Why Fuel Quality Standards are Important
Agenda

• Consensus Organizations Set Fuel Standards

• Fuel Standards Generally Ensure Good Fuel Quality:
  – Some Exceptions – “What’s Not in the Specs”

• Fuel Standards Ensure Fuel is Safe, Legal and Fit for Use
  – Some Exceptions to Fit for Use -- Contaminants, etc.

• Biofuel Challenges

• Good Fuel Housekeeping/Workmanship

• Fuel Additive Basics – Where Are They Applied & Are They Really Needed?

• Where Fuel Specs Apply

• Fuel Standards Need to be Living Documents:
  – Must change as Engine Technology Improves
Consensus Organizations Set Fuel Standards

• Organizations like ASTM International (formerly American Society of Testing Materials) set fuel specs:

• Usually have equal number of interest groups on committees (e.g. 100 Producers, 100 Users)

• Members work together to produce Fuel Specifications such as ASTM D975 (diesel fuel) and ASTM D4814 (gasoline)

• Standard Test Methods (STM’s) ensure that samples are tested for properties in the same way (D2068 STM for Determining Filter Blocking Tendency);

• A majority has to agree on proposals for new or improved specifications or STM’s, though all concerns or disagreements are heard and thoroughly discussed. It can take a long time (sometimes years) to reach consensus!

• Other Fuel Standard Setting Organizations Exist Globally (e.g. ISO, BSI, etc.) whose specifications may differ from ASTM
Global Fuel Specs Differ

<table>
<thead>
<tr>
<th>Property</th>
<th>US</th>
<th>EU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cetane number, min.</td>
<td>40</td>
<td>51</td>
</tr>
<tr>
<td>Sulfur content, ppm (μg/g) or mg/kg</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Conductivity, pS/m or CU min.</td>
<td>25</td>
<td>none</td>
</tr>
<tr>
<td>Water content, % vol, max and mg/kg</td>
<td>0.05*</td>
<td>200</td>
</tr>
<tr>
<td>Total contamination, mg/kg max.</td>
<td>none</td>
<td>24</td>
</tr>
<tr>
<td>Copper strip corrosion (3 hours at 50 °C), rating</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Oxidation Stability @ 95°C for 16 hr, g/m³, max.</td>
<td>none</td>
<td>25</td>
</tr>
<tr>
<td>Rancimat Oxidation Stability, 110°C, min. hrs.</td>
<td>none</td>
<td>20</td>
</tr>
<tr>
<td>Lubricity, wear scar diameter, μm, max. at 60 °C</td>
<td>520</td>
<td>460</td>
</tr>
<tr>
<td>Fatty acid methyl ester content, vol.%</td>
<td>5</td>
<td>7</td>
</tr>
</tbody>
</table>

* Total Water & Sediment
Fuel Standards Ensure Good Fuel Quality

• Having consensus agreement guarantees (mostly) that acceptable fuel is produced for the consumer

• Emissions regulations drive engine technology improvements which dictate needed fuel properties (sometimes changing fuel specs):
  
  — Diesel sulfur lowered from 500 to 15 ppm S in 2006
    
    • Much lower sulfur causes fuel to be less lubricious – lubricity specification needed. ASTM enacted fuel lubricity requirement.
  
  — High Pressure Common Rail (HPCR) diesel engines require cleaner, stable fuel (like “pressure cookers for fuel”)

Fuel Standards Ensure Good Fuel Quality

• Producing new, cleaner burning, lower emissions fuels doesn’t always guarantee suitability for today’s ultra sensitive and highly efficient engine systems.

• Changing to ULSD (Ultra Low Sulfur Diesel) significantly changed fuel’s componentry – generally lessening the fuel’s solvency:
  – Had a significant impact on solids formation
  – Peroxide formation is more of a problem
  – Wax precursors and solids propagators more pronounced

• What does all this mean? Generally, there may be more particulate and sediment in ULSD compared to LSD
# ULSD Changes – Impact On Water & Biological Problems

<table>
<thead>
<tr>
<th>Changes in ULSD</th>
<th>Impact on Microbial Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>↓ Sulfur reduction 500 to &lt;15 ppm</td>
<td>↑ Sulfur antagonistic to microbial growth*</td>
</tr>
<tr>
<td>↓ Aromatic and phenolic compounds</td>
<td>↑ Aromatic and phenolic compounds are good growth inhibitors</td>
</tr>
<tr>
<td>↑ Saturates</td>
<td>↑ Saturates preferred food source compared to aromatics</td>
</tr>
<tr>
<td>↑ Water (free, non-dissolved)</td>
<td>↑ Free water availability increases</td>
</tr>
</tbody>
</table>

*some debate about this
Fuel Specifications Mostly Ensure Good Fuel Quality – What’s Not in the Specs

• Lack of improved fuel specs may not adequately address water and contaminants that may lead to fuel storage, dispensing, and vehicle engine problems:
  – No real water spec – BS&W (Bottoms, Sediment & Water) spec (500 ppm) not stringent enough;
  – Too much water is bad and can lead to increased bug problems, corrosion – also holds contaminants that lead to engine filter/injector deposits
  – NACE corrosion – typically only measured at refinery – tends to degrade as fuel moves downstream – usually unknown at end user;
  – Particulate/sediment – no real gravimetric or particle size distribution requirement (other than BS&W). OEM’s prefer low PSD for HPCR.
Fuel Specifications – Fuel Must Be “Fit for Use”

• D975 and D4814 “specs” are minimums – and may on occasion be insufficient for good performance;

• All fuel tends to degrade in storage (this is normal) – degradation causes some fuel contaminants. Use of stability additive slows the degradation process;

• Water is fuel’s enemy and must be managed – it carries contaminants that can lead to bug problems and corrosion; fuel filter and injector deposit issues.

