Lean Gasoline Engine Emission Challenges

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A Note on Recent Database Upload to the CLEERS Website

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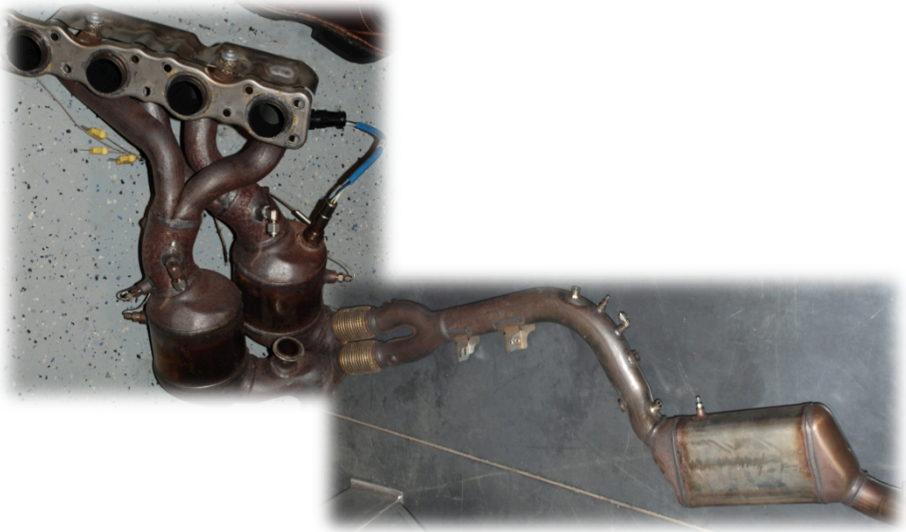
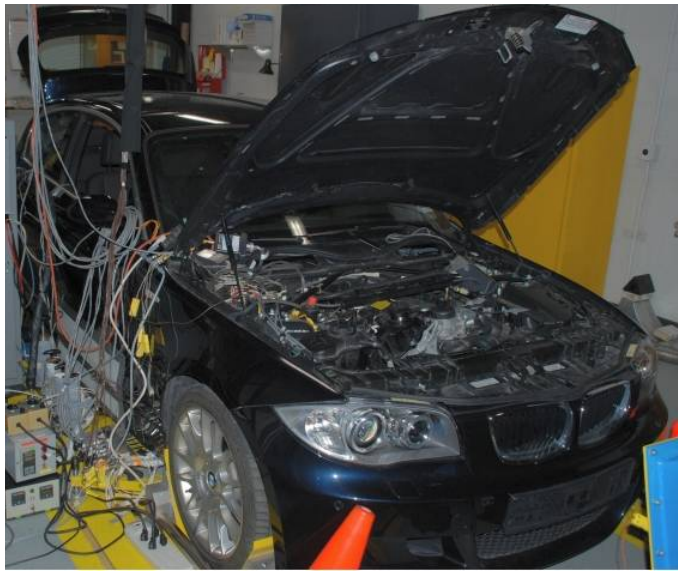
Background

