

## **Truck and Engine Manufacturers Association**

### **Alternative Fuel Properties for Compression Ignition Engines**

Fuel is the energy source utilized by engines to generate power. Using the compression ignition process, diesel engines convert a fuel's chemical energy to mechanical energy to propel vehicles or equipment, move materials, and conduct other forms of work. Historically, petroleum-derived fuels provided the exclusive source of power for compression-ignition engines. In recent years, alternative fuels, *i.e.*, liquid fuels derived from sources other than petroleum, have been introduced in the marketplace for use in compression-ignition engines. For an alternative fuel to be acceptable for use in a compression-ignition engine, it not only must provide the energy required to power the engine, it also must also meet certain performance, durability, operability, and emission requirements.

Standard-setting organizations, specifically ASTM International (ASTM D975), in North America, and the European Committee for Standardization (CEN EN590), in Europe, have adopted industry standards for diesel fuel. Yet, the ASTM and CEN standards were developed on the assumption that acceptable diesel fuel for use in compression-ignition engines would be derived from petroleum, and that the refining process would result in a fuel that provided certain performance properties naturally even if they were not specified in the standard. Thus, standards that were developed with the intent of applying only to petroleum-based fuels do not specifically include parameters to cover those certain properties that occur naturally in those fuels. As such, those standards are not adequate for evaluating, and cannot generally be relied upon in evaluating, the use of alternative fuels that do not contain the same performance properties as petroleum-based fuels. Although industry standards have been developed for certain alternative fuels (or blend stocks) used in compression-ignition engines (e.g., ASTM D6751 and EN 14214 for biodiesel and EN 15940 for renewable hydrocarbon diesel), those standards do not apply universally to all alternative fuels.

This document identifies fuel properties and test procedures that the Truck and Engine Manufacturers Association and its members consider important in evaluating whether an alternative fuel will be acceptable for use in a manufacturer's engines and vehicles. In addition, it is intended to serve as a starting point for industry to develop consensus standards for alternative fuels.

For example, Table 1, herein, lists alternative fuel properties that engine and vehicle manufacturers assess in terms of their impact on the following: combustion; power output; safety; durability/operability; compatibility; emissions; and storage/handling/cold flow. Table 2 identifies trace contaminants that may be derived from the materials processed to make the alternative fuel, the production process, or the distribution process required to move the fuel from the production site to the end user. Fuel providers are encouraged to work with engine and vehicle manufacturers to determine the acceptability of an alternative fuel in a given manufacturer's engine or vehicle.

**Table 1: Properties to be Reported**

Characteristic	Test Methods <sup>1</sup>	Impacted Performance
Cetane No.	D613 (D6890, D7170), ISO 5165, JIS K 2280	<b>Combustion</b> (soot formation, volume expansion, spray characteristics, temp of combustion, etc.)
Cetane Index	D4737, D976, ISO 4264, JIS K 2280	
Derived Cetane Number	D6890, D7170, D7668, ISO 498, EN 15195	
Aromatics, total (% m/m)	D5186	
Distillation profile (full)	D86, D2887	
Bulk Modulus	D6793	
Specific heat (at 0, 20, 100 °C)	D2766/E2716	
Surface tension (at 20 °C)	D1331/D971	
Hydrocarbon composition (paraffins/olefins, diolefins/aromatics)	GC	<b>Power Output</b> (energy content, chemistry, etc.)
Heating value by mass	D240/D4809	
Heating value by volume	D4810	
Density (at 15 and 25 °C) (kg/m <sup>3</sup> )	D876, D4052, D1298, D287, ISO 3675, 12185, JIS K 2249	
Flash point (°C)	D93, D56	<b>Safety</b>
Contaminants (methanol/ethanol), (% v/v)	D4815 (modified)	
Electrical Conductivity	D2624/D4308	
Ramsbottom carbon residue on 10% distillation residue	D524	<b>Durability/operability</b> (stability, emissions compatibility, wear and corrosion resistance, etc.)
High temperature stability	D6468	
Fuel Thermal Stability, Carbon Residue, (% m/m)	D4530, ISO 10370, JIS K 2270	
Fuel Oxidative Stability		
Method 1, (g/m <sup>3</sup> )	D2274, ISO 12205	
Method 2a (Rancimat, modified) (7), (hours)	EN 15751	
Method 2b (Delta TAN) (7), (mg KOH/g)	D664 & D2274 (modified)	
Method 2c (PetroOxy) (7), (Minutes)	EN 16091	
Total Acid number (mg KOH/g)	D664, ISO 6618	
Water and sediment	D2709	
Water content, (mg/kg)	D6304, ISO 12937, JIS K 2275	
Viscosity (at 0, 15 and 40 °C), (mm <sup>2</sup> /s)	D445, ISO 3104, JIS K 2283	
Lubricity (HFRR wear scar diameter @ 60°C), (micron)	D6079, ISO 12156-1.3	
Injector cleanliness (Method 1) % air flow loss	CEC-F-098-08 (DW-10), CEC-F-023-01 (XUD9)	
Injector cleanliness (Method 2) % power loss	Engine/injector tests	
Injector cleanliness – Injector Deposit Test	CEC-F-110-16 (DW10C)	
Filtration compatibility	D2068	
Appearance	D4176	

