Overview of High Octane Fuel Engine and Vehicle Efforts

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[*] ORNL

[**] General Motors

Auto/Ag/Ethanol Meeting

USCAR

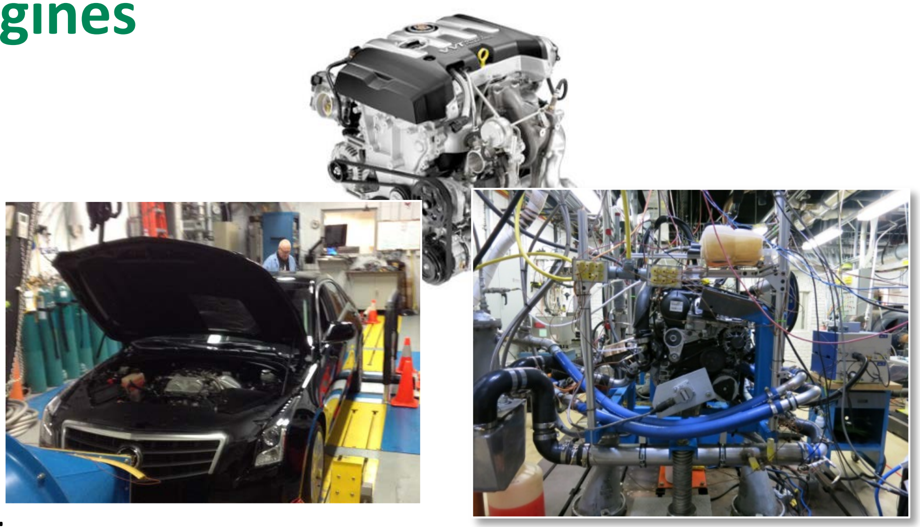
August 18, 2015

Work supported by
DOE Bioenergy Technologies Office
DOE Vehicle Technologies Office
Coordinating Research Council
Industry Partners

AAE WG

OAK RIDGE National Laboratory

Industry and DOE Investing In Programs to Quantify Benefits of High Octane Fuels in Turbo GDI Engines



DOE Work supported by

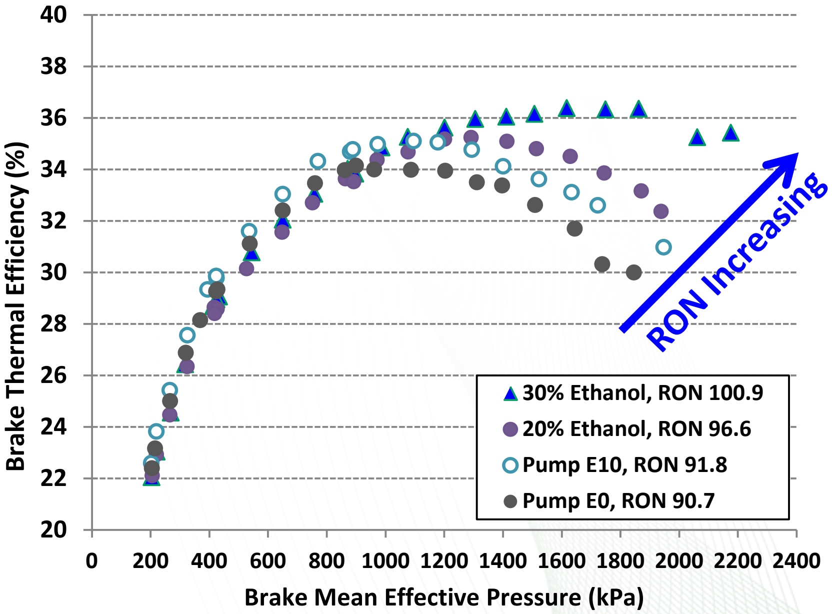
- Vehicle Technologies Office
- Bioenergy Technologies Office

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

- Ford
- General Motors
- Coordinating Research Council

- Thermal Efficiency of Ford EcoBoost➔

  (data from Sluder, ORNL)

