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Effect of Simulated Faults on Diesel Engine Emissions

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Natural Resources Canada

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Introduction

- Consultations with the Ontario MLRC.
- Effect of engine faults on mechanically-controlled engines is well known.
- Unclear how and when electronic engines would compensate for fault conditions.
- Emissions behavior could not be predicted.

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U/G Mining Prior Work

- Bureau of Mines work in 1985.
 - Deutz F6L912W engine.
 - Simulated faults on dynamometer.
- Deutz paper on engine maintenance.
- NIOSH EAMP.
- DEEP Maintenance Project.
 - Guidelines and Best Practices.
 - In-Mine Case Studies.

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USBM

- 1985 study of simulated faults in engines.
- Combinations of faults more severe than individual faults applied separately.
- No faults or maladjustments decreased DPM .

PERCENT DEVIATION OF EXHAUST EMISSIONS FROM BASELINE CAUSED BY INDUCED FAULTS IN A DEUTZ F6L 912 W DIESEL ENGINE

TEST NO.	FAULT DESCRIPTION	DEGREE OF FAULT	DEGREE OF FAULT			PARTICULATES *		
			HC	CO	NO _x	A	B	C
1-1	Intake Restriction (in - H ₂ O)	25	-28	+8	-15	+25	+31	+44
1-2	Intake Restriction (in - H ₂ O) ²	50	-36	+28	-12	+75	-11	+104
2-1	Exhaust Restriction (in - Hg)	3.0	+17	+1	+9	-15	+23	-8
2-2	Exhaust Restriction (in - Hg)	6.0	+2	+6	-3	-8	+16	-11
3-1	Timing Advance (from mfg. spec.)	-4*	+306	+53	-33	-4	+1037	-23

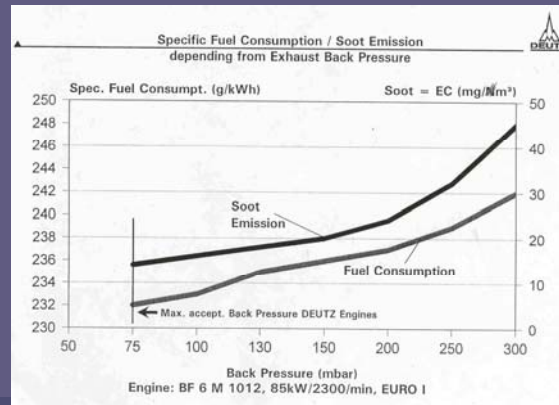
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Manufacturer Guidelines

- 1988 paper compiled specifically for mining.
- 1998 MDEC paper on DPF system.



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NIOSH EAMP

- Emissions-assisted maintenance procedure.
- Support of emissions testing regulation.
- Defined a repeatable emissions test procedure.
- Tested field and laboratory grade instruments.
- Evaluated different engine types.
- <http://www.cdc.gov/niosh/mining/topics/diesel/eamp/eamp.html>

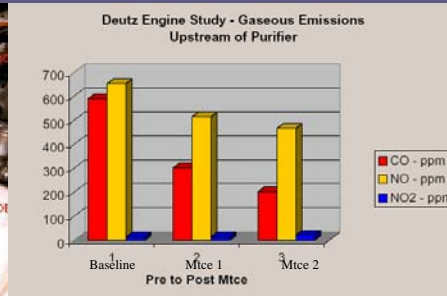
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DEEP Maintenance Project

- Systematic approach to maintenance.
- Fault diagnosis based on emissions testing.



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Why more work?

- Some uncertainty for newer engines:
 - Turbocharger / Intercooler system.
 - Electronic control system behavior.
 - Warm-up emissions.
- Test procedures for vehicles with manual transmissions and light hydrostatic drives.

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CANMET-MMSL Tests

- Laboratory emissions testing.
- Deutz Engine:
 - Confirmation of some USBM work.
 - Snap acceleration for smoke emissions.
- Detroit Engine:
 - General maintenance deficiencies.
 - Turbocharger / intercooler faults.
 - Sensor / electronics glitches.
 - Cold start and warm-up behavior.

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Test Engines

- Deutz F4L912W
- Detroit 11.1L Series 60



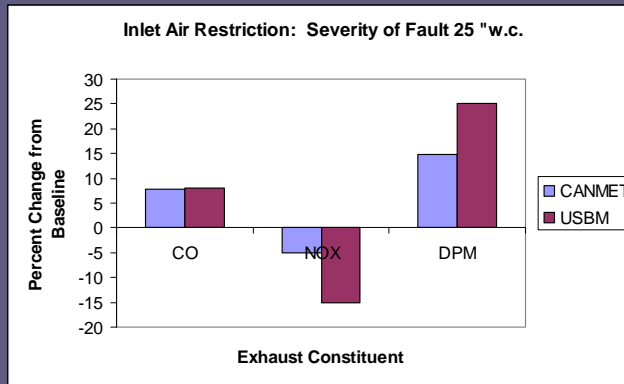
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Deutz Engine Tests (1)

- General agreement with USBM results.



