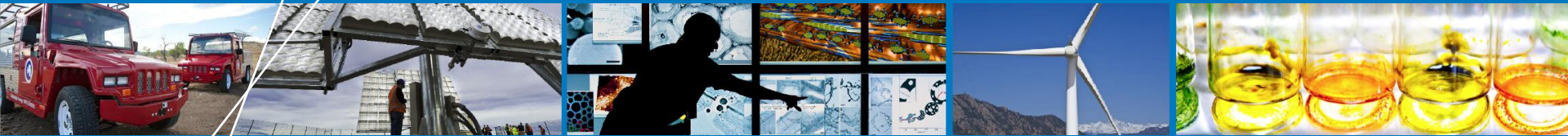


# Regulatory and Commercial Barriers to Introduction of Renewable Super Premium



**Robert L. McCormick**

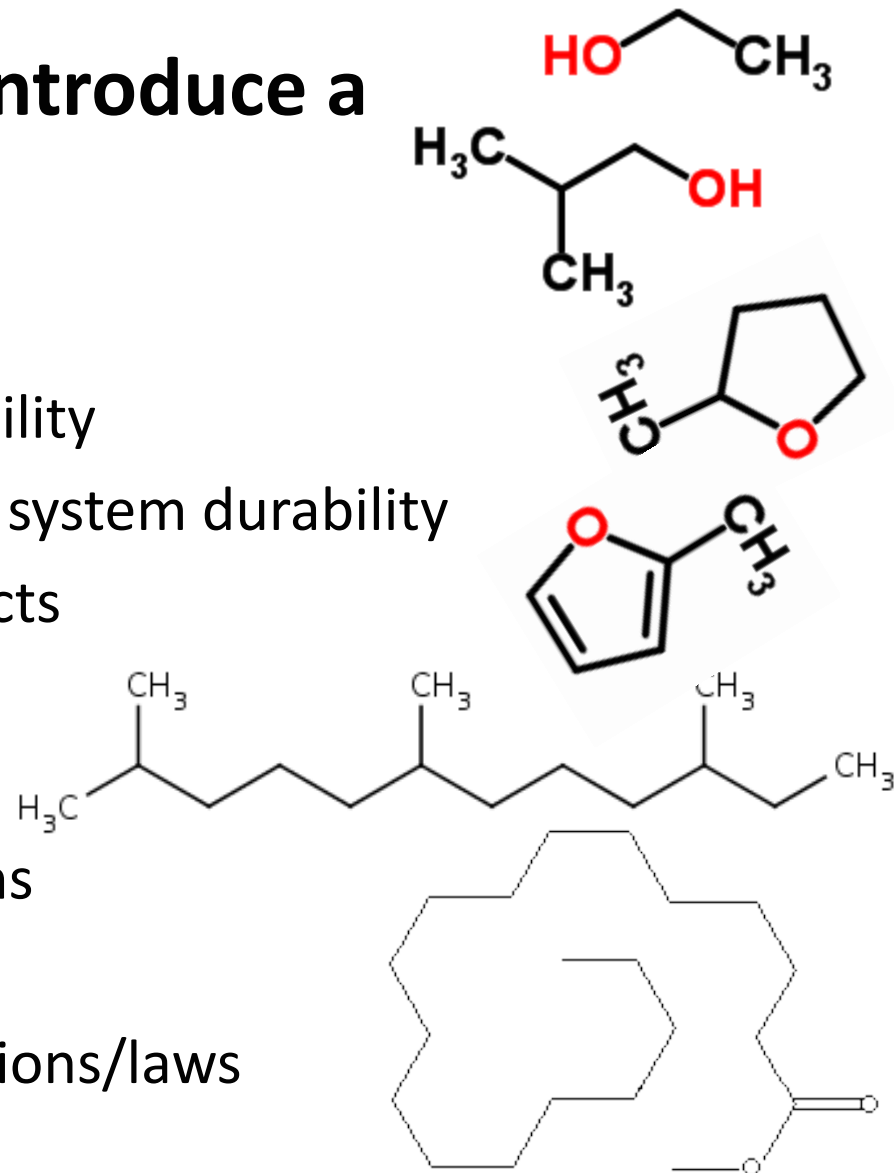
***Biomass 2013***

**July 31 - August 1, 2013**

**Washington DC**

# Introducing New Fuels

- Many steps and years to introduce a new fuel
- Impact on:
  - Vehicle performance and durability
  - Emissions and emission control system durability
  - Toxic emissions and health effects
  - Infrastructure compatibility
  - Fuel quality standards
  - Fire codes and safety regulations
  - Consumer protection laws
  - Federal, state, and local regulations/laws