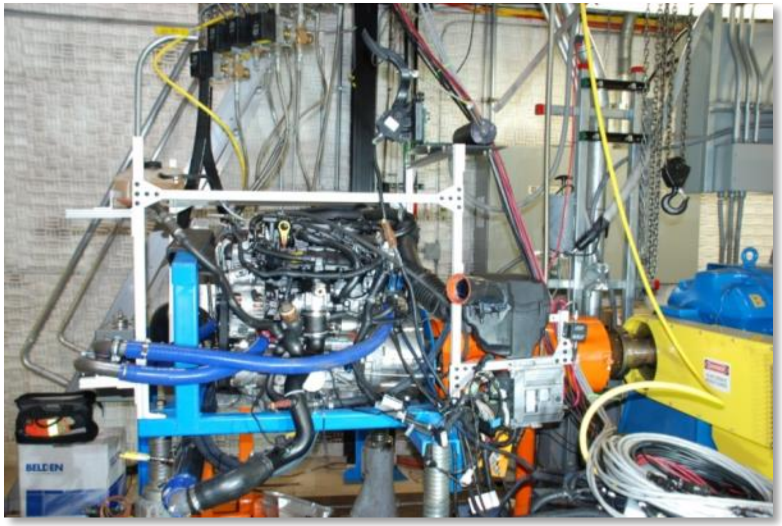


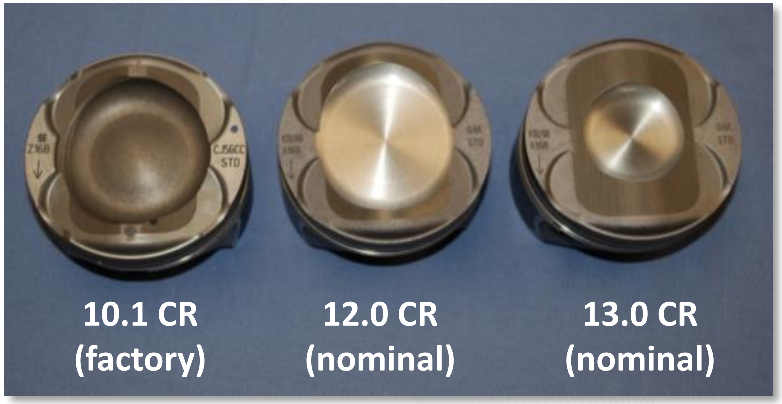
Engine-Based Projects. Summary slides on each project to follow

Test Program Attribute:	AVFL-20	AVFL-20A	AVFL-26	"open" DOE Project (Sluder)
Modified 1.6L GTDI engine (modified near/mid-term engine design)	YES	NO	NO	YES
Modified 2.0L GTDI engine (Advanced design, DOE FOA project)	NO	NO	YES	NO
Current production 1.4L FIRE NA engine	NO	YES	NO	NO
Long-term engine design (2 stage turbo, high energy ignition and EGR)	NO	NO	YES	NO
Modify compression ratios on engine (inc. CR = inc. efficiency)	YES	YES	YES	YES
Quantify higher octane impacts on gaseous/PM emissions	YES	YES	YES	YES
Quantify higher octane impacts on particulate number emissions	NO	NO	YES	NO
Determine ethanol impacts on gaseous/PM emissions (E10-E30)	YES	YES	YES	YES
Determine ethanol impacts on PN emissions (E10-E30)	NO	NO	YES	NO
Quantify E0 gasoline impacts on gaseous/PM/PN emissions	NO	NO	YES	NO
Determine PMI fuel impacts on gaseous/PM/PN emissions	NO	NO	YES	YES
Evaluate gasoline and ethanol interactions and the effects on engine efficiency on near to mid term engine design	YES	YES	YES	YES
Study of effects of sensitivity on gasoline-ethanol fuel blending to achieve target RON and effect of sensitivity on engine efficiency	YES	YES	YES	NO
Understand and quantify fuels effects (PMI) on future (long-term) engine technologies with respect to engine efficiency, gaseous/particulate emissions and fuel economy	NO	NO	YES	NO
Engine mapping with various compression ratios and octane levels to support vehicle modeling for estimating Fuel Economy benefits of HOF in downspeeded/boosted GDI engines	YES	YES	YES	YES

