Regulated and Air Toxic Exhaust Emissions from Nonroad Diesel Engines and Equipment

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Program Summary

* Three studies - 15 engines
  - Ten engine unregulateds
  - Three engine Mobile Source Air Toxics (MSATs)
  - Four engine in-use MSATs
* Two or more diesel fuels per engine
  - Nonroad 2500 ppmS
  - On-highway 2-D (390 ppmS)
  - Ultra-low sulfur diesel (ULSD, 50 ppmS)

Test Engine Criteria

* Rated Engine Power
  - less than 50 hp
  - 50 hp and greater
  - 150 hp and greater
  - 300 hp and greater
  - 500 hp and greater
  - 750 hp and greater
* Engine Management Technology
  - “Tier 0” / pre-regulation
  - Tier 1 / late 1990s
  - Tier 2 / early-mid 2000s
  - Tiers 3 & 4 / 2006 and beyond

Emissions Summary

- Criteria pollutants
- Selected unregulated emissions
  - Carbonyls, ammonia, N_2O and sulfate
- MSATs
  - Acetaldehyde, acrolein, benzene, 1-3,butadiene, formaldehyde and particulate matter
  - Metals - As, Cr, Mn, Ni, Pb and Hg
  - PAHs and n-PAHs

Ten-Engine NR "Unregulateds" Program

- Test engines ranged from 7 to 50 hp, and 250 to 850 hp
  - Engine Applications
    - typical; utility engines, 50 hp forklift to 320 hp excavator
  - Two to three test fuels/engine
    - 2D and ULSD, generally
    - 3300 ppmS nonroad (excavator)
  - Matrix of test cycles and fuels across engines

Ten Engine Unregulateds: Test Engines

Intended Application	Engine Mfr and Model	Rated Horsepower	Engine Control
Utility/pump	Hatz	7	Mechanical
Utility	Yanmar	9	Mechanical
Utility	Yanmar	14	Mechanical
Generator/pump	Lombardini	20	Mechanical
Forklift	Kubota	49	Mechanical
Tractor/trailer	Navistar	250	Electronic
Excavator	John Deere	320	Mechanical
Construction equipment	Cummins	330	Electronic
Construction/ agriculture use	Detroit Diesel Corp.	400	Electronic
Mining truck	Caterpillar	850	Electronic

Three-Engine Nonroad MSAT Study

- Test Engines
  - KubotaV2203-B @ 49 hp
  - Cummins QSL-9 @ 330 hp
  - CAT 3408 @ 480 hp
- 2-D & Nonroad fuels
  - Nonroad @ 2570 ppmS
- Unregulated & MSAT emissions
  - including C_1 - C_{12} compounds

Four-Engine In-Use Nonroad MSAT Program

- Test engines/equipment:
  - road grader 130 hp Tier 0
  - ditch excavator 190 hp;
    - Engine is highway-certified Cummins ISB190
  - excavator 275 hp Tier 1
  - ag tractor 420 hp Tier 2:
- 2-D & Nonroad fuels
- Unregulateds and MSAT emissions captured

