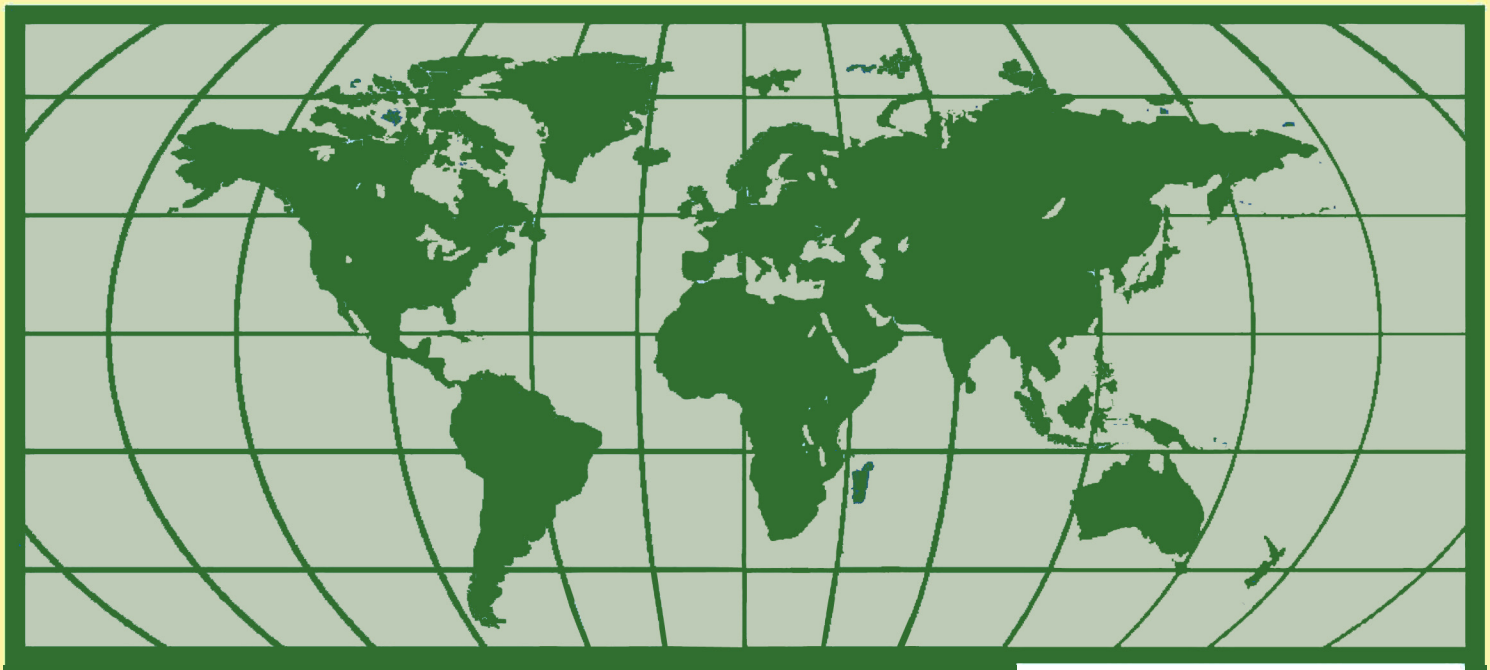

First edition

ETHANOL GUIDELINES

MARCH 2009

From the Worldwide Fuel Charter Committee

For copies, please visit the association websites.

ACEA

European Automobile Manufacturers Association
Rue du Noyer 211,
B-1000 Bruxelles, Belgium
Tel: 32 (2) 732-5550
Fax: 32 (2) 738-7310
www.acea.be

Alliance of Automobile Manufacturers

Alliance of Automobile Manufacturers
1401 Eye Street, N.W., Suite 900
Washington D.C., 20005
Tel: 1 (202) 326-5500
Fax: 1 (202) 326-5568
www.autoalliance.org

emа®

Engine Manufacturers Association
Two North LaSalle Street, Suite 1700
Chicago IL, 60602
Main Telephone: 1 (312) 827-8700
Facsimile: 1 (312) 827-8737
www.enginemanufactures.org

JAMA

Japan Automobile Manufacturers Association
Jidosha Kiakan
1-30, Shiba Daimon 1-Chome
Minato-ku, Tokyo 105-0012 Japan
Tel: +81-3-5405-6125
Fax: +81-3-5405-6136
www.japanauto.com

European Automobile Manufacturers Association

Alliance of Automobile Manufacturers

Engine Manufacturers Association

Japan Automobile Manufacturers Association

March 2009

Subject: **Worldwide Biofuels Harmonisation**

Dear Ethanol Guidelines Recipient:

On behalf of automobile and engine manufacturers from around the world, we are pleased to present this First Edition of Ethanol Guidelines from the Worldwide Fuel Charter (WWFC) Committee. We created the WWFC in 1998 to promote greater understanding of the impact of fuel quality on engine and motor vehicle emissions and performance and to promote harmonization of fuel quality worldwide in accordance with engine and vehicle needs in different markets.