AVFL-20 and DOE Project Using Ford 1.6 Liter EcoBoost To Explore High Octane Fuels and Engine Compression Ratio Synergies

- **Turbo-charged, direct-injection engine**
  - Full engine control provided by Ford
  - High compression pistons have been designed and machined
  - Supporting both DOE and CRC projects
- **Fuel blends will span various octane levels with different sources of octane number**
- **Full Engine maps with emissions and efficiency to support vehicle modeling**





DOE work supported by Vehicle Technologies Office, with engine and technical support from Ford

*CRC funds-in effort underway (AVFL-20)**

*http://www.crcao.com/about/Annual%20Report/2013%20Annual%20Report/2014%20Annual%20Report/AR2014Final.pdf

CRC Project AVFL20a

Objective:

Expand the results of AVFL20 to include impacts on port-fuel injected platforms that may exhibit different responses to changes in fuel formulation compared with GTDI platforms.

Approach:

Develop engine maps for a PFI platform followed by vehicle modeling to assess fuel economy impacts.

- Fuels same as those for AVFL20 phase 3.
- Chrysler FIRE 1.4L NA PFI
- Baseline CR plus one higher CR

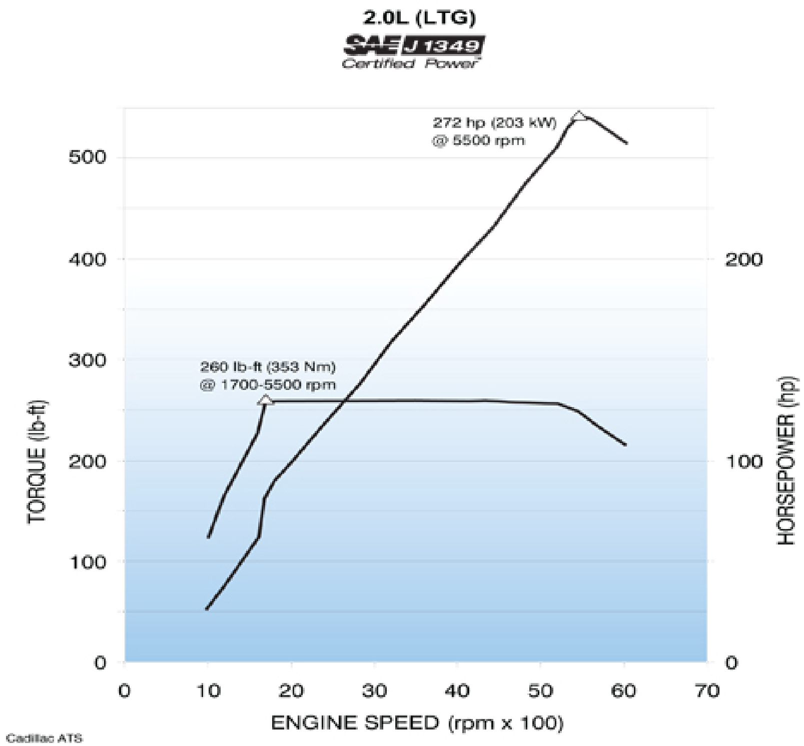
Status and Timing:

Contract with CRC and funding in place; awaiting engine delivery.

Completion estimated for calendar year 2016.