# Infrastructure-Underground Storage Equipment

- EPA's Office of Underground Storage Tanks (OUST)
  - 40 CFR Part 280 requires UST must be compatible with fuel stored
- OUST Issued "Guidance - Compatibility Of UST Systems With Biofuel Blends" in July 2011
- Existing equipment considered compliant with E10 and B20
- For higher blend levels, two paths to compliance:
  - Components are listed by an independent testing laboratory for use with the fuel stored
  - Components approved by the manufacturer to be compatible with the fuel stored
  - Steel tanks generally compatible with any ethanol blend
  - Fiberglass tanks generally compatible after 1990



# Infrastructure-Other Equipment

- OSHA requires third-party listing of dispenser, nozzle, and breakaway for specific fuel
- Local fire marshal may also require third party listing
- UL lists above-ground equipment for various fuels
- *All necessary equipment including shear valves, hanging hardware, and dispensers are available with UL approval up to E85*



# Fuel Quality Standards

- **Consensus commercial standards developed by ASTM members**
  - Anyone can join ASTM
  - But typically fuel producers and distributors, engine/car makers, state fuel regulators, other interested parties
- **New standard potentially required for renewable super premium**
- **Standard will focus on properties required to enable much more efficient engines**
  - But also include a range of other performance requirements, similar to D4814 and D5798

# Approaches to Increasing Engine Efficiency

- **Turbocharging**

- Recovering energy from the engine exhaust
- Required for engine downsizing

- **Engine down-sizing and down-speeding**

- Smaller engines operating at low-speed and higher load are more efficient
- Optimized with 6 to 9 speed transmission

- **Increased compression ratio**

- Greater thermodynamic efficiency

- **Direct injection**

- Fuel evaporates in the combustion cylinder, cooling the air-fuel mixture
- Also required for engine downsizing

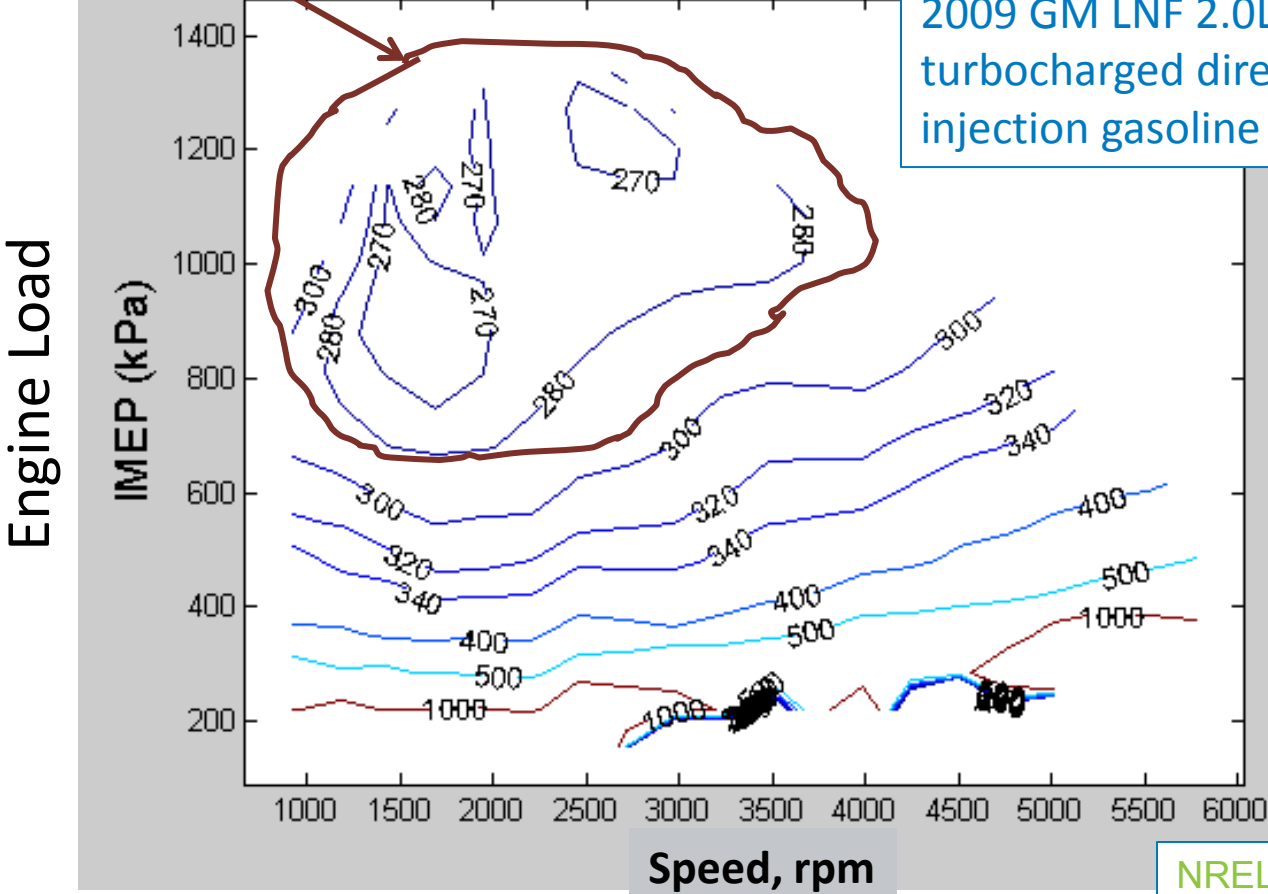
# Engine Downsizing/Down-Speeding Fuel Demand