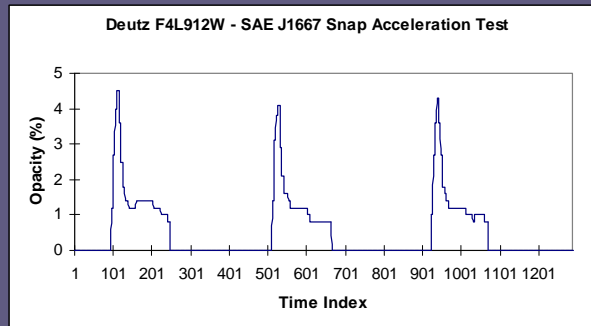
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Deutz Engine Tests (2)

- Snap Accelerations based on SAE J1667.
- 0 – 100% throttle (engine unloaded)



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Detroit S60 Engine Tests (1)

- General maintenance deficiencies.
- Stable operation even with faults.
- Requires severe degree of fault.

Test	Test Description	Speed rpm	Torque ft-lb	Engine Cooling Temp F	Inlet Vacuum in.w.g.	Exhaust Pressure in.w.g.	Turbo Boost Pressure psi	Fuel lbs/hr	CO ppm	NO ppm
9	Full Load Full Speed	2099	883	188	11.7	38.1	23.9	126	34	577
10	Torque Stall	1949	894	189	10.3	33.5	23.7	116	30	578
12	Restricted Intake 20°	1949	891	189	19.9	31.5	23	116	34	586
13	Restricted Intake 40°	1949	884	189	39.5	30	21.2	116	41	609
E2	Restricted Intake 40° ECOM								52	629
14	Restricted Intake (5)	2229	18.1	189	10.9	6.4	2.6	19.2	120	224
15	Restricted Exhaust (6)	1949	883	188	9.1	~ 80"	21.5	116	37	616
16	Restricted Exhaust	1199	1165	188	2.7	~ 80"	16.7	89.4	256	1179
17	Restricted Intake & Exhaust	1949	871	191	41.4	~ 80" 200 mBar	19.1	116	55	640
18	Intake Air at 60°F 16°C	1949	938	188	9.2	28.2	20.1	112	17	1225
19	Intake Air at 150°F 66°C	1949	890	189	9.7	32.7	24.9	116	16	699

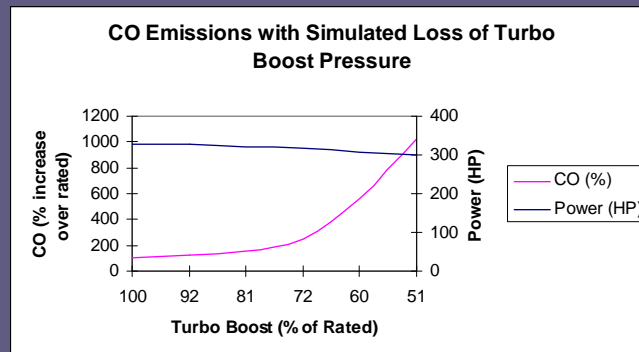
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Detroit S60 Tests (2)

- Turbocharger / intercooler faults.



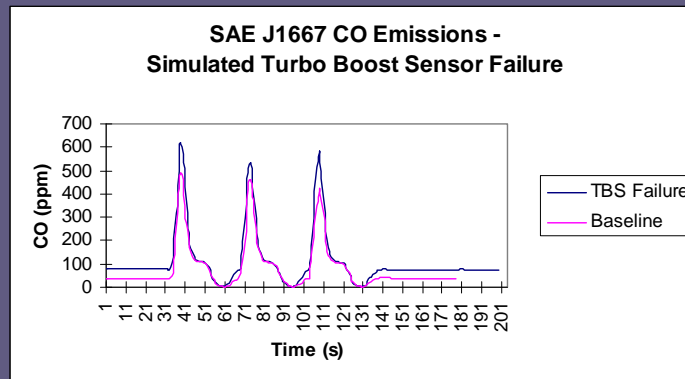
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Detroit S60 Tests (3)

- Sensor / electronics glitches.