Rapid growth in the use of ethanol and biodiesel has prompted the WWFC Committee to address the need for more information about these important renewable fuels. As with conventional gasoline and diesel fuel, biofuel quality must match the needs and capabilities of engine and vehicle technologies, especially as these technologies become more advanced to meet ultra-clean emission standards. This document provides our guidance on ethanol quality; a companion document provides guidance on biodiesel quality.

Given the wide variation in performance and measurement methods of biofuel blends at different blend levels, these guidance documents focus on the quality of the blendstock used to make finished biofuel blends, rather than on the finished fuels themselves. Specifically, we created this document to guide blenders who produce and use 100% ethanol and gasoline blendstocks to make finished 10% ethanol blends. The resulting finished fuels should continue to meet the recommendations contained in the WWFC for the various categories of market fuels.

The use of ethanol and biodiesel fuels is important to help extend supplies of gasoline and diesel fuel. As renewable fuels, they have the potential to help reduce emissions of greenhouse gases. Proper formulation also can help assure lower emissions of conventional pollutants. The key to achieving low emissions is to sustainably produce good quality blendstocks and to blend and distribute the finished fuels in a way that preserves their quality when they reach the consumer.

This document represents our best collective judgment at this time, based on experience with ethanol produced from conventional feedstocks, such as corn and sugarcane, and aided by comments from interested parties. We recognize that technical information will continue to evolve, so this document will also change over time as we learn more. We appreciate the efforts of those who provided information and comments, and we are especially grateful to those who expressed support for this endeavor.

We look forward to working with you to support the development and use of high quality renewable fuels for the benefit of consumers and the environment worldwide.

Ivan Hodac
Secretary General
ACEA

Dave McCurdy
President & CEO
Alliance

Jed R. Mandel
President
EMA

Yoshiyasu Nao
President
JAMA

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Vietnam Automobile Manufacturers Association (VAMA)

Supporting organisation:

Organisation Internationale des Constructeurs d'Automobiles (OICA)

Acronyms

ABNT NBR	Associação Brasileira de Normas Técnicas (Brazilian Standards Number)
ACEA	Association des Constructeurs Européens d'Automobiles (European automotive manufacturers association)
Alliance	Alliance of Automobile Manufactures
ASTM	ASTM International (formerly American Society for Testing and Materials)
C2-C5	Mono alcohol with two to five carbon atoms
C3-C5	Mono alcohol with three to five carbon atoms
CCD	Combustion Chamber Deposits
CEN	Comité European de Normalisation (European Committee for Standardization)
Cl^-	Chlorine ion
E10	10% ethanol blended gasoline
EC	European Commission
EMA	Engine Manufacturers Association
EN	European Norm
ICP	Inductively Coupled Plasma spectrometer
ISO	International Organization for Standardization
IVD	Intake Valve Deposits
JAMA	Japan Automobile Manufacturers Association
JAAS	Japan Alcohol Association Standard
JIS	Japanese Industrial Standards
Na^+	Sodium ion
ppm	parts per million
prEN	Provisional European Norm
SO_4^{2-}	Sulfate
µS/m	micro Siemens per meter
WWFC	Worldwide Fuel Charter

CONTENTS

Introduction

The purpose of the Worldwide Fuel Charter is to promote high quality and harmonized fuels on a global basis, considering the need for optimum engine and vehicle performance and durability and for the cleanest possible operation of engine and vehicle technologies. Meeting these objectives will benefit consumers, simplify fuel markets, facilitate trade and help governments meet public policy goals.

Biofuels are of particular interest today due to their potential to help reduce the use of petroleum-based fuels, improve energy security and reduce greenhouse gas emissions. Ethanol is one of these fuels that is viable and in use today as a direct gasoline additive as well as a feedstock for making ether gasoline additives. Other promising renewable blendstocks for gasoline include bio-ethers (e.g., ethanol tertiary butyl ether (ETBE) and tertiary amyl ethyl ether (TAEE)) and bio-alcohols (e.g., biobutanol). Good ethanol quality is fundamental to its continued success as a fuel as well as a feedstock for other fuel additives. The guidance presented here contains manufacturer recommendations regarding the ethanol quality needed for proper engine and vehicle operation.

The recommended limits are specifically established for anhydrous 100% ethanol (E100) blendstock intended for blending with petroleum-based gasoline to make a blend containing a maximum of 10% ethanol by volume (E10) suitable for use in vehicles with spark ignition engines. Higher level blends (greater than E10) are suitable for use only in vehicles designed for such fuel, such as "flexible fueled" vehicles, and ethanol used for higher blends may require different limits. The finished ethanol-gasoline blends (up to 10% ethanol), as well as the finished petroleum-based gasoline, should continue to meet the requirements of the appropriate gasoline category in the Worldwide Fuel Charter.

These guidelines are based on engine and vehicle manufacturer experience with ethanol fuels made from feedstocks commonly used today in various markets around the world (e.g., corn and sugarcane). The guidelines are performance-based and feedstock-neutral.