Most knock limited region – and highest fuel economy

Requires higher fuel knock resistance

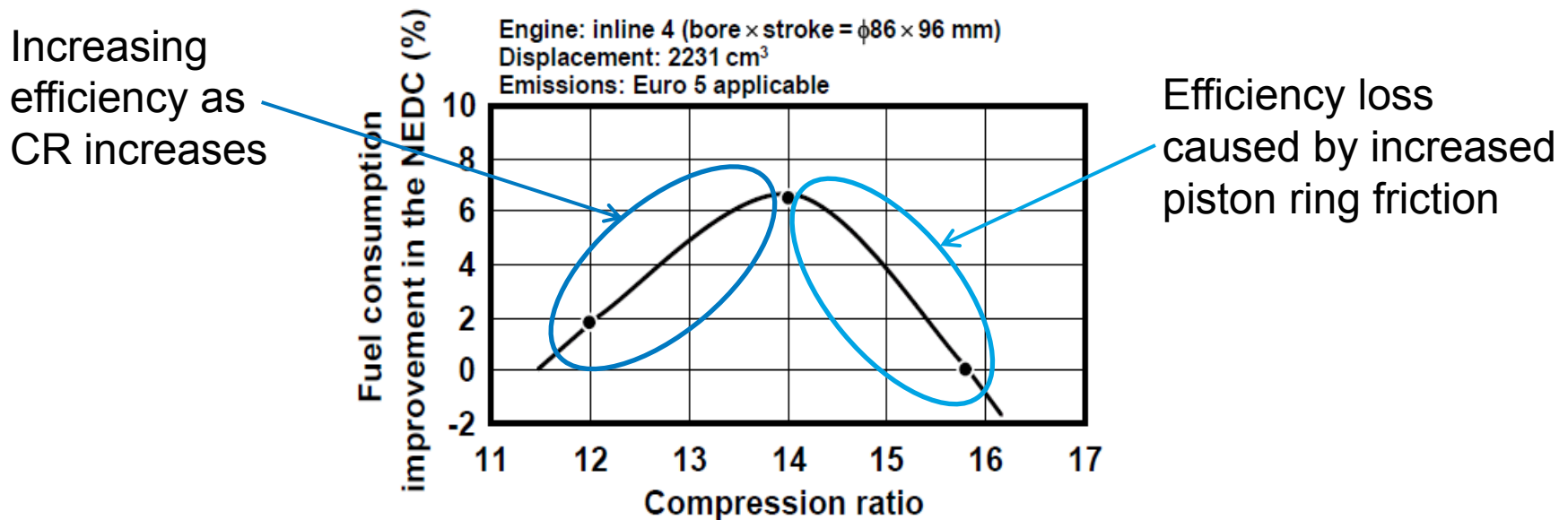
Contours are constant fuel consumption  
BSFC (g/kW-hr)

