FUEL PROPERTIES TEST

1. Density (Specific Gravity)

Density (or specific gravity) is an indication of the density or weight per unit volume of the fuel. Density is an essential parameter. As the density increases, the energy content increases per unit volume. Given an unchanging injected quantity of fuel, the energy supplied to the engine increases with the density, which increases engine performance. However, the exhaust emissions and, especially, the particles increase under a full load due to the richer mixture. On the other hand, the volumetric fuel consumption increases as density decreases.

Two methods most commonly used to measure density are:

- *Standard Test Method for Density, Relative Density (Specific Gravity) or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method* : The sample is brought to the prescribed temperature and transferred to a cylinder at approximately the same temperature. The appropriate hydrometer is lowered into the sample and allowed to settle. After temperature equilibrium has been reached, the hydrometer scale is read, and the temperature of the sample is noted. If necessary, the cylinder and its contents may be placed in a constant temperature bath avoid excessive temperature variation during the test.
- *Standard Test Method for Density, Relative Density of Liquids by Digital Density Meter*: A small volume (approximately 0.7 mL) of liquid sample is introduced into an oscillating sample tube and the change in the mass of the tube is used in conjunction with calibration data to determine the density of the sample (3).

The densities of the fuels measure with Kyoto Electronics DA-130 type density meter. This density meter uses the resonant frequency method to measure the densities. With the density meter we can also measure the specific weight, API gravity, % Brix, volume and mass alcohol rates. The measurement interval of the device is 0 to 2 g/cm^3 and 0 to 40 ºC. The device has a sensitivity of ±0.001 g/cm^3, and a stability of 0.0001 g/cm^3. The device is measuring according to the standards of TS EN ISO 12185 (4).

2. Viscosity

To define kinematic viscosity it is useful to begin with the definition of viscosity. Simply stated, viscosity, which is also called dynamic viscosity (η), is the ease with which a fluid will flow. Technically it is the ratio of the shear stress to the shear rate for a fluid. In contrast, the kinematic viscosity (v) is the resistance to flow of a fluid under gravity (5).

Fuel viscosity is specified in the standard for diesel fuel within a fairly narrow range. Hydrocarbon fuels in the diesel boiling range easily meet this viscosity requirement. Most diesel fuel injection systems compress the fuel for injection using a simple piston and cylinder pump called the plunger and barrel. In order to develop the high pressures needed in modern injection systems, the clearances between the plunger and barrel are approximately one ten-thousandth of an inch. In spite of this small clearance, a substantial fraction of the fuel leaks past the plunger during compression. If fuel viscosity is low, the leakage will be enough to cause a significant power loss for the engine. If fuel viscosity is high, the injection pump will be unable to supply sufficient fuel to fill the pumping chamber. Again, the effect will be a loss in power.

Two methods most commonly used to measure viscosity are:

- Standard Test Method for Kinematic Viscosity : The time is measured for a fixed volume of liquid to flow under gravity through the capillary of a calibrated viscometer under a reproducible driving a head and at a closely controlled and known temperature. The kinematic viscosity is the product of the measured flow time and the calibration constant of the viscosimeter.
- The viscosities of the fuels measure with Saybolt Universal Viscosimeter produced from Ubbelohde tube with ASTM D 88 standards. The measurement results record in seconds. Then using a conversion table the results convert from SSU (Saybolt Universal Second) to centistokes (cst) unit. The measurements are done at 40 °C according to the TS 1451 EN ISO 3104 (3).

I. Tanaka AKV 202 type kinematic viscosity meter is used for The kinematic viscosity measurements during the tests which has a measurement range of 20-100 ºC.

3. Cetane Number

The first diesel engines were large and slow-speed and were not particularly sensitive to the quality of the fuel they burned. As steady improvements were made to the engine, there was a need to improve fuel quality as well. Gradually, the heavier, more viscous, diesel fuels disappeared with lighter and higher speed engines. The higher speed engines are more sensitive to the ignition quality of the fuel; therefore, cetane numbers became the property of greatest concern to both producers and users.

Cetane number is a measure of the fuel's ignition and combustion quality characteristics. The Cetane number measures how easily ignition occurs and the smoothness of combustion. Higher the cetane number results better its ignition properties. Cetane number affects a number of engine performance parameters like combustion, stability, drivability, white smoke, noise and emissions of carbon monoxide (CO) and hydrocarbons (HC). The cetane number is the primary specification measurement used to match fuels and engines. It is commonly used by refiners, marketers and engine manufacturers to describe diesel fuels.

Higher cetane number fuels tend to reduce combustion noise, increase engine efficiency, increase power output, start easier (especially at low temperatures), reduce exhaust smoke, and reduce exhaust odor (3).