Equipment from Four-Engine In-Use Nonroad MSAT Program

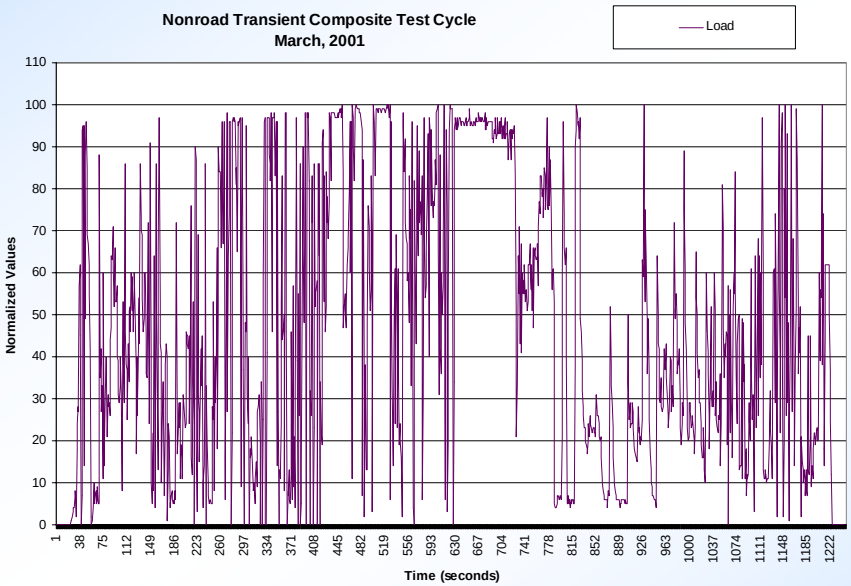
Steady-State Duty Cycles

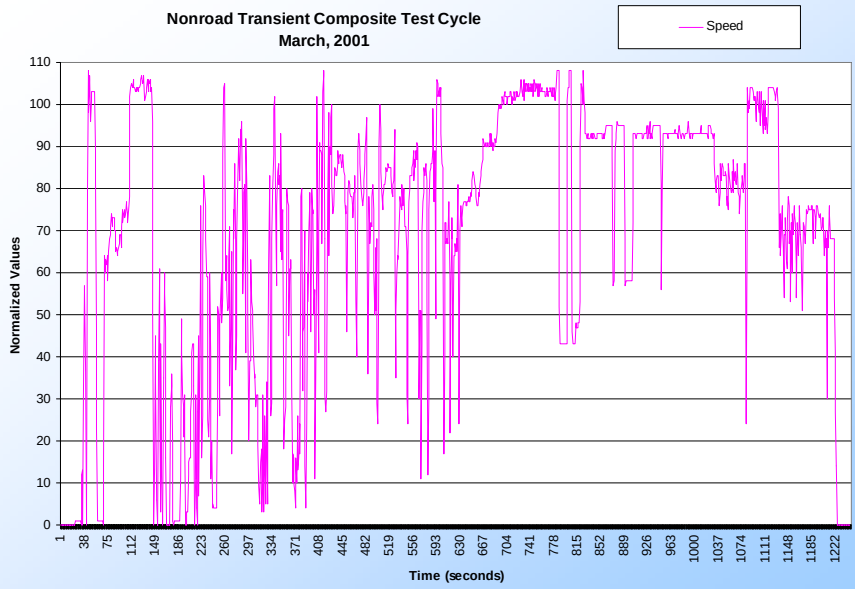
	Load		*8-modeC1			
	10%	25%	50%	75%	85%	100%
Speed	*"idle"-0% load*					
10%						
25%						
50%						
60%			7	6		5
75%						
100%	4		3	2		1
	* Including E3, "marine", test run.					

* Federal 8-mode, “C1”-weighting on all engines
* Some engines tested at 14 modes; some tested at full 40 mode procedure

Regulatory Transient Test Duty Cycles

* Heavy-duty Federal Test Procedure (FTP)
* European Transient Cycle (ETC)
* Nonroad Transient Composite (NRTC)





Non-regulatory Transient Application Duty Cycles

* Agricultural Tractor
* Backhoe Loader
* Crawler-Dozer
* Excavator

* Arc Welder
* Rubber-tired Loader
* Skid-steer Loader

“First Look” at Data from Ten Engine Unregulateds Program

	8-Mode, "C-1" Composites				
Engine	**HC**	**CO**	**NOX**	**PM**	**CO2**
Hatz	0.619	4.131	5.462	0.512	819.250
Lombardin	0.263	2.945	2.994	0.669	768.487
Kubota	0.069	0.960	4.206	0.607	661.936
Navistar	0.086	0.439	4.358	0.077	582.297
*Deere	0.472	0.837	5.303	0.125	499.896
Cummins	0.052	1.182	4.199	0.128	493.417
Caterpillar	*0.352	1.201	10.144	0.158	501.733

Ten Engine Unregulateds Study: "First Look" at Data

- Brake-specific PM seems to track falling fuel sulfur levels
- As engine displacement and power falls,
  - Total PM, ammonia and N_20 may be rising
  - Total aldehyde concentrations appear to rise
    - Formaldehyde, though, seems stable
- Transient cycle effects on emissions from the same engine quite varied
  - may need engine cycle-specific emission profiles

Questions to Be Addressed

- Differences between regulated and “Tier 0” engines
- Fuel sulfur impacts
- Emission duty cycle differences
- PAHs and nitrated-PAHs (type & quantity)
- Metals
  - Both particulate and vapor-phase, e.g., mercury

Uses for New Nonroad MSAT Data

* Responsive to MSAT Rule (March, 2001) Technical Analysis Plan
* Enhance national/nonroad emission inventories
  - NEI for Hazardous Air Pollutants
    - Used in National Air Toxics Assessment (NATA)
  - Nonroad Mobile Inventory Model (EPA-NMIM) updated with engine profiles
    - output used to update NEI
  - Results used to populate Motor Vehicle Emissions model (EPA-MOVES)

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