

High Octane Fuels, Making *Better* use of Ethanol

Brian West

Fuels, Engines, and Emissions Research Center

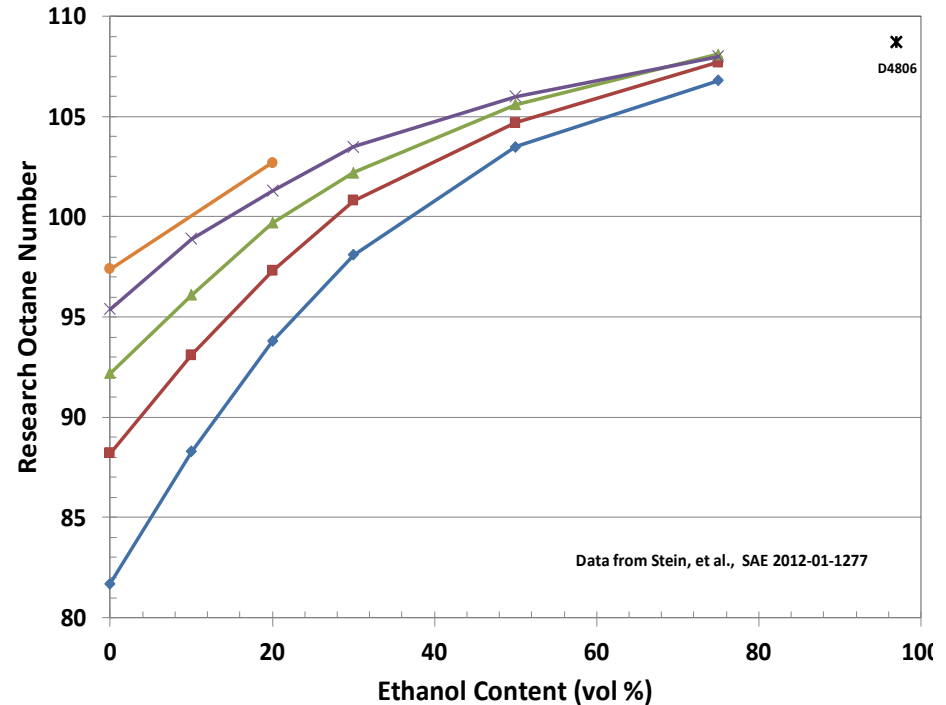
**EESI High-Octane Fuels Briefing
Washington, DC
November 13, 2017**

**Work supported by
DOE Office of Energy Efficiency and Renewable Energy
Ag/Auto/Ethanol Workgroup**

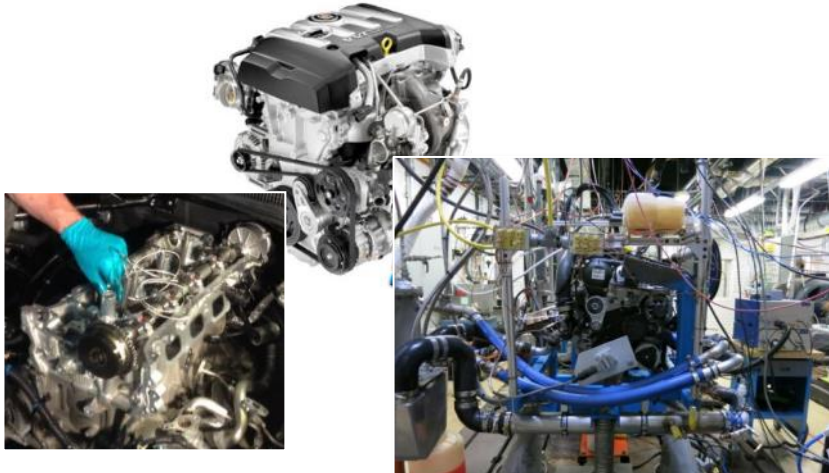


Ethanol is a very effective octane booster

- $\sim 2/3^{\text{rd}}$ of octane benefit from first $1/3^{\text{rd}}$ of ethanol volume percent
- U.S. EPA opened the door for a high octane $\sim E30$ fuel in Tier 3 rule
 - “...we allow vehicle manufacturers to request approval for ... fuel such as a high-octane 30 percent ethanol ... blend (E30) for vehicles ... optimized for such fuel”
- Road fuel infrastructure for a mid-level ethanol blend is not trivial (but significantly less complex than many other alternatives)
 - USDA Biofuel Infrastructure Partnership is helping grow number of stations capable of dispensing E25 and higher blends