The cetane numbers measure by Zeltex ZX440 type device, which works under the close infrared spectrometer (NIR) principal. With the help of this principal the cetane number measurement experiment became very fast and cheap with only 3% error compared to the time consuming expensive motor tests.

4. Octane number

The critical fuel property of gasoline for internal combustion engines is resistance to engine knocks, expressed as the octane number of the gasoline. During a normal (no knock) combustion cycle, a flame front travels smoothly from the point of ignition at the spark plug outward toward the cylinder walls. While this is occurring, the end gas, or unburned fuel/air mixture ahead of the flame front is heated and compressed. If the end gases ignite before the flame front arrives, the resulting sudden pressure wave reverberates across the combustion chamber, causing an audible engine knock. This adversely affects output power and dramatically increases heat transfer to the piston and other combustion chamber surfaces. While this can cause damage on its own if severe enough, knock induced preignition can cause rapid catastrophic engine failure. This tends to be a runaway condition. Once started, it gets progressively worse until eventual engine failure, unless the throttle/load is cut quickly, as failure can occur in less than a few minutes.

Research Octane Number (RON)

The research method settings represent typical high load (throttle open) and low to medium engine speeds resulting in low inlet mixture temperatures and moderate loads on the engine.

Motor Octane Number (MON)

The conditions of the Motor method represent severe, sustained high engine speed, high load (but no wide open throttle) driving (2).

Octane numbers measure by Zeltex ZX440 liquid fuel analyzer. It's measurement principle is based on Near Infra-Red (NIR) technology. Light energy that enters the sample is scattered and absorbed with in the sample, and directly displays the product's constituent concentrations. The picture octane number analyzer is given in figure 3. and some properties of equipment are outlined in table 1 (6).

Table 1. Properties of Octane Analyzer(6)

Optical Capabilities	
Spectrum Range	37 Filters covering wavelengths from 604 to 1045 nm
Scan Speed	Up to 10 scans per seconds
Optical Range	0 to 5 AU
Resolution	0.00001 AU
Stability	0.02 mili-AU
Measurement Modes	Diffuse transmittance
Measurement Time	Up to 30 seconds
Measurement Data	Log 1/T values, 1 to 37 primary wavelengths, 442 usable wavelengths
Sample Information	
Sample Size	200 ml with 75 mm wavelength
Sample Holder	Reusable glass with chemical seal cover
Measurement Range	From 0.05 to 99%.

5. Copper Strip Corrosion

The test method for copper strip corrosion is:

- *Standard Test Method for Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test*: A polished copper strip is immersed in a given quantity of sample and heated at a temperature and for a time characteristic of the material being tested. At the end of this period the copper strip is removed, washed, and compared with the ASTM Copper Strip Corrosion Standards.

The copper strip corrosion test covers the detection of the corrosiveness to copper of aviation gasoline, aviation turbine fuel, automotive gasoline, natural gasoline, or other hydrocarbons having a Reid vapor pressure no greater than 124 kPa (3).

Crude petroleum contains sulfur compounds, most of which are removed during refining. However, of the sulfur compounds remaining in the petroleum product, some can have a corroding action on varies metals and this corrosivity is not necessarily related directly to the total sulfur content. The copper strip corrosion test is designed to assess the relative degree of corrosivity of a petroleum product.

The corrosiveness of a fuel is measure using the copper strip corrosion test, which is TS 2741 EN ISO 2160. Copper and copper compounds tend to be particularly susceptible to chemical attack. The corrosivity of a fuel has implications on storage and use of the fuel. As an indicator of the tendency of a fuel to cause corrosion, polished copper strips are placed in the fuel for 3 hours at 50 °C. Then the strips wash in a solvent and compare to the descriptions in TS standard (5).

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FUEL PROPERTIES TEST

INTRODUCTION

Diesel Fuel

The word "diesel" is derived from the German inventor Rudolf Diesel who in 1892 invented the diesel engine. Diesel engines are a type of internal combustion engine. Rudolf Diesel originally designed the diesel engine to use coal dust as a fuel. He also experimented with various oils, including some vegetable oils, such as peanut oil, which was used to power the engines which he exhibited at the 1900 Paris Exposition and the 1911 World's Fair in Paris.

Diesel fuel in general is any liquid fuel used in diesel engines. The most common is a specific fractional distillate of petroleum fuel oil, but alternatives that are not derived from petroleum, such as biodiesel, biomass to liquid (BTL) or gas to liquid (GTL) diesel, are increasingly being developed and adopted. To distinguish these types, petroleum-derived diesel is increasingly called petrodiesel. Ultra-low sulfur diesel (ULSD) is a standard for defining diesel fuel with substantially lowered sulfur contents.