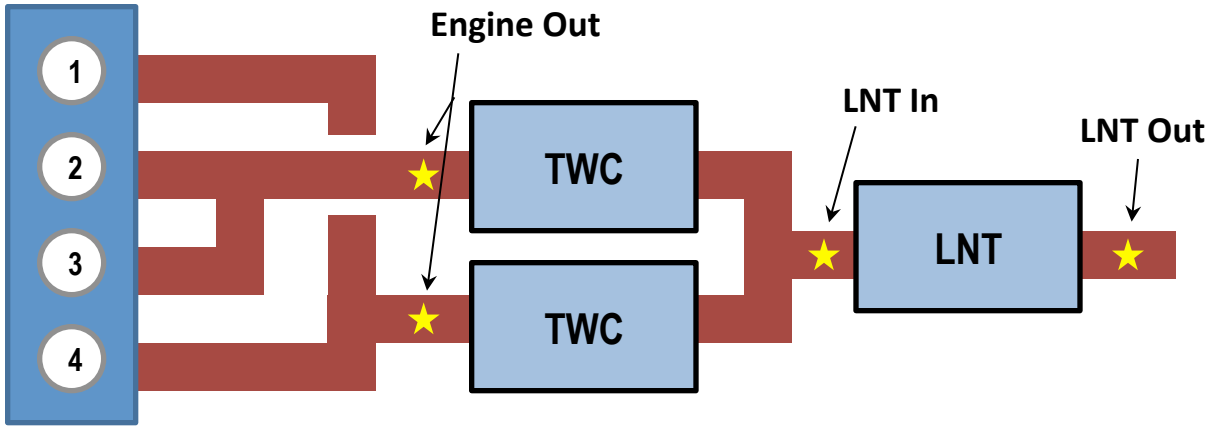
- **Relevance:**
  - U.S. passenger car fleet is dominated by gasoline-fueled vehicles.
  - Enabling introduction of more efficient lean gasoline engines can provide significant reductions in passenger car fuel consumption
    - thereby lowering petroleum use and reducing greenhouse gases
    - lean gasoline is one of many options being considered, but it is an option that has synergy with other technologies (e.g. HEVs)
- **Experimental Studies:**
  - ORNL studied a modern lean gasoline vehicle (BMW 120i) on a chassis dynamometer
  - Fuel saving benefits of the lean combustion were characterized
  - Combustion (AFR, etc.) and emissions data were also collected
- **Database:**
  - Engine map data with emissions has been uploaded to the CLEERS website