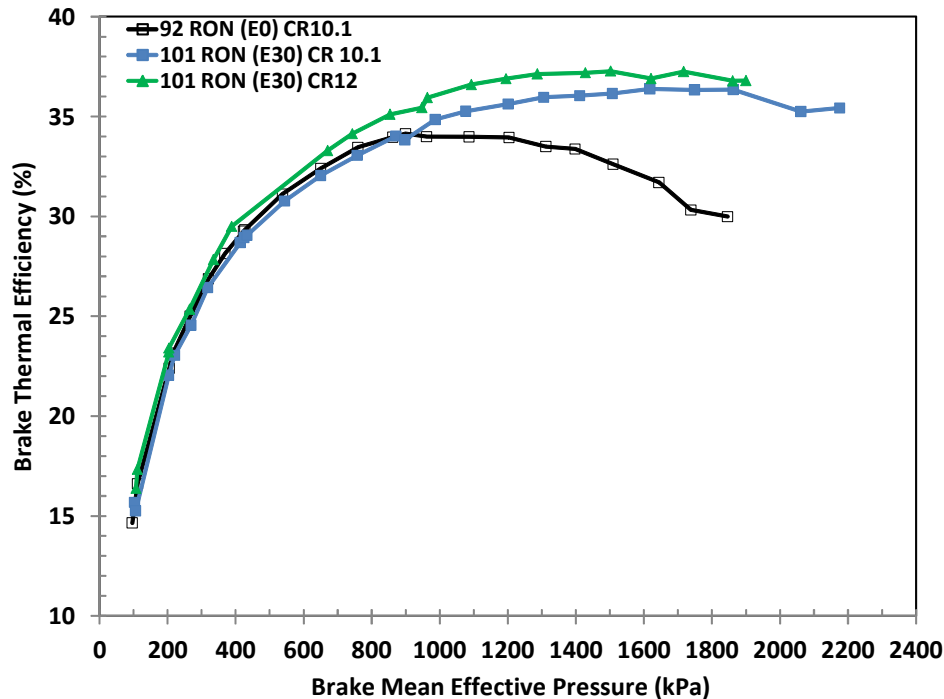


Industry and DOE Investing In Programs to Quantify Efficiency and GHG Benefits of High Octane Fuels



DOE Work supported by

- Vehicle Technologies Office
- Bioenergy Technologies Office



Industry Cost-Share, Funds-in, and Tech Support

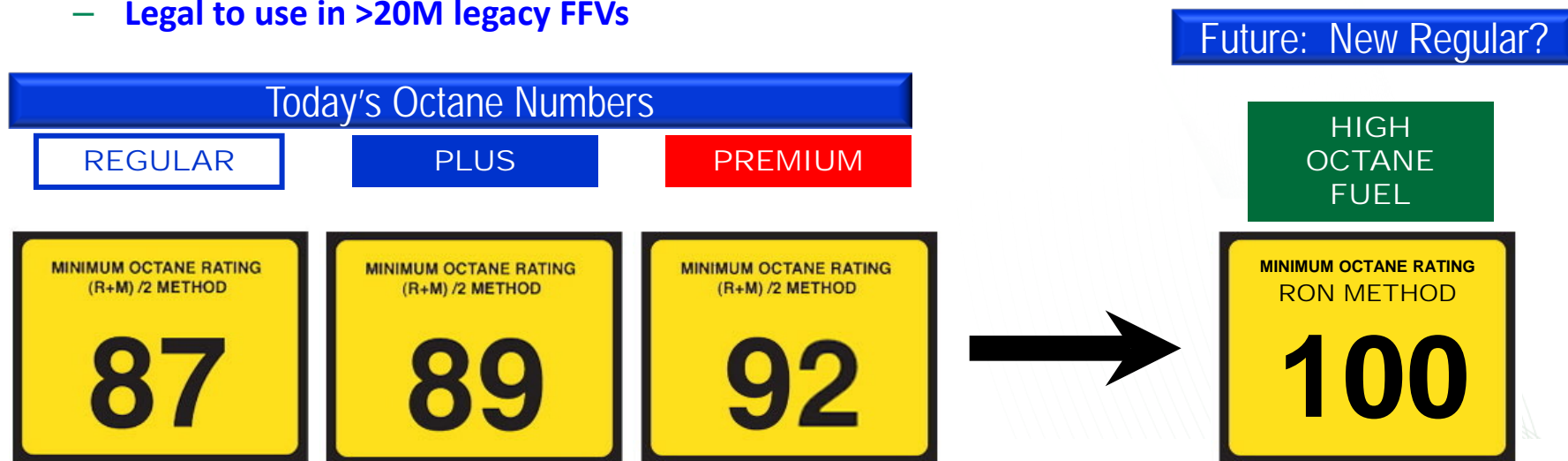
- Ford
- General Motors
- Fiat Chrysler
- Coordinating Research Council
- Ag/Auto/Ethanol Workgroup

← Thermal Efficiency of Ford EcoBoost

(data from Sluder, ORNL)

A New High Octane Fuel Could Make *Better* Use of Ethanol's Properties, Moving The U.S. Toward Multiple Goals

- Engine efficiency can be improved with increasing ethanol and octane rating
- E25-E40 blend in *future vehicles* can return equivalent “tank mileage” as E10 in today's comparable vehicles
 - Energy density penalty is *linear* with increasing ethanol concentration
 - Power and efficiency gains are *non-linear*
 - **Volumetric Fuel Economy Parity** means *every gallon of ethanol* displaces *a gallon of gasoline*
 - Efficiency/fuel economy benefit to OEM is significant
 - Can help U.S. Comply with Renewable Fuel Standard
 - **Legal to use in >20M legacy FFVs**