Petroleum diesel, also called petrodiesel, or fossil diesel is produced from the fractional distillation of crude oil between 200 °C and 350 °C at atmospheric pressure, resulting in a mixture of carbon chains that typically contain between 8 and 21 carbon atoms per molecule.

Diesel-powered cars generally have a better fuel economy than equivalent gasoline engines and produce less greenhouse gas emission. Their greater economy is due to the higher energy per-litre content of diesel fuel and the intrinsic efficiency of the diesel engine. While petrodiesel's higher density results in higher greenhouse gas emissions per litre compared to gasoline, the 20–40% better fuel economy achieved by modern diesel-engined automobiles offsets the higher per-litre emissions of greenhouse gases, and a diesel-powered vehicle emits 10-20 percent less greenhouse gas than comparable gasoline vehicles. Petroleum-derived diesel is composed of about 75% saturated hydrocarbons and 25% aromatic hydrocarbons. The average chemical formula for common diesel fuel is $C_{12}H_{23}$, ranging approximately from $C_{10}H_{20}$ to$C_{15}H_{28}$.

Gasoline

Gasoline or petrol isa petroleum-derived liquid mixture which is primarily used as a fuel in internal combustion engines. It is also used as a solvent, mainly known for its ability to dilute paints. It consists mostly of aliphatic hydrocarbons obtained by the fractional distillation of petroleum, enhanced with iso-octane or the aromatic hydrocarbons toluene and benzene to increase its octane rating. Small quantities of various additives are common,for purposes such as tuning engine performance or reducing harmful exhaust emissions. Some mixtures also contain significant quantities of ethanol as a partial alternative fuel.

Gasoline is produced in oil refineries. Material that is separated from crude oil via distillation, called virgin or straight-run gasoline, does not meet the required specifications for modern engines (in particular octane rating; see below), but will form part of the blend. The bulk of a typical gasoline consists of hydrocarbons with between 4 and 12 carbon atoms per molecule (commonly referred to asC_4-C_{12}).

Many of the hydrocarbons are considered hazardous substances and are regulated in the United States by the Occupational Safety and Health Administration. Thematerial safety data sheet for unleaded gasoline shows at least fifteen hazardous chemicals occurring in various amounts, including benzene (up to 5% by volume),toluene (up to 35% by volume), naphthalene (up to 1% by volume), trimethylbenzene (up to 7% by volume), Methyl *tert*-butyl ether(MTBE) (up to 18% by volume, in some states) and about ten others.

Discussed in this section will be some key fuel properties as well as the methods to measure these properties. The properties listed below will be specific gravity, kinematic viscosity, cetane number, octane number, flash point, heat value (calorimeter), cold behaviors (pour point, cloud point, cold filter plugging point), distillation, reid vapor pressure and micro carbon residue.

1. FlashPoint

The flash point is the lowest temperature at which a combustible mixture can be formed above the liquid fuel. It is dependent on both the lean flammability limit of the fuel as well as the vapor pressure of the fuel constituents. The flash point is determined by heating a sample of the fuel in a stirred container and passing a flame over the surface of the liquid. If the temperature is at or above the flash point, the vapor will ignite and an easily detectable flash can beobserved.

The flashing point parameter is used to limit the level of un-reacted alcohol remaining in the finished fuel. The flashing point also has an important connection with the legal requirements and safety precautions involved in fuel handling and storage.

Flash points measure with TS EN ISO 2719. Tanaka Automated Pensky-Martens Closed Cup Flash Point Tester is used for the flash point measurements during the tests which has a measurement range of 20-370 ^{o}C.

