TOP TIER™ Program

40th API Automotive/Petroleum Industry Forum

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General Motors
TOP TIER™ Detergency Gasoline Program

OEMs, working with Fuel Marketers, create a voluntary program to address global fuel detergency needs without mandatory regulation changes -

Program Start: April 2004
United States and Canada
Nine auto company sponsors:

US Required Treat Rate
100 hrs.
ASTM D6201

TOP TIER gasoline Treat Rate
100 hrs.
ASTM D6201
The Need for a Detergent Gasoline Program

Gasoline with the U.S. mandated minimum deposit control additive produced higher valve deposits than the same fuel containing no additive in ASTM D6201 Valve Deposit Tests.

100 hr. Keep Clean Cycle in ASTM D6201
(Ford 2.3L Dyno Engine Test)

Increasing Detergency Concentration
Decline in U.S. Detergency Treat Rates

Unwashed Gum - USA
mg/100mL
Regular unleaded gasoline

Start of TOP TIER

LAC Rule
What are Engine Deposits?

**Carbon build-up** is a generic term used to describe the dark sticky or hard deposits that form on internal engine components. They are byproducts of combustion and will accumulate at different rates based on factors such as fuel quality and detergency.
Symptoms of Engine Deposits

Drivability Concerns

- Rough Idle
- Long crank or No Start
- Engine Misfire
- Engine hesitation/less power
- MIL Light

Engine Damage

- Sticking intake/exhaust valves
- Fouled spark plugs
- Valve damage
- Compression loss

Causes

- Fuel injector spray clogging
- Unburned/unvaporized fuel
- Loss of sealing
- Increased effective compression ratio (material build up)
TOP TIER™ Detergent Gasoline Performance Standard
-requirements to finished fuel (post pipeline)

TOP TIER™ Performance Standard
- Intake Valve Cleanliness –modified ASTM D6201 engine dyno test
  - 500 mg/valve dirty up on base fuel no additive
  - 50 mg/valve avg. keep clean with base fuel + additive
- Additional No Harm Tests
  - Combustion chamber build up limit
  - Valve sticking test
- Independent ISO-17025 lab verification of test results

Prohibits “MMT” (Manganese organo-metallic fuel additive)
- Plugs catalysts
- Fouls spark plugs
- Damages oxygen sensors

Developing a DI Engine Performance Requirement

EPA allows TOP TIER test results in Tier 3 in place of LAC testing
TOP TIER™ Program Objectives

Customer is focus of the program
A fuel quality initiative to enable optimal vehicle performance

Motivation for Fuel Marketers
- Help in product differentiation, sales promotion, advertising and better brand recognition
- Higher customer satisfaction, prevent vehicle claims
- OEM recommends fuel – brings vehicle owners to station

Motivation for Automakers
- Restores vehicle performance from low quality gasoline
- Ensures long term vehicle performance for owners 1,2,3...
- Update program with evolving engine needs

OEMs partnering with fuel marketers to direct customers to a higher standard of fuel to enable optimal vehicle satisfaction.
Automakers recognize and recommend TOP TIER fuel to customers

TOP TIER recommended in 13 Million new US vehicle owner’s manuals in 2017

STARTING AND OPERATING  589

Designated TOP TIER Detergent Gasoline contains a higher level of detergents to further aide in minimizing engine and fuel system deposits. When available, the usage of Top Tier Detergent gasoline is recommended.

Visit www.toptiergas.com for a list of TOP TIER Detergent Gasoline Retailers.
• Assurance that current additive packages protect DI engines
• Additional to ASTM D6201 PFI Injector Valve test
• Evaluating most reliable metrics which correlate to injector build up, keep clean and clean up

DI Engine Test for TOP TIER Program

DI Injector Test Development Cycles

Graphic example not actual data
Global Evolving Engine Cleanliness Needs

Future emissions requirements
- SIDI injector deposit effects on emissions
- Vehicle emissions in-use is becoming a greater focus
- Deposits behave like sponges to trap fuel and release later

Vehicle Drivability with evolving requirements
- Issues anticipated from deposits as emissions and fuel economy regulations demand lean operation

Low Speed Pre Ignition (LSPI) research
- Research underway on Poor Fuel, Lubricants and Additives
TOP TIER Global Expansion

Central America: May 2017
• Panama, El Salvador, Guatemala, Honduras

Mexico
• First Mexico TOP TIER location opened August 2017

China Clean Fuel – NOT TOP TIER
Efforts by division of China gov’t in a detergency program in China.
• Some TOP TIER OEMs participation in region as sponsors
• TOP TIER team enthusiastic about CCF program – proper solution for China
Diesel quality has not kept up with diesel engine technology

- Modern engines require fuel to be extremely clean with acceptable properties for trouble free operation

Sponsorship to include Heavy Duty Equipment Manufacturers

Launched October 2017 and expansion outside US/Canada TBD

Performance Specification

- Oxidation Stability for Biodiesel
- Lubricity
- Detergency Requirement
- Water control
- Particulate filtration
- No Harms

Clogged Station Dispenser Filter
TOP TIER™ Diesel Fuel Standard

#1. Injector Deposits
Deposit control additive
DW10B and DW10C

#2. Lubricity
460 micron max.