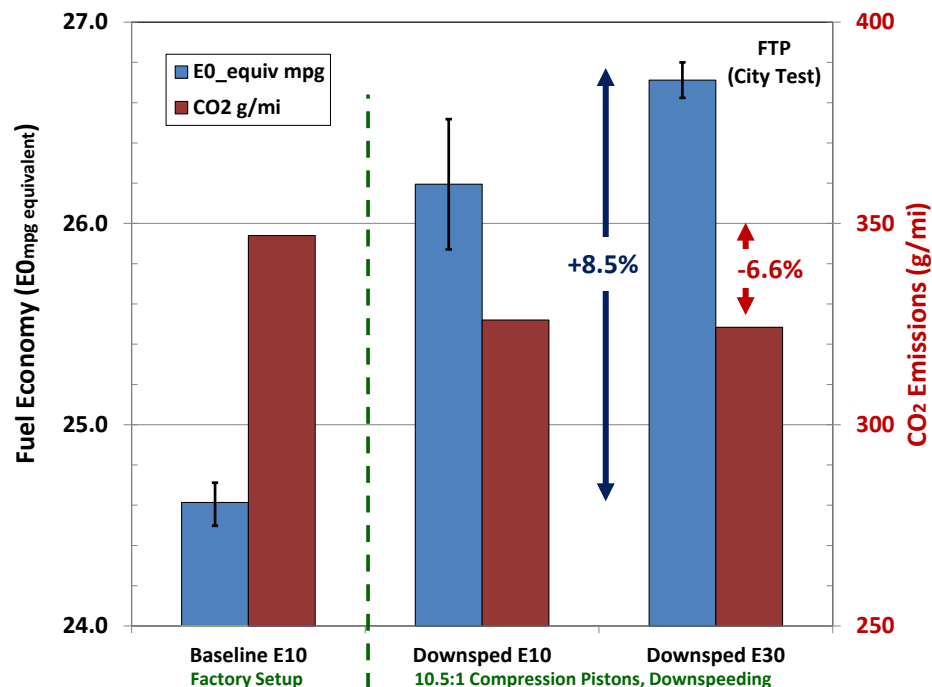
A few example results

High Octane Vehicle Demonstration Supported by DOE Bioenergy Technologies Office and follow-on work by Ag/Auto/Ethanol

- Objective: Demonstrate High Octane fuel benefits at the vehicle level
- Late model vehicle with 2.0 liter, 4-cylinder, turbocharged GDI engine
- **Efficiency gains of 5-10% demonstrated with high-octane mid-level blends**



Cadillac ATS equipped with a 2.0 liter turbocharged, direct-injection engine and manual transmission



Range bars denote max and min of multiple tests



Ag/Auto/Ethanol Supporting Mini Cooper E25 Demonstration



• Vehicle Specs:

- 2.0 liter turbo GDI
- Factory pistons and drivetrain
- Why Mini? *Owner's manual calls out E25:*

FUEL Fuels with a maximum ethanol content of 25 %, i. e. E10 or E25, may be used for refueling.

GAGE GAGE PRODUCTS CO.
821 WANDA AVENUE
FERNDALE, MI 48220
(248) 541-3824

Page: 1
Date: 05/19/16 at 1:32 PM

Gage Products Company
Certificate of Analysis / QC Results

Customer PO # :

Packaged Product: 42051-55F
EPA Tier 3 Cert Fuel Regular

Property	Test Method	UOM
RESEARCH OCTANE NUMBER	ASTM D2699	RON
MOTOR OCTANE NUMBER	ASTM D2700	MON
OCTANE RATING	GAGE-CALCULATED	R+M/2
OCTANE SENSITIVITY	GAGE-CALCULATED	R-M