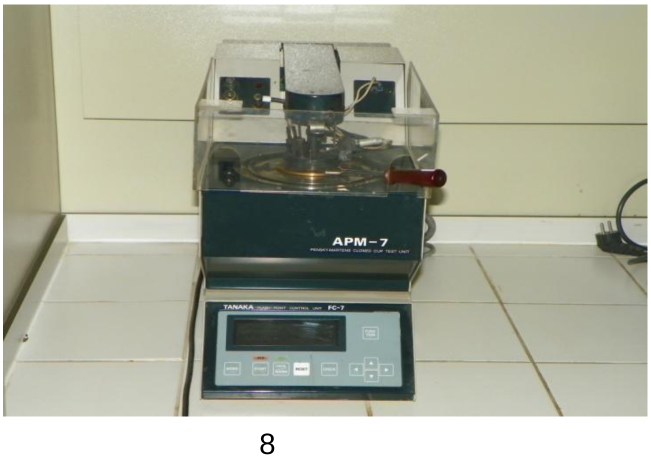

Figure 1. Tanaka APM-7

2. Micro carbon residue

The carbon residue is a measure of how much residual carbon remains after combustion. The test basically involves heating the fuel to a high temperature in the absence of oxygen. Most of the fuel will vaporize and be driven off, but a portion may decompose and pyrolyze to hard carbonaceous deposits. This is particularly important in diesel engines because of the possibility of carbon residues clogging the fuel injection. Micro carbon residue measures by Tanaka ACR M3 automatic micro carbon residue analyzer. The Tanaka ACR M3 automatic micro carbon residue analyzer is shown in figure2.

Figure 2. Tanaka ACR M3

3. Calorimeter

There are actually two heating values in common use, the higher, or gross, heating value and the lower, or net, heating value. Both quantities are measured using a calorimeter where the heat transfer from the hot gases resulting from combustion of the fuel with air is measured as the gases are cooled to the initial temperature of the reactants. The procedure is described in ASTM D 240. The higher heating value assumes that all of the water in the products is condensed liquid while the lower heating value assumes all of the water is present as vapor, even though the product temperature may be below the dew point temperature. The lower heating value is the most common value used for engine applications. It is used as an indicator of the energy content of the fuel.

The heat capacities of liquid fuels can be measured automatically with IKA-Werke C2000

calorimeter. The working temperatures are between +15 ºC to +35 ºC. The combustion is done with a cotton wire instead of a tungsten wire.

Figure 3. IKA-WERKE C2000 calorimeter

4. DistillationCharacteristics

Distillation characteristics measure by Tanaka AD-6 automatic distillation analyzer. The Tanaka AD-6 distillation analyzer is shown in figure 4. Some properties of equipment are outlaned in table 2.

Table 2. Properties of Distillation Analyzer

Temperature range	Selectable from RT to 300ºC/400ºC (fuel oil) or RT to 200ºC/400ºC
Temperature Meas.	Pt100 Probe
Meniscus Detection	By photoelectric devices with pulse motor
Distillation Rate	Selectable form 2.0 to 9.0 ml/min with 0.5 increment
Display	Monochrome LCD distillation curve and other test parameters, status, and trouble message displayed
Condenser Tube	Brass tube or stainless steel tube controlled at 0 to 70ºC by Peltier elements
Receiver Room	Controlled at 0 to 70ºC by Peltier elements
Safety Features	Heater shuts down at the upper end of scale (200/300/400ºC). Upon detecting fire by thermofuse, warning buzzer beeps, heater shuts down and fire containment system activates. The firecontainment system consists of a mechanical shutter and N_2 gas injector.

Figure 4. Tanaka AD-6

For Diesel

Properties	METHOD	TS– EN 590+A1		Analyze Results
		Unit	Values	
Flash Point	TS EN ISO 2719	°C	55 (minimum)	
Density (15°C)	TS EN ISO 12185	kg/lt	0.820 -0.845	
Cetane Number	TS 10317 EN ISO 5165		51 (minimum)	**6.**
Cetane Index	TS EN ISO 4264		46 (minimum)	**7.**
Viscosity(40°C)	TS 1451 EN ISO 3104	cSt	2.00 - 4.50	8.
Pour Point	TS 1233 ISO 3016	°C		
Cold Filter Plugging Point	TS EN 116	°C	-15(Maximum) 5(Maximum)	
Micro Carbon Residue	TS EN ISO 10370	% mass	0.30(Maximum)	
Heat Value	ASTM D 240	cal/g		
Distillation	TS EN ISO 3405	%(V/V)	250 °C' de 65 (maximum) 350 °C' de 85(minimum) 360 °C' de 95(minimum)	
Copper Strip Corrosion	TS 2741 EN ISO 2160		1 (A,B,C)	

For Gasoline

Properties	METHOD	TS EN 228		Analyze Results
		Unit	Values	
Density (15°C)	TS EN ISO 12185	kg/lt	0.820 -0.845	
Motor Octane Number	TS EN ISO 5163		85 (minimum)	**9.**
Research Octane Number	TS EN ISO 5164		95 (minimum)	**10.**

Distillation	TS EN ISO 3405	%(V/V)	70 °C 20-48 100 °C46-71 150 °C 75 (min.)	
Copper Strip Corrosion	TS 2741 EN ISO 2160		1 (A,B,C)	

5.Cold BehavierAnalyzer

A fuel property that is particularly important for the low temperature operability of diesel fuel is the cloud point. The cloud point is the temperature at which a cloud of wax crystals first appears in a liquid upon cooling. Therefore, it is an index of the lowest temperature of the fuel's utility under certain applications. Operating at temperatures below the cloud point for a diesel fuel can result in fuel filter clogging due to the wax crystals. The cloud point is determined by visually inspecting for a haze in the normally clear fuel, while the fuel is cooled under carefully controlledconditions.