<sup>1</sup> The test methods included are intended to aid in the evaluation of the fuel properties. It should be noted, however, that some test methods must be modified for use with an alternative fuel, and not every property and every test method is critical in the evaluation of each alternative fuel.

Materials compatibility - non metallics		<b>Compatibility</b> (materials, switch loading, other fuels, lube oil, etc.)
Materials compatibility - metallics		
Fuel and lube oil compatibility	D4740	
Fuel and additives compatibility	D4054	
Miscibility with other fuels		
Corrosion - copper	D130, ISO 2160, JIS K 2513	
Corrosion - iron	D665 (Procedure A)	
Sulfur content, (mg/kg)	D5453, D2622, ISO 20846, ISO 20884, JIS K 2541	<b>Emissions</b> (compatibility with aftertreatment devices)
Trace metals/contaminants	(Refer to list below)	
Ash	D482	
Oxygen content		
Nitrogen content	D5291	
Storage stability (peroxides: 24, 48, 72 hours)	Filterability	<b>Storage and Handling, Cold Flow</b> (cold startability, shelf life, etc)
Storage stability (total insolubles)	D5304, D2274	
Microbial growth potential	D2500 & D4539	
Toxicity	D130 (Cu)	
Cloud point, (°C)	D2500,D5771,D5772,D5773, ISO 3015, JIS K 2269	
Pour point, (°C)	D97, D5949,D5950,D5985	
Cold Filter Plugging Point (CFPP), (°C)	D6371, JIS K 2288, EN 116	
Low Temperature Flow Test (LTFT), (°C)		

**Table 2: Trace contaminants**

<b>Contaminants</b>	<b>Units</b>	<b>Test Methods <sup>2</sup></b>
Solids	mg/l	D6217 (Biodiesel-free), D7321 (with Biodiesel)
Liquid	cc/l	D6304
Sulfur	ppmw	D2622, D5453, ISO 208846, ISO 20884, JIS K 2283
FBN	ppmw	D4629
Na+K	ppmw	D7111, EN 14538
Vanadium	ppmw	D7111
Lead	ppmw	D7111
Ca+Mg	ppmw	D7111, EN14538
Fluorine	ppmw	D1179
Chlorine	% wt.	D512
Mercury	ppmw	D7111
Cadmium	ppmw	D7111
Bismuth	ppmw	D7111
Arsenic	ppmw	D7111
Antimony	ppmw	D7111
Phosphorus	ppmw	D7111, D4951
Boron	ppmw	D7111
Gallium	ppmw	D7111
Indium	ppmw	D7111
Aluminum	ppmw	D7111
Silicon	ppmw	D7111
Ash content	% wt.	D482
Glycerol (free and total)	ppmw	D6584
Methanol	% wt.	EN 14110
Manganese	ppmw	D7111
Any raw material or process specific materials other than hydrocarbons		

Dated: February 2018

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