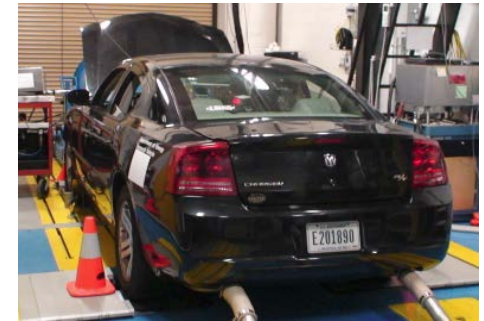
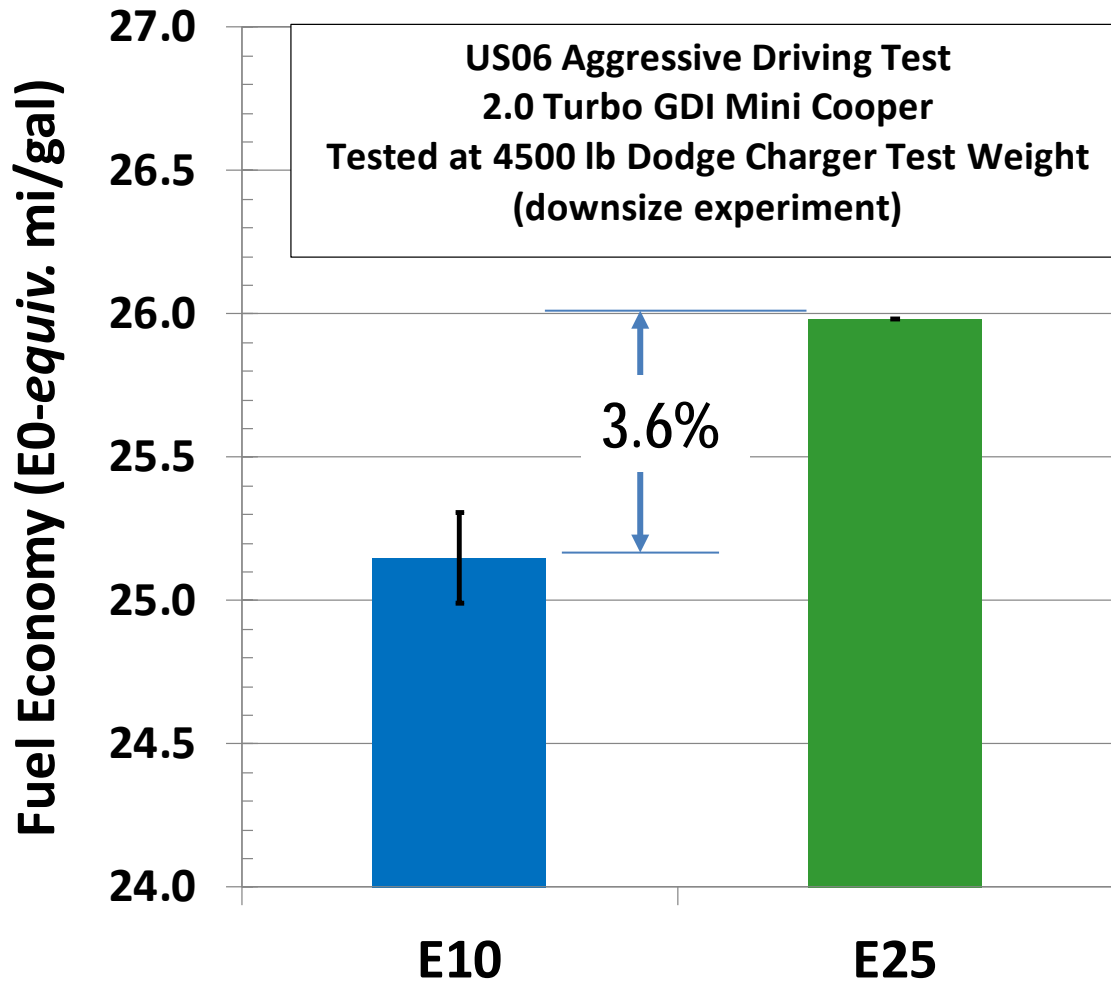
- Tier 3 E10 and “Tier 3 E25” fuels
- **High-Octane E25 provides efficiency and performance gains**



Property	Test Method	Tier 3 E10 Value	'Tier 3 E25' Value
Research Octane Number	ASTM D2699	92.3	98.9
Motor Octane Number	ASTM D2700	84.5	87.5
AKI	(RON+MON)/2	88.4	93.2
Sensitivity	RON-MON	7.8	11.4

*Acknowledgement to BMW for informal technical support

Downsizing experiments conducted with Mini Cooper on dynamometer using 2006 Dodge Charger test weight and road load. High-octane E25 on aggressive US06 test provides efficiency gain over regular E10.

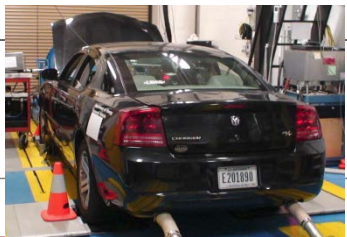
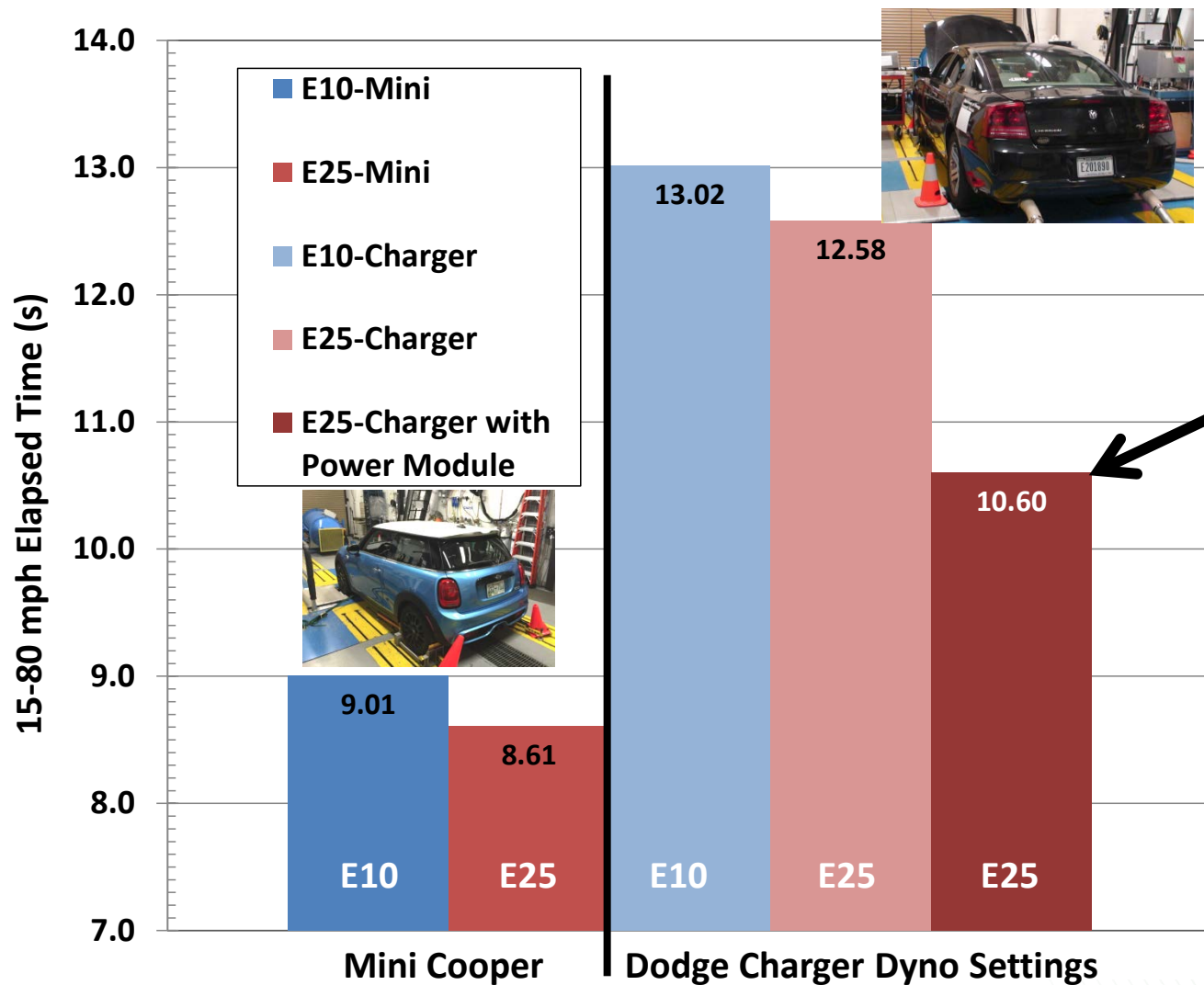