2009 GM LNF 2.0L turbocharged direct injection gasoline engine



NREL, unpublished data

# Effect of Increasing Compression Ratio



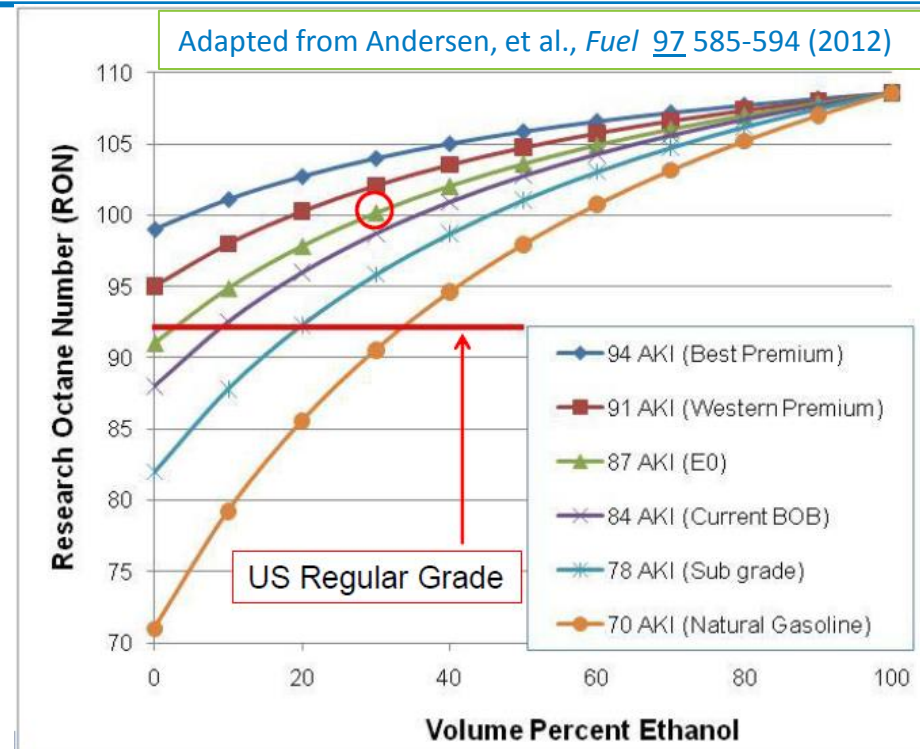
- Higher compression ratio yields higher temperature and pressure; and hence higher efficiency
- Requires higher fuel knock resistance
- An optimal CR exists (typically in the teens) and depends on other engine design features (primarily piston bore size)
- Current engine CR about 10 or lower

Toyota, Aachen Colloquium October 2010



# Octane Number and Engine Knock

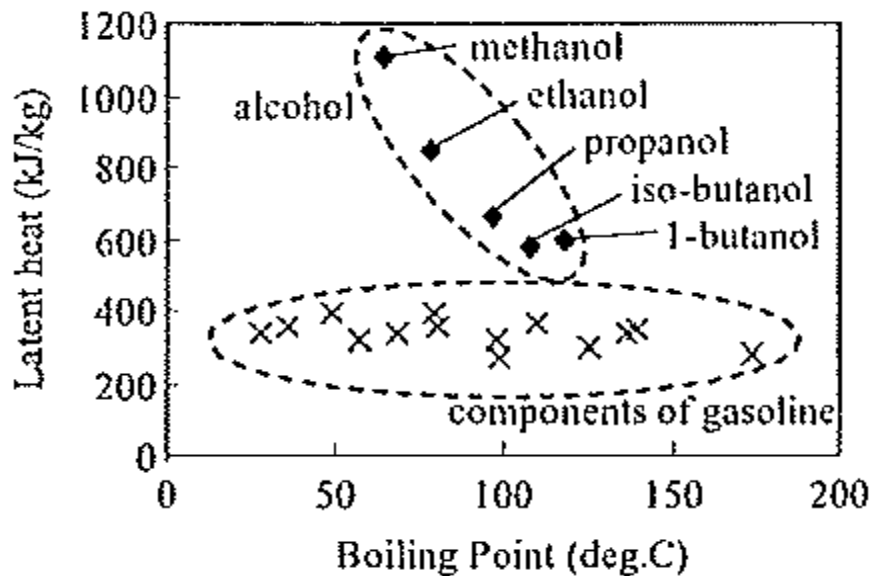
- ON is a measure of resistance to autoignition caused by high temperature and pressure
- Autoignition is knock and can damage the engine
- Higher ON is required for higher CR, turbocharged engines
- Research Octane (RON) – cool and slow
  - Best predictor for small modern engines
- Motor Octane (MON) – hot and fast