BMW 120i Lean Gasoline Vehicle





Thanks to GM for loan of vehicle

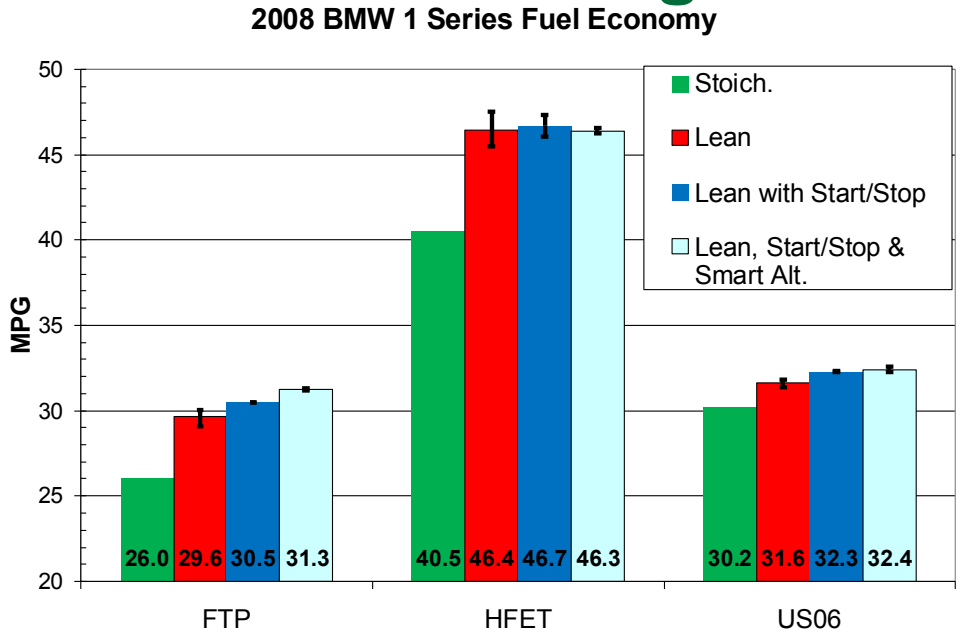


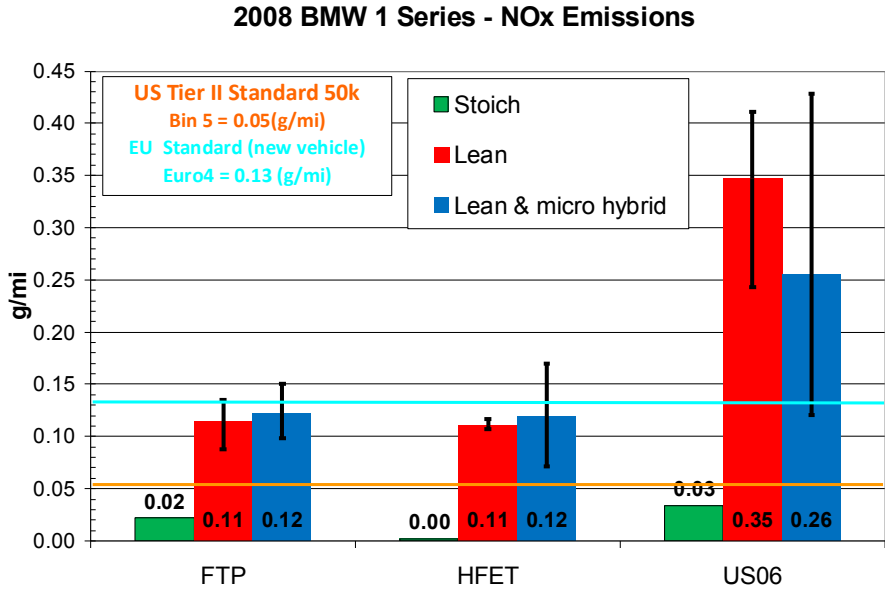
Engine Specs (N43B20):

2.0-Liter 4-cylinder
Lean burn combustion
200 bar direct Injection
170 hp (130 kW) at 6,700 rpm
210 Nm (155 ft-lb) at 4,250 rpm
12:1 compression ratio
Dual VVT and EGR

Lean Engine Operation Gives Primary Fuel Economy Benefit *but* Does Not Meet U.S. Emission Regulations

- Vehicle has multiple technologies for fuel economy improvement
- Lean operation offers most significant fuel economy improvement
- Start/Stop operation and mild hybridization via intelligent alternator control also contribute to fuel economy improvements



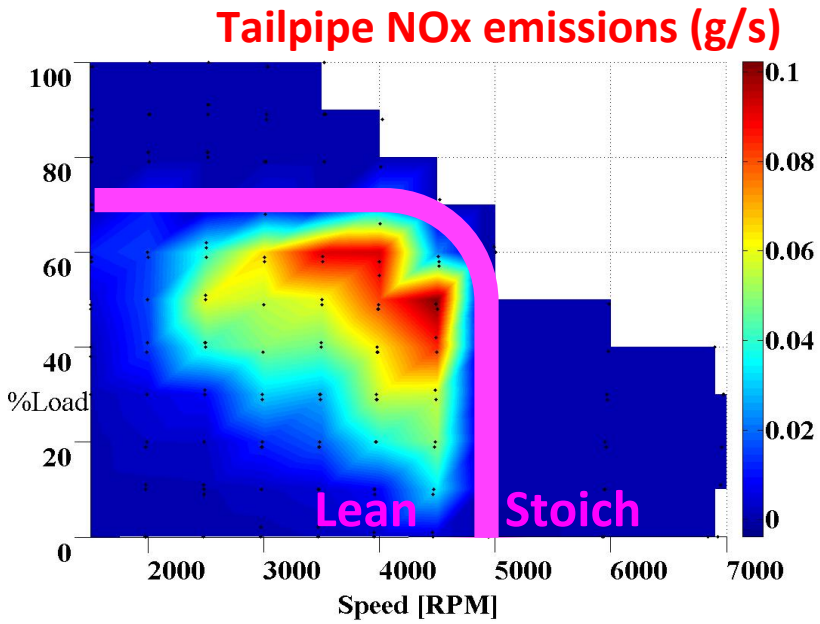


Lean engine improves fuel economy but fails to meet US emission standards

4-15% Fuel Economy Benefit from Lean Combustion *but* NOx Emissions Problematic during Lean Mode

- Vehicle designed to meet emissions levels required by European regulations
- NOx emission levels exceed U.S. Tier II Bin 5, 0.05 g/mile at 50k miles
  - Bin 2 → 0.02 g/mile
- NOx emissions during lean operation are problematic
- Particulate matter (PM) emissions may also be of concern with respect to particle number regulations*

*see SAE 2010-01-2117, SAE 2010-01-2129, SAE 2010-01-2125, etc.