2006 Dodge Charger dynamometer settings used with Mini Cooper vehicle to simulate downsizing



Extreme downsizing can improve fuel economy at the expense of acceleration performance. Mini is 0.4s quicker with high-octane E25 than with E10. With Charger test weight, vehicle considerably slower; high-octane E25 again provides 0.4s quicker acceleration.

Aftermarket “Power Module” increases boost, improves acceleration time by 2.4 s with HO E25 fuel.



2006 Dodge Charger dynamometer settings used with Mini Cooper to simulate downsizing



NM Engineering Power Module (PM) intercepts T-MAP sensor and increases boost. PM installed by previous owner; PM was disconnected for all tests except these final E25 WOT tests.

<http://www.nm-eng.com/338/0/0/3128/nm648846-nm-eng-power-module.html>

F150 EcoBoost* Currently Under Test

*3.5L Turbocharged V6

Status

✓ **Baseline testing at ORNL with Tier 3 E10 and E25** Complete**

✓ **Piston swap complete**

- Mahle designed, fabricated, and delivered high-compression pistons (target +2.2 CR)
- More significant CR increase than previous experiments

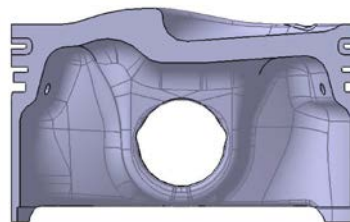
• **High Compression Experiments Underway**

• **Measurements planned**

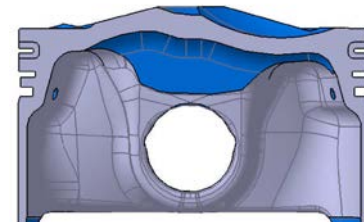
- Fuel Economy
- NMHC/NMOG, CO, NOx emissions
- PM mass (cold LA4)
- Acceleration