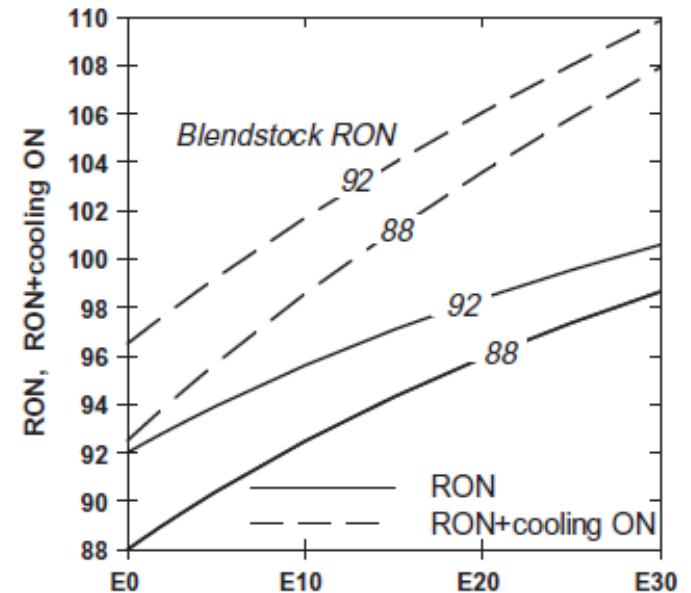
	RON	MON	AKI
Typical US Regular	92	83	87.5
Ethanol	109	90	99.5
Isobutanol	105	90	97.5
Iso-octane	100	100	100
n-Pentane	62	62	62
Toluene	118	104	111

# Heat of Vaporization Effect

- For direct injection engines fuel evaporation occurs in the cylinder – cooling the charge and reducing knock tendency
- Alcohols have significantly higher heat of vaporization
- Not captured by ON measurements



Nakata, et al. *Int. J. Engine Res.* 12 274-281 (2011)



Andersen, et al., *Fuel* 97 585-594 (2012)

# Summary Comment

- **Infrastructure**

- *Dispensers compatible with higher level ethanol blends are available, but not widely deployed*
- *Most storage tanks are compatible with high level ethanol blends (especially steel), but not all*

- **Quality standard**

- *Existing E51-83 standard (ASTM D5798) does not capture fuel properties that enable highly efficient engines*
- *A new standard may need to be developed that includes both the octane number and heat of vaporization effects on knock resistance – along with other fuel quality parameters*

# Acknowledgments

- **USDOE Bioenergy Technologies Office**
  - Alicia Lindauer and Chris Ramig
- **USDOE Vehicle Technologies Office**
  - Kevin Stork and Steve Przesmitzki
- **Brad Zigler and Kristi Moriarty at NREL**