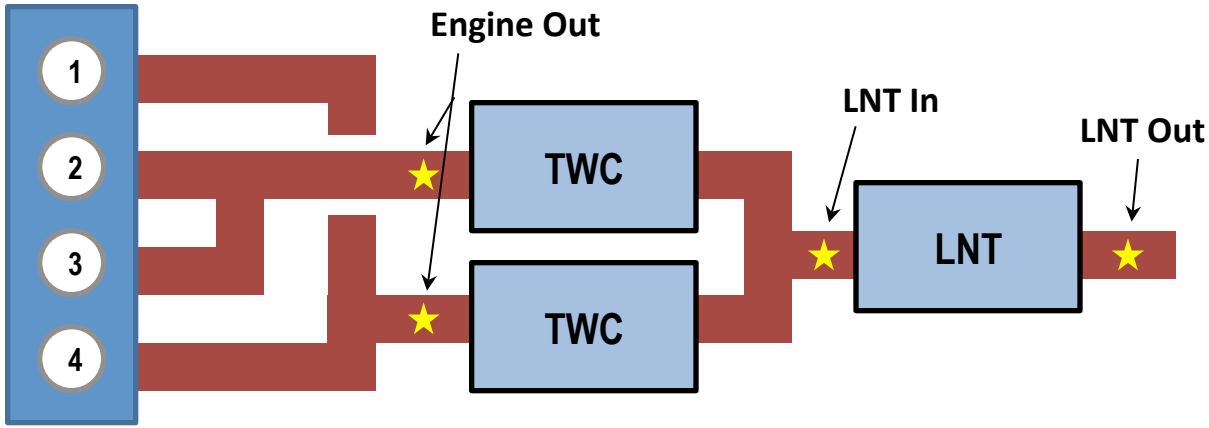
Improved Lean NOx catalysis required for deployment of lean gasoline vehicles

Drive Cycle	Fuel Economy Improvement**	NOx Emissions (g/mile)
FTP	10.0%	0.11
HFET	14.6%	0.11
US06	4.4%	0.35

**comparing stoichiometric operation to lean

A Note on Analytical Tools Used in Study

- Emissions and Reductant Species
  - UEGOs for both exhaust manifold legs
  - General emissions analyzers at engine out and tailpipe positions
  - Reductant focused emissions analysis at LNT inlet position
    - FTIR (NO, NO_2, N_2O, NH_3, HCs, CO, etc)
    - Mass Spectrometry (SpaciMS) (H_2, O_2)



Database Uploaded to CLEERS Website

http://www.cleers.org/databases/

Files Uploaded to CLEERS Website

- Recent CLEERS telecon presentation uploaded for reference information
- (3) Excel files uploaded containing data as function of engine maps
  - Lean operation
  - Rich operation
  - Merged data set
- Matlab m-file used for translation of engine shaft work to wheel work (transmission factor)
  - Experiments were performed on vehicle on chassis dynamometer
  - Fixed gear operation for steady-state engine map data
  - A translation factor was applied to determine engine shaft work from the wheel work (measured)
  - M-file generated for translations supplied here for users who may want to perform system level modeling (Autonomie, etc.)

Many thanks to Dean Edwards and Paul Chambon for their work on this data set

Files Uploaded to CLEERS Website

- Data includes:
  - Engine data such as AFR, air flow, fuel consumption, etc.
  - Engine out emissions (CO_2, CO, O_2, THC, NOx)
  - TWC Out/LNT In emissions (includes NO/NO_2, some HC speciation)
  - Tailpipe emissions (CO_2, CO, O_2, THC, NOx)
  - Exhaust system temperature and pressure data
  - PM emission data
    - Note: sparse non-replicated PM data (use with caution)
- Engine map data forced to square data matrices for ease of use in matrix math programs by filling edge regions with max, min, or interpolated values
  - The filled data is noted by the font color red

Conclusions

- Chassis dynamometer study of a lean gasoline engine vehicle (BMW 120i)
  - Fuel economy improvements from lean operation (vs. stoichiometric) were 4-15% and varied with drive cycle, but U.S. Tier II Bin 5 NOx emission level were exceeded
- Database of engine emissions and operational parameters (including emissions at various points in exhaust system) has been uploaded to CLEERS website

Questions:
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