Regulatory and Commercial Barriers to Introduction of Renewable Super Premium

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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


- 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

Engine Load

IMEP (kPa)

Speed, rpm
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

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<th></th>
<th>RON</th>
<th>MON</th>
<th>AKI</th>
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<td>83</td>
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Adapted from Andersen, et al., *Fuel* 97 585-594 (2012)
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

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
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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.


Efficiency Benefits of Increased CR and RON

K = knock limited

2800 rpm, 75 mm bore, 4 cylinder NA engine

Ethanol has High “Effective” RON

2500 rpm, CR=10, single cylinder engine

Knock limited IMEP

CRC Project No. CM-137-11-1b 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