AVFL-26, DOE Funding Opportunity (Competitive), FOA991 Awarded 2015
Gasoline Engine and Fuels Offering Reduced fuel Consumption and Emissions

- **GM 2.0 LTG Engine**
- **Cost share with CRC**
- **Technical support from GM**
- **Target 25% reduction in petroleum consumption**



Work supported by DOE Vehicle Technologies Office, engine and technical support from GM/CRC

CRC project AVFL-26*

New LTG engine is excellent candidate for downspeeding/downsizing enabled with high-octane fuels

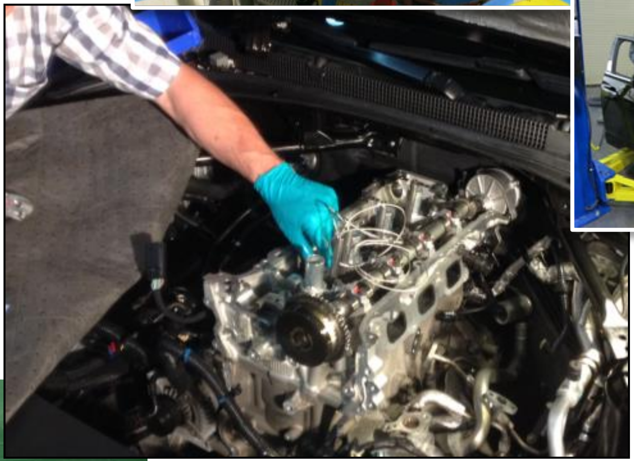
*http://www.crcao.com/about/Annual%20Report/2013%20Annual%20Report/2014%20Annual%20Report/AR2014Final.pdf

Vehicle-Based Projects. Summary slides on each project to follow

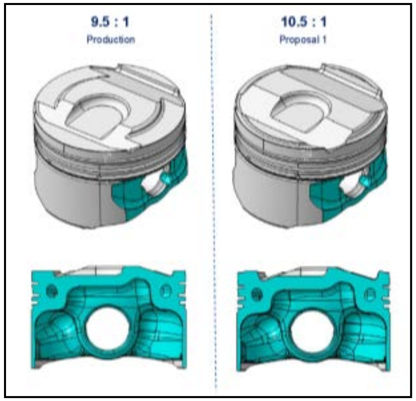
Test Program Attribute:	BETO HOF Vehicle Demo	Fiesta EcoBoost Demo	Flex Fuel Vehicle Performance Study
GM 2.0 Turbo GDI (LTG Platform)	YES	NO	NO
Current production 1.0L EcoBoost engine	NO	YES	NO
Current production Normally Aspirated FFVs (4).	NO	NO	YES
Modify compression ratios on engine (inc. CR = inc. efficiency)	YES	NO	NO
Quantify higher octane impacts on acceleration performance	YES	YES	YES
Quantify higher octane impacts on whole vehicle fuel economy (mpg)	YES	YES	YES
Examine HOF ranging from 87 AKI to 100 RON with various levels of ethanol	YES	NO	NO
Compare E10 to E30	YES	NO	YES
Compare E0 to E15	NO	YES	NO
Determine PMI fuel impacts on gaseous/PM/PN emissions	NO	NO	NO
Simulate downspeeding and downsizing via vehicle changes and vehicle test weight	YES	NO	NO
Combustion analysis being conducted to quantify CA50	YES	NO	NO
Criteria pollutants measured and reported	NO	YES	YES
Work completed and published?	NO	YES	YES

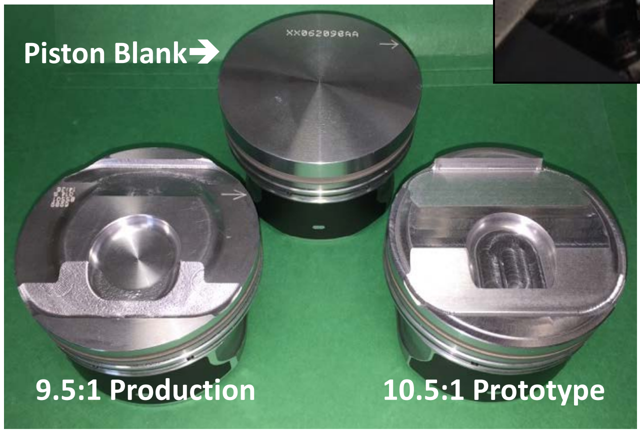
BETO Project Demonstrating High Octane Fuel Benefits at the Vehicle Level