Ford F150 in ORNL Laboratory



Factory 10:1



MAHLE 12.2:1

Ford F150 Pistons

***Same fuels used in Mini Cooper*

Work supported by Ag/Auto/Ethanol Workgroup

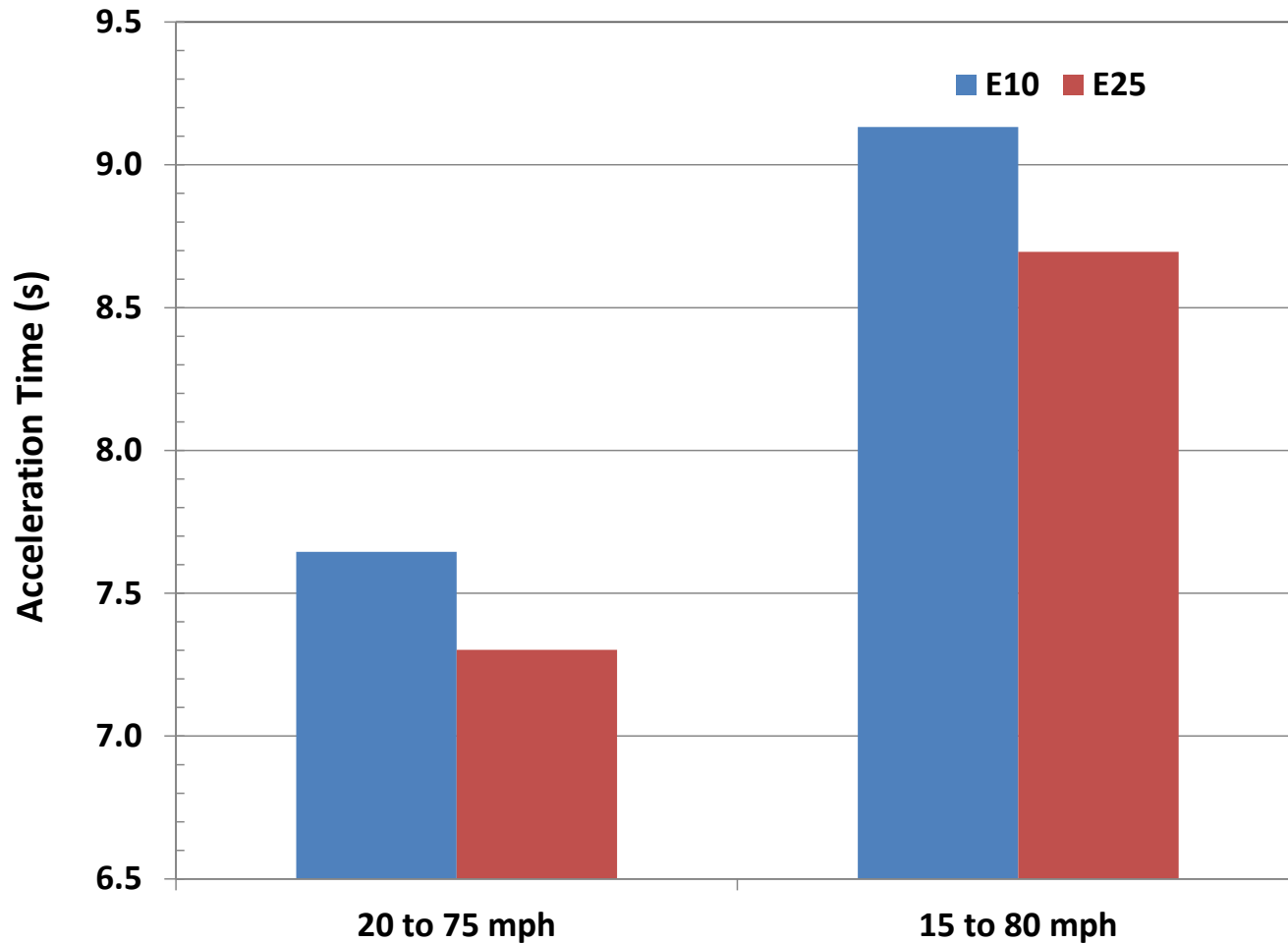
Factory and High Compression Pistons for Ford EcoBoost Engine from MAHLE Powertrain



Factory 10:1

Prototype 12.2:1

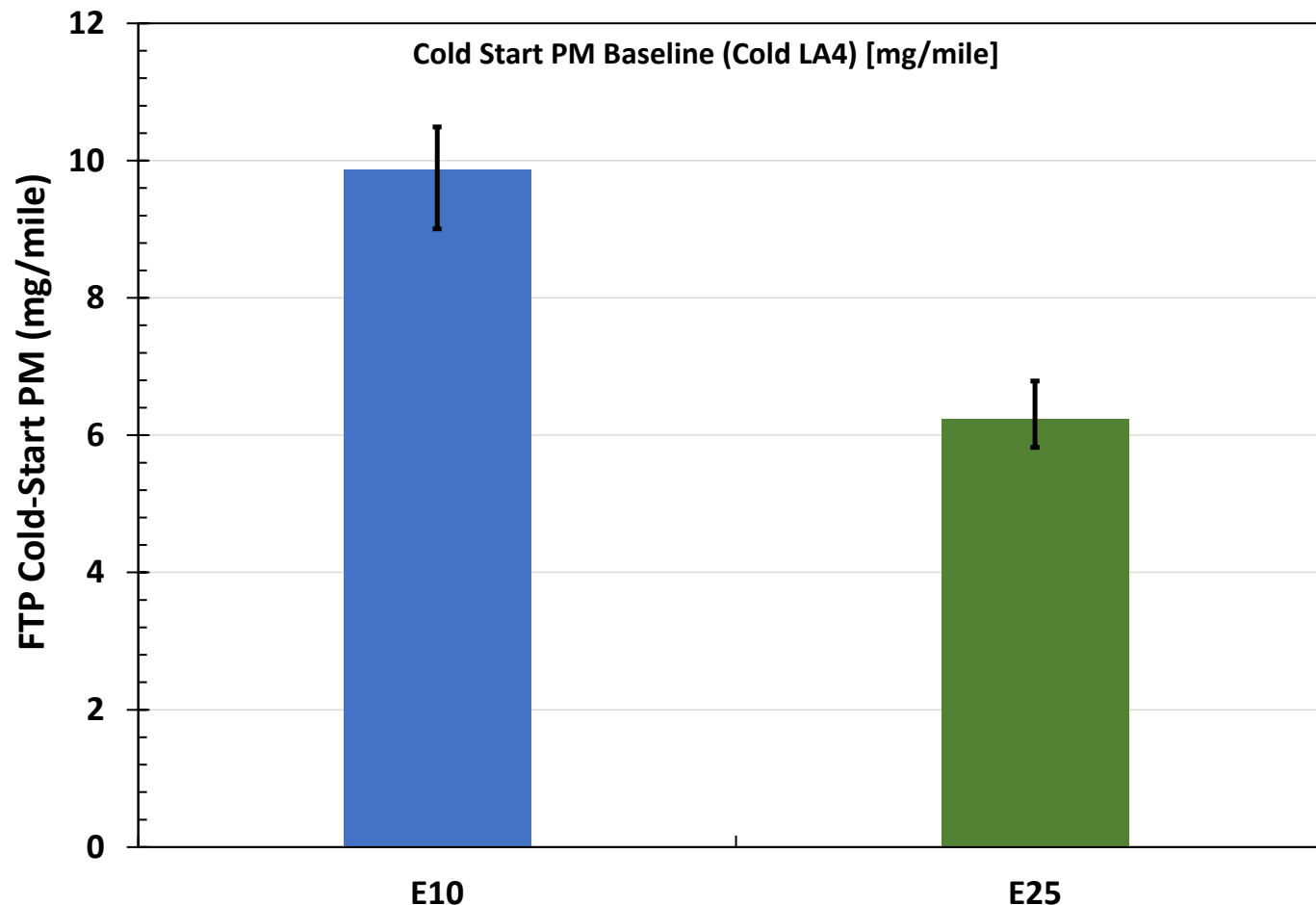
F150 EcoBoost V6 Acceleration: High Octane E25 Provides performance difference over regular E10 in baseline (factory) test condition