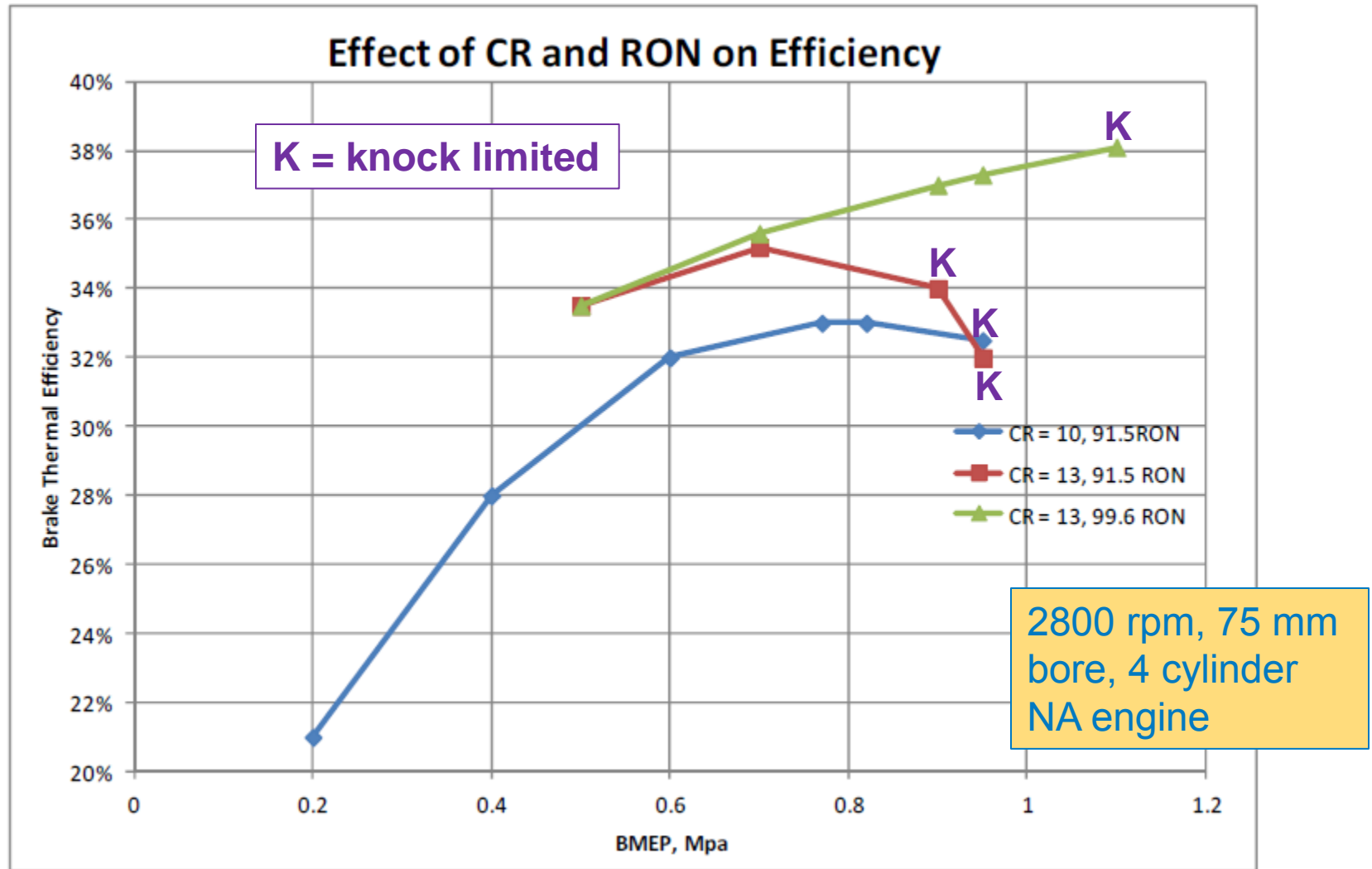
**Thank You!**

**robert.mccormick@nrel.gov**

# Tank Compatibility

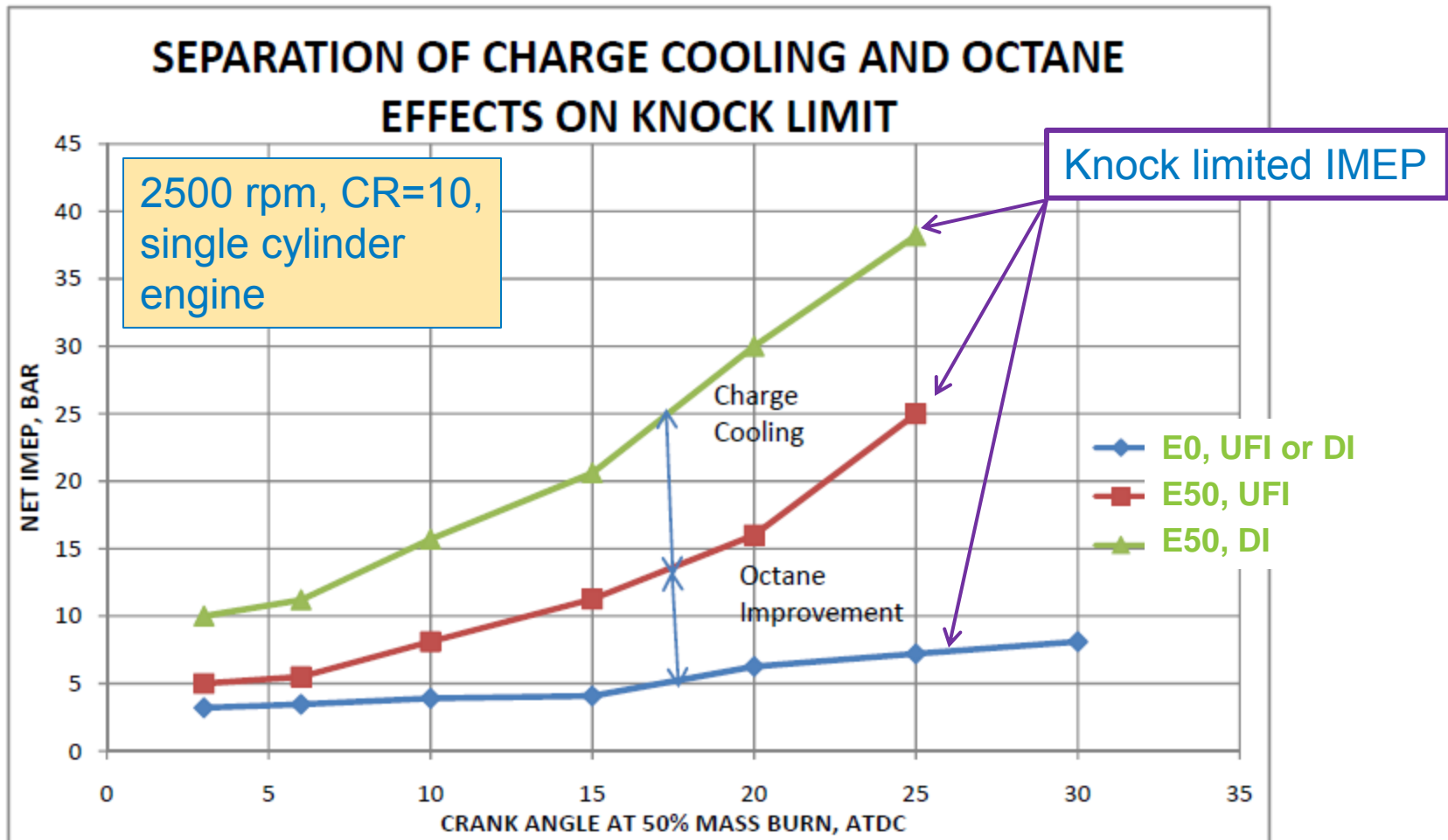
- **Steel Tank Institute has letters from 24 steel tank manufacturers stating compatibility with all ethanol (up to E100) and biodiesel blend (up to B100)**
- **Fiberglass Tank Compatibility:**
  - Owens Corning—single wall up to E10; double wall E10 (1965-7/1/1990) and E100 (7/2/1990-12/1994); no statement on biodiesel
  - Containment Solutions—all tanks all blends E0-E100; B0-B100
  - Xerxes—Tanks prior to 1981 not compatible with any blend; single wall E10 (2/81-7/2005) E100 (7/2005-present); double wall E10 (prior-4/1990) E100 (4/1990-present); all tanks all years for B0-B100
- **Statements of compatibility from associated equipment manufacturers: Ameron, Bravo, Brugg Pipesystems, Morrison Bros., National Environmental Fiberglass, NOV Fiber Glass Systems, Nupi Americas, Omegaflex, Plasteel, Vaporless Manufacturing, and Western Fiberglass**
- **Steel Tank Institute Letters Stating Compatibility:**  
<http://www.steeltank.com/Publications/E85BioDieselandAlternativeFuels/ManufacturerStatementsofCompatibility/tabid/468/Default.aspx>
- **Petroleum Equipment Institute Letters Stating Compatibility:**  
<http://www.pei.org/PublicationsResources/ComplianceFunding/USTComponentCompatibilityLibrary/tabid/882/Default.aspx>

# Efficiency Benefits of Increased CR and RON



CRC Project No. CM-137-11-1b [www.crao.org](http://www.crao.org) after Nakata et al., SAE 2007-01-2007