- **Late model vehicle with TGDI engine**
  - Turbo-charged GDI engine, <u>manual</u> transmission
  - Baseline Experiments Completed
    - Factory compression ratio
    - 87 AKI to 100 RON
    - E0 to E30
    - Downsped and downsized
    - Cylinder pressure data collected
  - Compression ratio change imminent
    - High compression pistons acquired



Cadillac ATS acquired. Instrumented cylinder head installed to support combustion analysis





Pistons designed by Kolbenschmidt. Engine modeling/design guidance from GM. Blanks provided by Kolbenschmidt, machined in Oak Ridge

OEM Tech support
- *High compression pistons*
  - *Engine modeling to ensure no interference*
- *Engine controls support (spark, boost, etc)*
  - *NDA recently signed under auspices of FOA*
- *Ability to monitor cylinder pressure*
  - *GM provided machined cylinder head*
- *Source for taller gears (final drive ratio)*

Work supported by DOE Bioenergy Technologies Office, *GM providing technical support (vehicle uses same engine as DOE FOA project [CRC AVFL-26])*

Vehicle Study to Determine Potential Performance Improvement of Legacy FFVs with High Octane Blends

Work supported by DOE Bioenergy Technologies Office

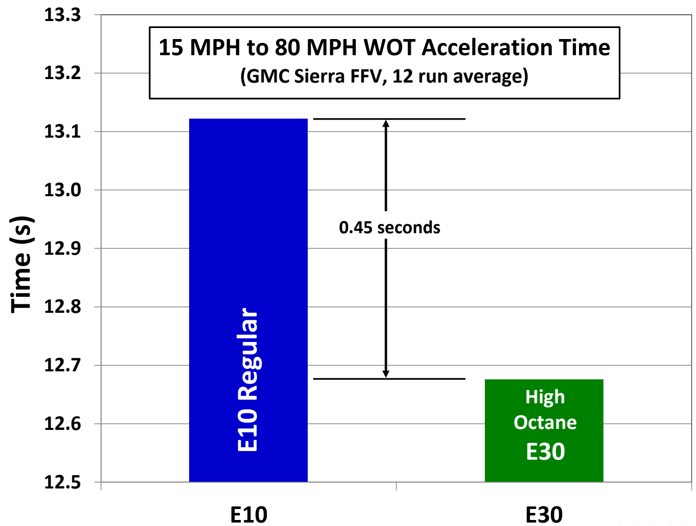
- **Motivation: Measureable performance improvement in legacy FFVs could enable early adoption of "High Octane Fuel for Your FFV"**
- **Acquired 4 "ethanol tolerant" FFVs**
  - GMC Sierra
  - Chevrolet Impala
  - Ford F150
  - Dodge Caravan
- **Prep and Baseline "wide open throttle" (WOT) test with Regular E10**
- **Prep and WOT test with ~100 RON E30**