A second measure of the low temperature performance of diesel fuels is the pour point. The pour point is the lowest temperature at which a fuel sample will flow. Therefore, the pour point provides an index of the lowest temperature of the fuel's utility for certain applications. The pour point also has implications for the handling of fuels during cold temperatures.

MPC-102 series has been designed for automatic determination of Pour Point (PP) and Cloud Point (CP) with small specimen size and shorter test cycle time while securing better test precision than the conventional manual methods. PP measurement is made utilizing a new ASTM D6749 on Standart Test Method for Pour Point of Petroleum Products test method namely Air Pressure Method, which yields eventually no bias against the conventional test method, repeatability/reproducibility of 1/2°C and 2-3 times faster determinations. The epochmaking high accuracy justifies PP determination at 1°C interval, which can help increasing the yields in the process. The CP/PP mode executes a CP determination and then PP determination consecutively, which further improves the test throughput in the lab. Multiple-tests versions with 6 test heads and 3 test heads are also available for higher vo lume tests.

The typical repeatability and reproducibility are 1°C and 2°C respectively, when PP is determined at 1°C intervals. This high precision attributes to the patented Air Pressure method, in which the disturbance to the formation of wax crystal structure through the test process is kept at a minimal and consistent level. With this high precision, PP can be determined at 1°C intervals for more precise process control, and therefore a considerable savings in the process can berealized.

Just set up a sample, select a test mode and then press the START key. The sample coolsatthesteepestpossibleratewithoutaffectingtheformation/growthofwaxcrystal,which has been to be a critical factor for PP/CP determination. The test cycle time is typically 1/3 to 1/2 of that of the conventional tilting methods.

Since the required sample volume is a mere 4,5 ml and the sample cup is a test-tube type removable jar, the sample handling is extremely easy. Use of Peltier Cells for sample cooling/heating made this mini tester not only compact in design but energy efficient. Depending on the temperature range, air, tap water or small chiller with anti-freeze suffices the coolingrequirement

Figure 1. Tanaka MPC-102

6. Reid Vapor Pressure(RVP)

Reid vapor pressure (RVP), determined by the ASTM test method D323, is widely used in the petroleum industry to measure the volatility of petroleum crude oil, gasoline and other petroleum products. It is a quick and simple method of determining the vapor pressure at 37.8 °C (100 °F) of crude oil and petroleum products having an initial boiling point above 0 °C (32°F).

Reid vapor pressure measures by Tanaka AVP 30D automatic RVP analyzer. Tanaka AVP 30 D RVP analyzer is shown figure 10.

Figure 2. Tanaka AVP-30D

For Diesel

Properties	METHOD	TS– EN 590+A1		Analyze Results
		Unit	Values	
Flash Point	TS EN ISO 2719	°C	55 (minimum)	
Density (15°C)	TS EN ISO 12185	kg/lt	0.820 -0.845	
Cetane Number	TS 10317 EN ISO 5165		51 (minimum)	**11.**
Cetane Index	TS EN ISO 4264		46 (minimum)	**12.**
Viscosity(40°C)	TS 1451 EN	cSt	2.00 - 4.50	13.

	ISO 3104			
Pour Point	TS 1233 ISO 3016	°C		
Cold Filter Plugging Point	TS EN 116	°C	-15(Maximum) 5(Maximum)	
Micro Carbon Residue	TS EN ISO 10370	% mass	0.30(Maximum)	
Heat Value	ASTM D 240	cal/g		
Distillation	TS EN ISO 3405	%(V/V)	250 °C' de 65 (maximum) 350 °C' de 85(minimum) 360 °C' de 95(minimum)	
Copper Strip Corrosion	TS 2741 EN ISO 2160		1 (A,B,C)	

For Gasoline

Properties	METHOD	TS EN 228		Analyze Results
		Unit	Values	
Density (15°C)	TS EN ISO 12185	kg/lt	0.820 -0.845	
Motor Octane Number	TS EN ISO 5163		85 (minimum)	**14.**
Research Octane Number	TS EN ISO 5164		95 (minimum)	**15.**
Distillation	TS EN ISO 3405	%(V/V)	70 °C 20-48 100 °C46-71 150 °C 75 (min.)	
Copper Strip Corrosion	TS 2741 EN ISO 2160		1 (A,B,C)	