#3. Fuel stability
Biodiesel Rancimat: 8 hr. B100 or 24 hr. > B5
Base Fuel PetroOxy > 60 min. B0

#4. Water and particulate
10 micron H₂O absorbing filter at dispenser

Detailed standard can be found at toptiergas.com
Need for Higher Standard in Diesel Fuel

Customer satisfaction is key for all OEMs and include:

- Power
- Maximum fuel efficiency
- Minimum downtime and maintenance cost

Emissions standards are driving major changes to the vehicle

- Requires very precise control of the fuel combustion process

Fuel Quality is key to meeting customer and regulatory requirements

- Proper fuel chemistry can prevent corrosive acids, peroxides, gums or deposits
- Fuel must be extremely clean to avoid damage to the fuel system components
- Current ASTM standards do not address all fuel quality problems
- Fuel related customer concerns are near top of warranty claims
Summary

Global detergency
- Customers responding to fuel quality recognition
- OEMs interest in higher standards for fuel quality regionally

Evolving engines and additives role in solutions
- SIDI engines – need for updated detergency spec.
- Additives role in PM, SPI, RDE

Diesel TOP TIER™ program:
- Housekeeping practices – inconsistent and not standard
- Minimum standards approach is not adequate
  - Fuel issues prevalent in field and out of spec fuel found
- Monitoring and enforcement to ensure quality
- Need distinction of brands to stand up for diesel fuel quality
Thank you!

www.TopTierGas.com
TOP TIER™ Diesel Performance Standard

Fuel must meet relevant country/regional standards (e.g., ASTM D975 or ASTM D7467) and these additional requirements:

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxidation Stability (Rancimat IP method)</td>
<td>EN15751 (Rancimat IP method)</td>
<td>&gt;8 hours for B100 as blend component OR</td>
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<tr>
<td></td>
<td></td>
<td>&gt;24 hours for up to B5 Biodiesel blend at retail OR</td>
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<tr>
<td></td>
<td></td>
<td>&gt;20 hours on &gt; B5 the biodiesel blends at retail</td>
</tr>
<tr>
<td></td>
<td>ASTM D7545 (PetroOxy Test)</td>
<td>&gt; 60 minutes for B0 fuel</td>
</tr>
<tr>
<td>Lubricity</td>
<td>ASTM D6079</td>
<td>460 micron max</td>
</tr>
<tr>
<td>Detergency -Injector Cleanliness</td>
<td>DW-10B (CEC F-98-08)</td>
<td>&lt; 2% power loss</td>
</tr>
<tr>
<td></td>
<td>DW-10C (CEC F-110-16) –Place holder until approved by CEC</td>
<td>Rating of &gt; 9 on Demerits Scale</td>
</tr>
<tr>
<td></td>
<td>Qualified engine/vehicle test from fuel marketer or additive company to demonstrate performance for clean up of IDID deposits</td>
<td>Results on the qualified test as approved by OEM sponsors</td>
</tr>
<tr>
<td>Water</td>
<td>Refueling Station Housekeeping</td>
<td>Water detection media filter or approved water detection process</td>
</tr>
<tr>
<td></td>
<td>ASTM D6304</td>
<td>To be monitored during audits</td>
</tr>
<tr>
<td>Particulate Contamination, Size Distribution</td>
<td>Retailer dispenser filter</td>
<td>&lt; 10 microns absolute for low speed pumps (30 micron accepted for high flow)</td>
</tr>
<tr>
<td></td>
<td>ISO 4406</td>
<td>To be monitored during audits</td>
</tr>
</tbody>
</table>

NOTE: Additive package will also have to pass ‘no-harms’ testing.
Examples of Fuel Quality Concerns on Vehicle

“Ball Seat Erosion” Example

Fuel control valve

Biodiesel related Deposits

Clogged fuel filter due to biodiesel deposits

Water related corrosion

Source: General Motors
Bulk Tank Issues Experienced in the Field

- Vent Line Contamination
- Plugged Dispenser Filter
- Corroded Tanks
- Rusted Pump Head (in-vapor space)
- Failed Veeder Root
- H2O in Bulk Tank

Contamination from Vendor:
- 2% Bio
- H2O + Ethylene Glycol
- Water + Sediment
- Bugs + 10k ppm Sulfur

Source: Detroit Diesel Corporation