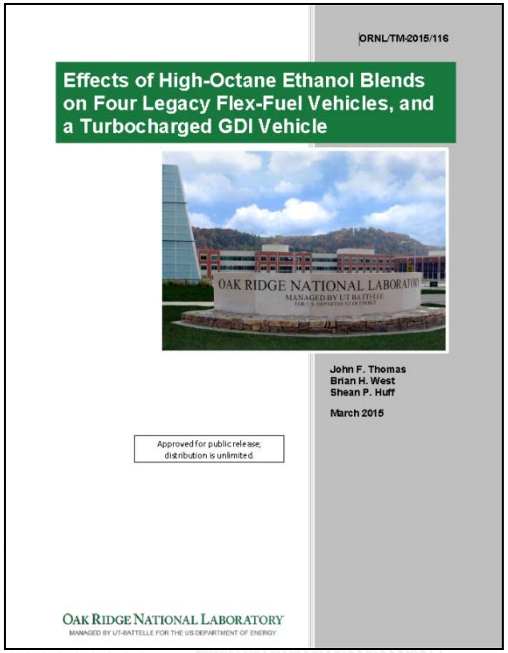
HIGH OCTANE FUEL
For your FFV

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

- **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 ➔





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

If *half* FFVs on road today filled up with E30 *half* the time, consume *half-billion* gallons more ethanol

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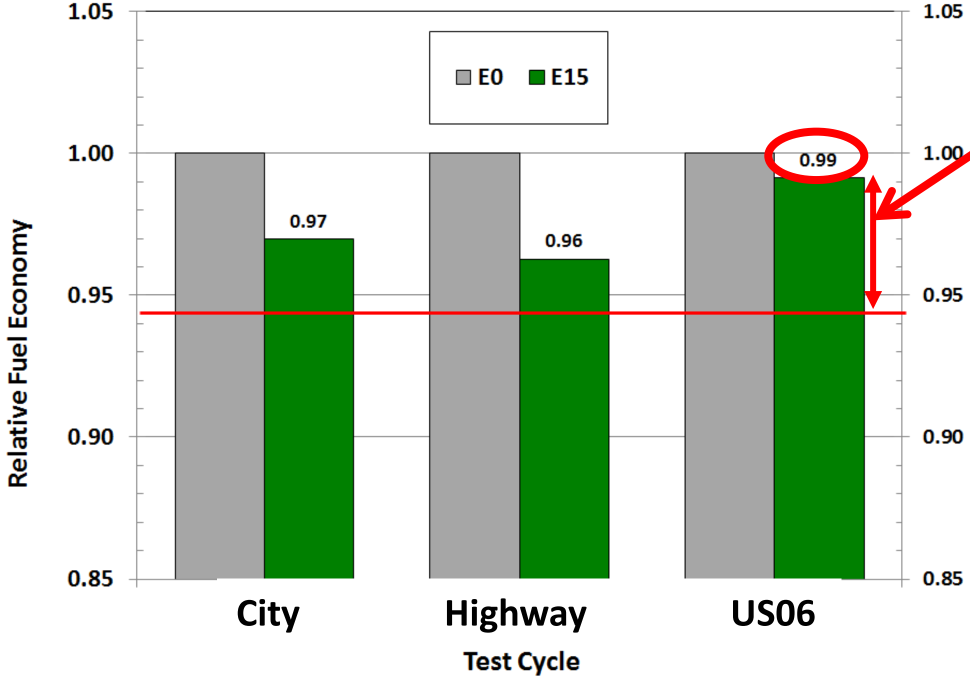
Benefits of Engine Downsizing with High Octane E-Blend Demonstrated on Late-Model Turbo GDI Vehicle

- **E15-Compatible Ford EcoBoost Fiesta**
  - **1.0 liter, 3-cylinder turbo GDI engine**
- **Owner's Manual:** **"Regular unleaded gasoline…is recommended….premium fuel will provide improved performance and is recommended for severe duty usage…"**
- **Experiment:**
  - **Blend regular 87 octane E0 with 15% Ethanol**
    - **Boosts octane, lowers energy content**
  - **Test on City, Highway, and US06 (high-load cycle)**
  - ***No Changes*** **to engine, vehicle, calibration or shift schedule**
  - **Results within 1% of *Volumetric Fuel Economy Parity* with E15 on US06**

4.6% Efficiency Improvement



Fuel:	E0	E15
RON	90.7	97.8
AKI	87.7	92.6
Btu/gal	113,100	106,700
Relative Btu/gal	1.00	.943

Addition of 15% ethanol boosts octane, improves engine performance & efficiency.