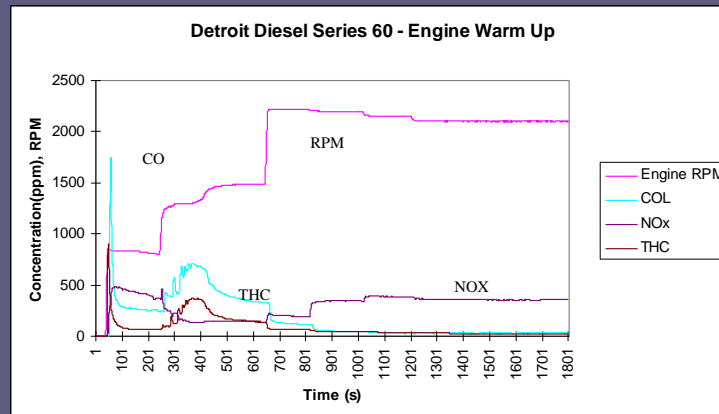
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Detroit S60 Tests (4)

- Cold start and warm-up behavior.



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Field and Lab Testing

- Good agreement of ECOM portable gas instrument with laboratory analyzers.
- But only with regular calibration and maintenance.
- Confirmation of NIOSH EAMP findings.
- Some of these portable analyzers have passed the US EPA Technology Verification program (ETV).

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Snap Acceleration Tests

- Some light-duty vehicles are difficult or impossible to test under load.
- 100% fuel delivery is not achieved.
- SAE J1667 test procedure for snap acceleration based smoke emissions.
- Light extinction (opacity) meter for visual smoke measurement.
- Procedure is in-use already for Ontario, BC and other jurisdiction for highway vehicles.

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SAE J1667

**ONTARIO DRIVE CLEAN PROGRAM
HEAVY DUTY DIESEL
VEHICLE EMISSIONS INSPECTION REPORT**

Certificate Number: 208 490 0437
Test Date/Time: 09/06/2000 @ 10:20:51

VEHICLE/ENGINE INFORMATION

Chassis	1993	Engine	1993
Lic. Plate	XV9823	Make	CHEV
VIN	1G2WU23P2J268913	Year	1993
Inspection Type	1	Model	3500
Unit Number	NONE	Year	GM
		Black Box	3
		Cylinders	6
		HP Range	151 to 200

SAE J1667 SNAP ACCELERATION EMISSIONS INSPECTION

Step	1	2	3	4	5	6	7	8	9	Result	Limit
Objective (%)	14.9	14.6	15.0							14.8	40.0
RFM	3662	3662	3662								

Key Drive (%) 0.4 - 2.0
Spread (%) 0.4

OVERALL TEST RESULTS: PASS

NOTE: THIS VEHICLE IS STILL SUBJECT TO ROADSIDE ENFORCEMENT

DRIVE CLEAN FACILITY

Facility Name: Kiewit Automobiles
Address: 2195 Westford Dr., #202
City: ON M9A 1L6
Phone: 4162811084
Inspector Name: Robert Gaynes

Facility Number: 000952
DCE #: 2238
Ann. Year #: A2084
New Train. Version: 1.24
Reference Number: 00437

Inspector's Signature: [Signature]

SAE J1667 SNAP ACCELERATION TEST
DOSEH RTT 100

FORM SHOWN # [Handwritten]

DOSEH FUL 912W (1.87 V_{max} x 1.0_{min} BURDEN) BACKMARCH NUMBER [Handwritten]

← Two (2) F800 SNAP ACCELERATIONS INDICATE THE ONE HOURS SAMPLE TIME.

← FULL RATED POWER (97 HP @ 2300 RPM)

← SIMULATED TRANS CONVERSION STILL 2650 RPM @ 100% LOAD

← SIMULATED TRANS CONVERSION STILL + HYDRAULIC STILL 1800 RPM @ 100% LOAD

← HARD IDLE

← LOW IDLE

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Conclusions (1)

- Mechanical engines behave predictably and linearly under induced fault conditions.
- Electronic engines can maintain good emissions performance under faults of increasing severity – up to a point.
- Turbo / intercooler systems are very important as emission control devices. Power and fuel economy can often be maintained with large faults while emissions quality deteriorates.

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Conclusions (2)

- ECOM portable gas analyzers agree well with lab instrumentation provided a regular calibration schedule is maintained.
- SAE J1667 snap acceleration procedure is a possible option for emissions testing of some light-duty vehicles.

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Acknowledgements

- Ontario Ministry of Labour – Mining Legislative Review Committee (MLRC).
- DEEP Maintenance Project – Sean McGinn.
- Deutz
- Detroit Diesel

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Questions?



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