F150 EcoBoost V6 Particulate Matter:

Baseline tests show E25 provides statistically significant reduction in cold start particulate matter over regular E10.

Cold portion of test generally produces ~90% of particulate matter in certification test



Range Bars Show min and max of three measurements

Summary

- High-octane fuels can enable improved vehicle efficiency (in vehicles designed for their use)
 - Vehicle-level demonstrations have shown *efficiency gains can more than offset lowered energy density of added ethanol*
 - Vehicle efficiency gains of up to 12% demonstrated
- Improved torque and power can provide performance improvement (or permit smaller engines)
 - Legacy FFVs, turbo GDI engines (Mini Cooper) show improved acceleration, demonstrate potential for OEMs if fuel widely available



Contact Information

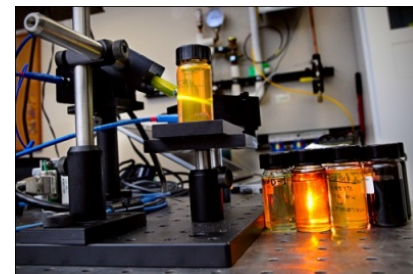
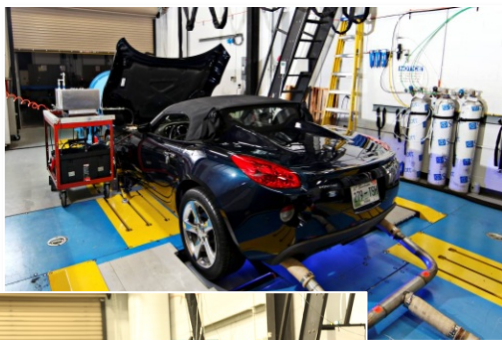
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Acknowledgements

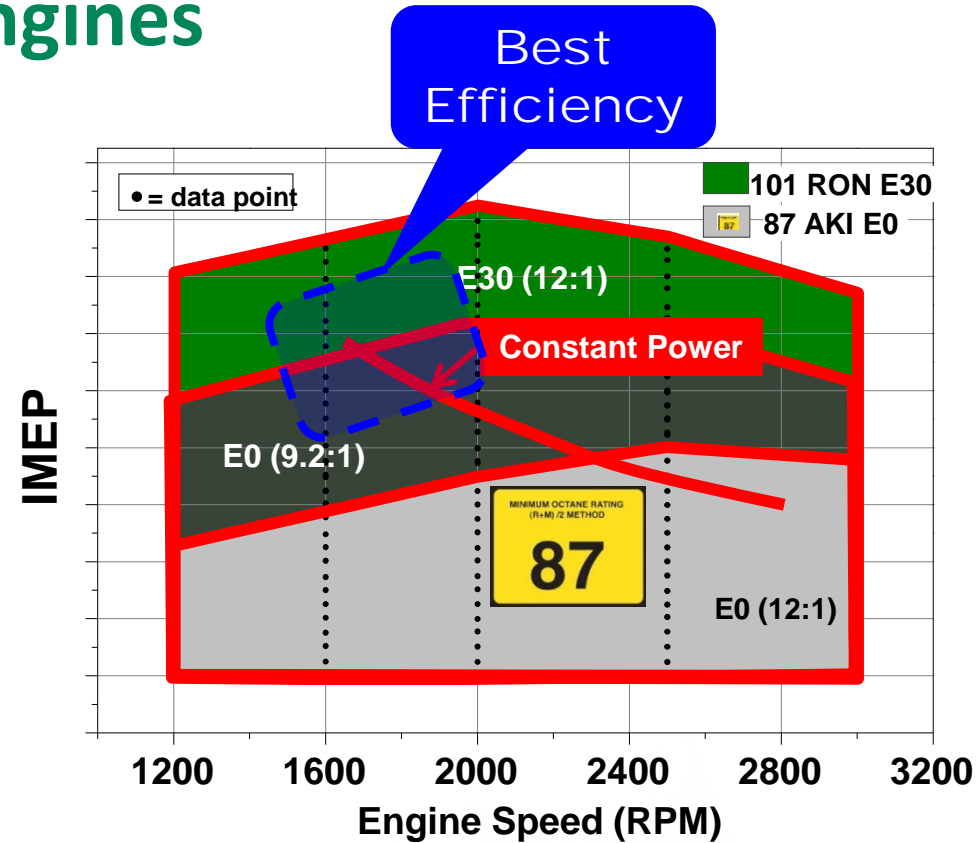
- **DOE Vehicle Technologies Office**
- **DOE Bioenergy Technologies Office**
- **Ag/Auto/Ethanol Workgroup**
 - National Corn Growers
 - Illinois Corn Marketing Board
 - Missouri Corn Growers
- **Industry Partners and National Lab Peers**
- **Fuels, Engines, Emissions Research Center (FEERC) colleagues**



