on mining machines.

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Field Trials

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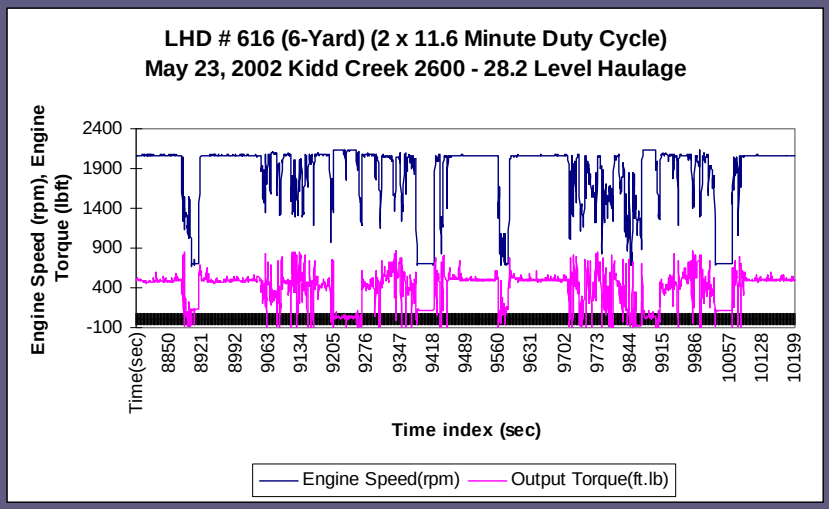
Mining Duty Cycles



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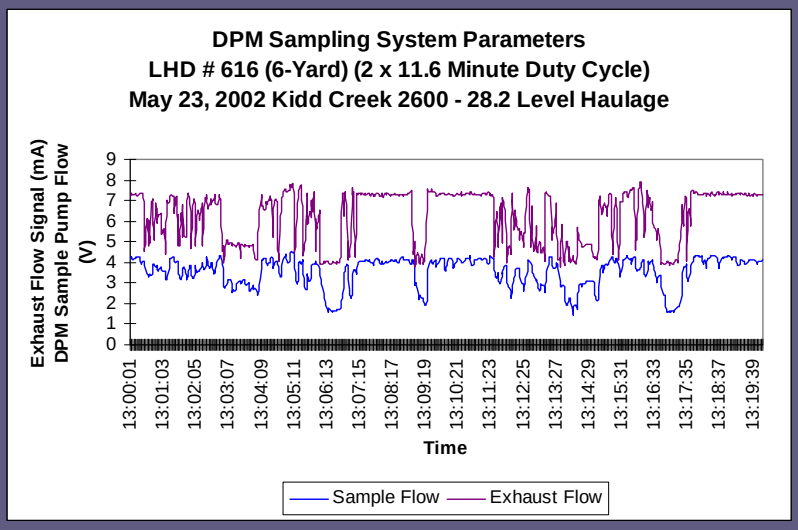
System Response



Durability

Conclusions

- System can provide user with information on actual in-mine DPM emissions.
- Adaptable to any vehicle.
- Powered by the vehicle for fully autonomous operation anywhere in the mine.
- Can be used to compare different duty cycle's effect on emissions.
- Can be used to compare light and heavy duty vehicles.

Prototype Development

- Reduce number of discrete components.
- Consolidate electrical power bus.
- Standardize control signal formats.
- Provide user interface and integrate data logging system.
- Reduce physical size and weight.

Questions?