Fuel Economy Data

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Heavy Duty
Fuel Economy & Consumption
J1939 HD Engine Parameters

- Engine speed, load (absolute & calculated)
- Vehicle speed
- Injector Flow Rate to engine
- Temperatures: coolant, ambient, catalyst
- Accelerator pedal and throttle position
- Diagnostic Trouble Codes (DTCs)
- Many, many parameters are available on J1939.
Fuel Economy
Easy to Get on HD Vehicles

- Engine Fuel Rate – Resolution is 0.050 L/H
- Engine Total Average Fuel Rate
- Trip Average Fuel Rate

- High Resolution Total Vehicle Distance
  – Resolutions is 0.005km
- High Resolution Trip Distance

- Engine Average Fuel Economy – Resolution is 0.0195 km/kg
- Engine Instantaneous Fuel Economy
- Engine Total Average Fuel Economy
- Trip Drive Fuel Economy
How Accurate is Fuel Data

- NREL stated J1939 reports 6% better fuel economy than their lab testing on a conventional vehicle (UPS truck).
- And J1939 reports 11% better fuel economy than lab testing on a hybrid vehicle.
- Two approaches measured simultaneously
- Reported highly consistent results.

SAE paper 2012-01-2049, Measured Laboratory & In-Use Fuel Economy… by M.P. Lammert, et al.
How is Fuel Consumption Determined on J1939?

- Both torque and fuel consumption are calculated not measured. Based on proprietary messages.
- Fuel rate is based on Command-Fuel-Quantity. This is based on the Injector-Command to Fuel-Quantity-Calibration curve.
- Verified with fuel-rail-pressure and fly-wheel feedback.
- Torque is based on Command-Torque relative to the Torque-Curve for the engine. Related to engine speed, boost, altitude, temperature, etc. % Load is reported on J1939.
Engine Torque on J1939
Today’s Focus:
Light Duty
Fuel Economy & Consumption
Sample OBD-II Parameters From LD Engine Controller

- Engine speed, load (absolute & calculated)
- Vehicle speed
- Temperatures: coolant, ambient, catalyst
- Accelerator pedal and throttle position
- Diagnostic Trouble Codes (DTCs)
- Mass Air Flow (MAF) Rate to engine
- Manifold Air Pressure (MAP)
- O₂ sensor data, Lambda (A/F)
- Fuel trims (long and short term)
Fuel Economy from Injectors

Fuel economy (miles/gal)

\[ = 784.05 \times \frac{\text{VSS (KM/HR)}}{\left(\frac{\text{Injector Volume (mL)}}{N}\right)} \times \text{Eng. Speed (rev/min)} \times \text{No of cylinders} \]

Where \( N \) = number of injections summed before reporting a value for a given cylinder, e.g. Toyota sums 10 pulses before transmitting.

Using EOBD fuel injector data. Update rate is typically 1-2/sec
LD Injector Flow Rate

- PID $5E$ in J1979 for OBD-II defines Injector Flow Rate – but seldom used.

- Injector Flow Rate as part of EOBD data
  Some OEMs provide, but many do not.

- Other key parameters are generally available with OBD-II as defined in J1979.

- So how to calculate fuel consumption and fuel economy without injector flow rate?
Fuel Economy Calculations
From MAF and A/F Ratio
Fuel Economy

Most vehicles provide mass air flow (MAF) rate to calculate fuel consumption/economy

- Need: stoichiometric A/F ratio, vehicle speed, lambda, and fuel density
- Most commonly used, but Chrysler and some Honda vehicles don’t provide MAF.

If no injector data or MAF, then need to use MAP and ideal gas law. Helpful to model the engine. Least accurate.
Fuel Economy from MAF

Fuel Economy (MPG)

\[ = \lambda \times 6.807 \times \text{VS (KPH)} / (\text{MAF(g/s)}) \]

or

\[ = \lambda \times 11.00 \times \text{VS (MPH)} / (\text{MAF(g/s)}) \]

Use either average or instantaneous values.

Lambda is a ratio that defines the deviation from stoichiometric

6.17 - Density of gasoline (lb/gal)  
454 - Conversion (g/lb)  
0.62137km/mile  
3600 - Conversion (sec/hr)

gal (fuel) = \left(\text{gal}/6.17\text{lb} \times \text{lb/454g}\right) / 14.08(A/F) = 1/39,440.6 gal/g  
39,440.6 / 3600 = 11.00 g-hr/gal-sec
LD Engine Data
Two Studies Presented

First study is on the presenter's 2010 Prius HEV

Second study is from an OEMs fleet of 111 LD vehicles.

Assumes 10% ethanol
## Fuel Economy MPG Calculations
### 2010 Prius HEV

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<th>Instr. Panel</th>
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Conclusions from Prius Testing

- Fuel injector data agrees well with fuel tank after 30 gal of fuel added
- MAF based results show 5% higher fuel economy than fuel tank & injectors
- MAF based data correlates with instrument panel display
- So instrument cluster MPG is 5% high
2nd Test Study

- Fleet from one OEM
- Fuel Economy calculations were made as part of their study by HEM Data
- Tested in several states IL, CA, MO, NY, GA, LA, OH, MD, OR, TX, MA
- Sorted by engine model
- Test period from 12/11 to 1/13 – so over a year
# Overview of 111 LD Vehicles

## Fuel Economy Comparison Study

### Fleet Overview by Engine Type

11 Engine Type(s)

Select an engine type:

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<tr>
<th>Engine Type</th>
<th>Driving Duration (hr)</th>
<th>Distance Traveled (mi)</th>
<th>Trips</th>
<th>Fuel Economy (A/F) (mpg)</th>
<th>Fuel Economy (Inj) (mpg)</th>
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**Fuel Economy Comparison Study**

**Engine Type Summary**

- Engine: 6 Cylinders
- Last Trip Update: Dec. 5, 2012, 9:56 a.m.

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shows excellent correlation
Correlation not as Good

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Some MAF Sensors Report
0 g/s some of the time

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Summary of Differences
Fuel injector vs. MAF Based

Average = 2.8%
Std Dev = 5.1%
Mode = 1.2%

60 of the 111 vehicles were within ±5%
32 of the 111 vehicles were within ±3%

Summary chart % differences by model ranged from -5.2 to + 7.9%.
Conclusions from Fleet Study

- Using MAF and A/F ratio is valid alternative to calculating fuel consumption and fuel economy if injector data is not available.

- MAF approach generally shows lower fuel consumption and higher fuel economy.

- 25 of 111 vehicles showed the opposite result.

- Consistent results with hybrid vehicles as the first study shows.

- Injector data and > 30 gal of gasoline refueling give excellent results.
Conclusions from Fleet Study

Error could be 10% without noticing it on a single vehicle.

If injector data is not available, then to gain confidence compare MAF calculations to:
- Fuel tank additions of more than 30 gal, or
- Compare to a larger vehicle population

Could use this known difference to adjust the results to better match the injector results

Study is available at http://fuel.hemdata.com/
Fuel Economy Data

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