# Ethanol has High “Effective” RON



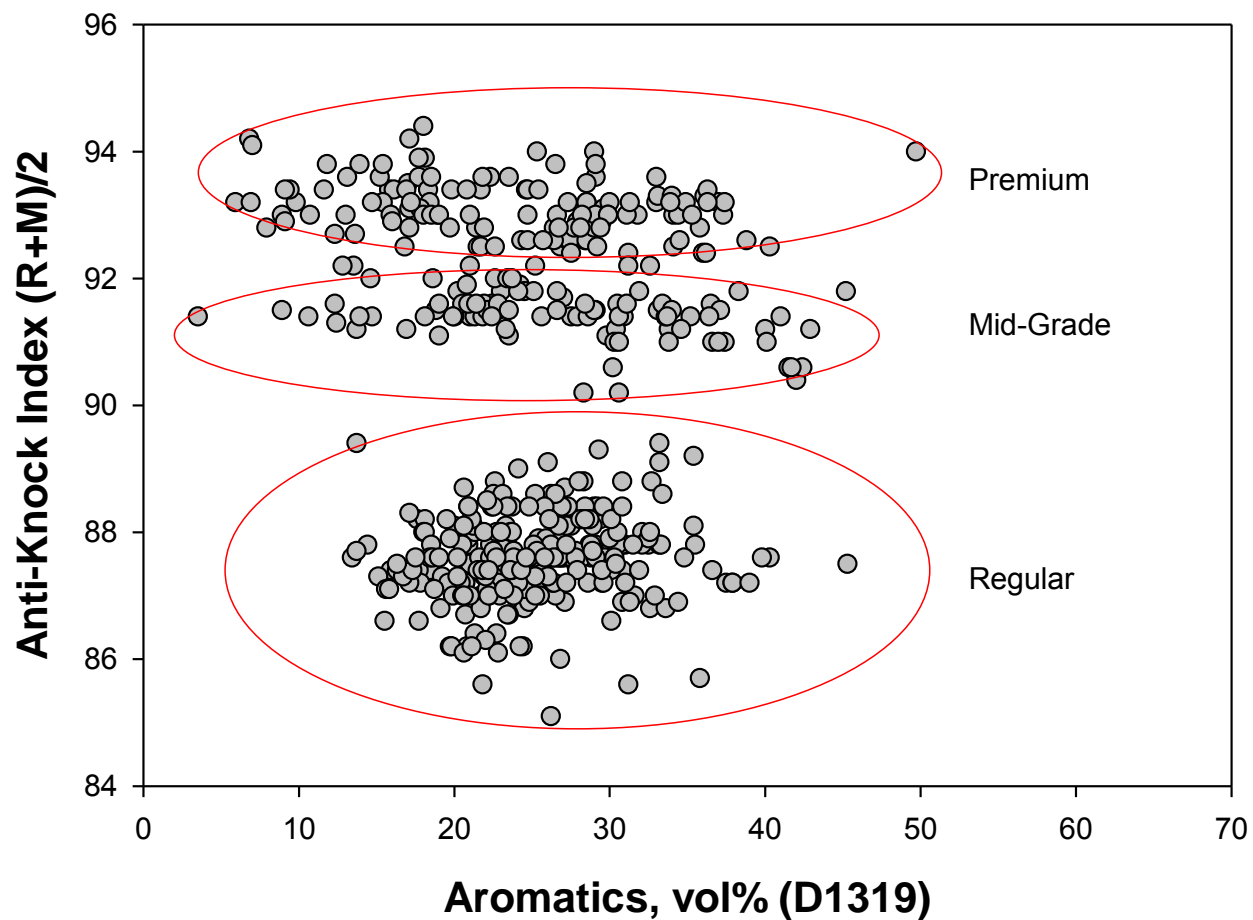
CRC Project No. CM-137-11-1b [www.crcao.org](http://www.crcao.org) after Stein, et al. SAE 2012-01-1277

# Other Issues

- **State consumer protection laws**
  - May adopt a version of ASTM standards
  - National Conference of Weights and Measures (NCWM) develops model laws and regulations on fuel quality (NIST HB 130)
  - State laws may forbid use of fuels other than those adopted
- **OEM warranty coverage**
  - Warranties cover defects in materials and workmanship – not problems caused by fuel
  - OEM will not cover fuel problems but typically will say what fuels are acceptable in owner's manual – a marketing advantage
  - Actual voiding of a warranty is a violation of federal law
- **National Fire Protection Association (NFPA) 30 & 30A**
  - May need to be updated to include new fuel
  - Updated every 3 years
- **Renewable Fuels Standard pathway definition**



# Aromatics and AKI of US Gasoline



Data from AAM summer 2011 US gasoline survey