Backup Slides

Recent Experiments Highlight Efficiency Benefits of High Octane Fuel for SI engines

- Engines can make more torque and power with higher octane fuel
- Ethanol is very effective at boosting octane number
 - 87 AKI E0 + 30% Ethanol = 101 RON Fuel
- Increased torque enables downspeeding and downsizing for improved fuel economy
 - For future vehicles, engine and system efficiency can balance lower energy density of ethanol blends



In a high compression research engine, high-octane E30 enables doubling of available torque compared to 87 AKI E0 fuel

- Splitter and Szybist, ORNL

Legacy FFVs Realize Performance Gain with High Octane Mid-Level Ethanol Blends

Work supported by DOE Bioenergy Technologies Office

- **Motivation: Measureable performance improvement in legacy FFVs could enable early adoption of “High Octane Fuel for Your FFV”**

- **Tested 4 “ethanol tolerant” FFVs**

- GMC Sierra
- Chevrolet Impala
- Ford F150
- Dodge Caravan

- **Prep and Baseline “wide open throttle” (WOT) test with Regular E10**

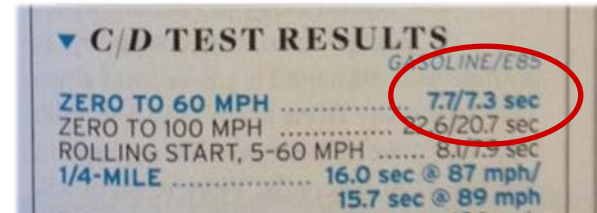
- **Prep and WOT test with ~100 RON E30**

- **Report available:**

- 3 of 4 FFVs show acceleration improvement with E30
 - ORNL’s Sierra results with E30 similar to Car and Driver test with E85 →

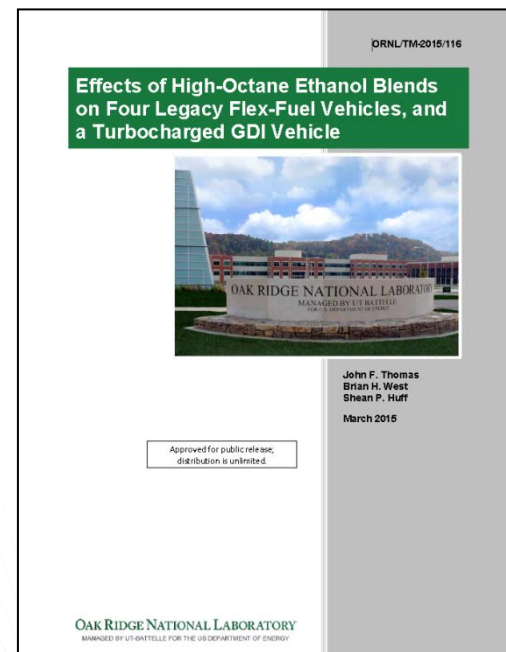
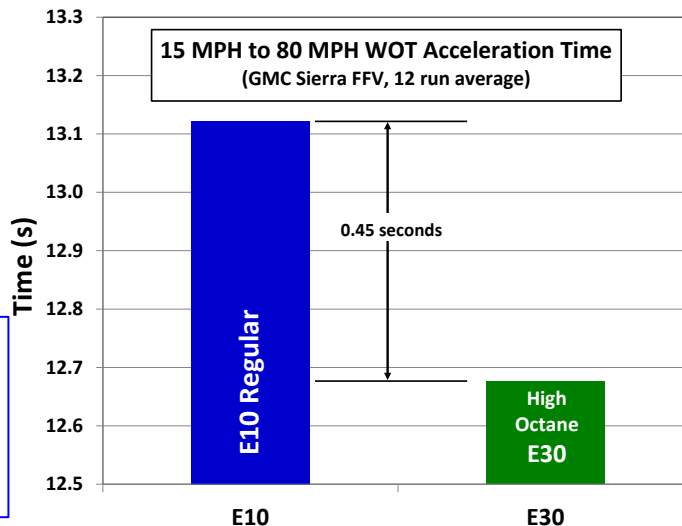
If half of FFVs on road today filled up with E25 half the time, nation would consume over half-billion gallons more ethanol

HIGH OCTANE FUEL
For your FFV



Car and Driver FFV test shows 0.4 second faster 0-60 mph time with E85

www.caranddriver.com/reviews/2014-chevrolet-silverado-v-6-instrumented-test-review



<http://info.ornl.gov/sites/publications/Files/Pub54888.pdf>