• Both gasoline and diesel fuel must be safe to use, meet legal specifications and be “fit for use”
Biofuels – New Challenges to Good Fuel Quality

The inclusion of biofuels -- both ethanol in gasoline and biodiesel in diesel fuel has generally been good for the industry:

- Lessens US demand on foreign oil
- Supports US farmers
- Mostly enhances blended fuel properties:
  - Biodiesel – higher cetane, lubricity, generally improves emissions
  - Ethanol – increased octane, substitutes hazardous lead and MTBE, generally improves emissions

With the addition of bio components comes new challenges with water management and increased filter change-outs though:

- Biodiesel holds more water;
- Too much water in ethanol blends can lead to phase separation.
- Both bio components can have a tank cleaning effect.
Good Fuel Housekeeping & Workmanship -- Leads to Good Fuel Quality

Simple steps can lead to improved fuel quality:

– Manage water -- remove tank bottoms routinely
– Keep water out of biofuels, especially ethanol blends

– Routine Fuel Sample Testing:

  • Bug testing -- prevents biological growth, helps control downstream problems;
    – Proper biocide addition kills bugs and prevents corrosive acids from forming;

  • Corrosion testing -- protection diminishes as fuel travels downstream;

– Consider use of anti-foulant additive to prevent filter and injector plugging
Reasons for Using Fuel Additives

• Fuel quality varies widely but can be improved through additive use:
  – Brings fuel into specification (low cetane, etc.)
  – Corrects deficiencies (poor storage stability, etc.)
  – Safety concerns (conductivity, etc.)
  – Asset protection (corrosion inhibitors, etc.)
    • Poor lubricity, biological degradation/corrosion, etc.
  – HPFI engine deposit problems (stabilizers, detergents, etc.)

• Unfortunately, diesel fuel is generally made to minimum ASTM D975 specifications and may occasionally not be fit for use – additives can help bridge this gap.
Fuel Additives – Are They Necessary?

Gasoline and diesel fuel contain many additives essential for good fuel quality and necessary for good fuel stability and performance:

- Stability additives -- prolongs fuel life, limits oxidation/degradation and metal interaction reactions;
- Corrosion inhibitors -- protects metal in fuel systems;
- Conductivity improvers – lessens static electricity, prevents fires/explosions;
- Lubricity improvers – provides needed lubrication in diesel injection systems;
- Biocides – preventive use minimizes bugs which may lead to corrosion;
- Anti-foulant additives – counteract fuel degradation & contaminant inter-actions that lead to filter/injector plugging
Where Are Fuel Additives Applied?

<table>
<thead>
<tr>
<th></th>
<th>Refinery</th>
<th>Pipeline/Terminal</th>
<th>Fleet/Distributor/Jobbers/Aftermarket/End User</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biocides</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cetane Improvers</td>
<td></td>
<td></td>
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<tr>
<td>Cold Flow Improvers</td>
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<td></td>
<td></td>
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<tr>
<td>Conductivity Improver</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Corrosion Inhibitors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gasoline/Diesel Detergents</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>De-icers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stabilizers/Dispersants</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Lubricity Improvers</td>
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<td></td>
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<tr>
<td>Marker Dyes</td>
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<td></td>
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</tr>
<tr>
<td>Demulsifiers and Dehazers</td>
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<td></td>
<td></td>
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<tr>
<td>Metal Deactivators</td>
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</tbody>
</table>
Where Fuel Specs Apply

Most ASTM fuel motor fuel (gasoline and diesel) specs apply at the point of manufacture – refineries generally have to meet pipeline or exchange partner specs:

- NACE corrosion spec of B+ or better for pipelines;
- Most other specs listed in D975 or D4814 tables;
  - Flash point, distillation, sulfur, etc.
- Some specs apply at terminals or as delivered to end users
  - lubricity, conductivity
- There is growing belief that all specs should apply at the end user level.
Fuel Specifications Need to be Living Documents

• Significantly lowering sulfur content of both gasoline and diesel fuel along with inclusion of fuel ethanol and biodiesel highlight the need for improved fuel specs:
  – Many of today’s specs were set for older engine technologies;
    • Standard octane/cetane test engines are single cylinder with 50+ year old technology;
    • Stability tests such as D525, D2274, D6468 may no longer be applicable
  – New engine technologies (like diesel HPCR – High Pressure Common Rail) demand almost particulate and water-free, stable fuel;
  – Good fuel corrosion from the refinery to the end user would likely lessen distribution system and vehicle corrosion problems

• ASTM and other fuel standard setting bodies will continue to work towards making fuel specifications better,
  – Concerned parties should get involved and voice their concerns!