Ethanol fuel blends must have uniform properties throughout to ensure a consistent quality. High speed injection blending is generally preferred to splash blending as a means to ensure uniform quality throughout the final fuel blend. Local regulations may require certain additives (e.g., U.S. denaturant requirements). Maintaining good fuel quality requires good housekeeping practices throughout production, distribution, blending and storage. All parties handling ethanol and its blends should watch for condensation and phase separation; fuel contaminated with water should not be sold to consumers. Blenders and retailers are advised to change filters regularly.

Ethanol-gasoline blends, especially those above 10% ethanol, must be properly labeled at the dispenser to enable the consumer to determine the fuel's compatibility with the engine or vehicle manufacturer's fuel recommendations and warranty statements. This guidance includes suggestions for pump labeling, to help inform marketers about the type of information needed and to encourage market uniformity.

Engine and vehicle manufacturers will continue to evaluate these Guidelines for ongoing applicability to increasingly sophisticated vehicle systems and components, which must comply with numerous government regulations. The WWFC Committee will review and revise these recommendations as necessary to reflect changes in engine and vehicle technologies, ethanol production and marketing practices and test methods.

Guidelines for E100 Blendstock for use in up to E10 Blends

Property	*Value*	*Units*	*Test methods*[1]
Ethanol plus C3-C5 saturated alcohols (anhydrous)	99.2 min	% m/m	EN 15721 ASTM D5501 Other: JAAS001-6.2
C3-C5 saturated alcohols (anhydrous)	2 max	% m/m	EN 15721
Methanol	0.5 max	% m/m	EN 15721 ASTM D5501

Ethanol to C5 Saturated Alcohols (anhydrous)

This recommended limit, which applies to anhydrous ethanol, is a measure of quality that should be viewed together with methanol and water limits. It is an acceptable limit for lower level ethanol blends; a minimum of 99.5 % v/v is recommended, however, for blends between E5 and E10.

Some countries require producers to denature the ethanol before it can enter commerce as a transportation fuel or blendstock; blenders should follow local rules regarding the concentration and type of denaturant. Blenders should review components if the non-ethanol components comprise more than 5% of the volume of the ethanol blendstock. Blenders should match the recommended limit to the test method used.

C3-C5 Saturated Alcohols (anhydrous)

These alcohols usually enter the fuel ethanol as production by-products and are limited as a way to control the purity of the ethanol.

Methanol

Fermentation processes can produce small amounts of methanol, and some countries require a small amount as a denaturant, but methanol has harmful effects so it should be minimized.

Notes regarding test methods:

When testing by ISO methods, the ethanol should meet the specified limits before any denaturant is added, recognizing that a buyer may have difficulty verifying the limit where the ethanol has been previously denatured.

Problems may occur when measuring higher alcohols if gasoline is used as a denaturant.

[1] When testing by ISO methods, the limit shall apply to un-denatured ethanol. Unless otherwise noted, the CEN test methods have been shown to apply to ethanol in an interlaboratory test programme: "Ethanol Test Methods—Interlaboratory Study, CEN/TC 19/WG 27, "Elemental Analysis of Petroleum Products," available from NEN, P.O. Box 5059, NL-2600 GB Delft, The Netherlands. Precision data from the programme are incorporated into the test method.

Water	0.3 max	% m/m	EN 15489 ASTM E203 JIS K8101

Water in the fuel can promote corrosion and microbial growth. Water can enter ethanol during production and through condensation during the fuel's distribution and storage. If the water content is too high, phase separation may occur after blending with gasoline. Undissolved water in the fuel line can cause the engine to run unevenly or stall.

Adding ethanol to gasoline changes the amount of water that can be contained in the gasoline mixture without separating, since the three components (gasoline, water and ethanol) have different solubilities. Ethanol dissolves in both gasoline and water, but water does not dissolve in neat gasoline except in minute amounts. This means that gasoline-ethanol blends will allow more water in the fuel mixture, thereby increasing the potential for corrosion and microbial growth. It also means that phase separation will occur more readily at lower ethanol levels in the gasoline blend. The water limit was selected for problem-free vehicle operation even at low level ethanol blend rates (for example, at or below 5% by volume), considering handling and distribution practices as well as the potential for additional mixing in the vehicle tank. Temperature also plays a role, so where regional conditions permit, a higher level of water, up to 0.7 % m/m, is allowed.

In determining the best way to handle fuel ethanol, blenders and distributors should consider the ethanol's purity and local humidity levels. They should strive to minimize water content throughout distribution through careful handling and good housekeeping. The presence of water indicates a need to improve ethanol handling practices, such as by adding a nitrogen seal to the storage tank.

Notes regarding test methods:

Regarding EN 15489, a cross check validation may show that a Karl Fischer volumetric method also applies.

Density	report	kg/m^3	ASTM D4052 Other: ABNT NBR 5992

Density is a measure of the quality of the blendstock. Fuel ethanol should be comprised almost entirely of ethanol molecules, so its density should approximate that of pure ethanol. A density measurement is also needed to convert mass results to volumetric results and to correct the volume for temperature.

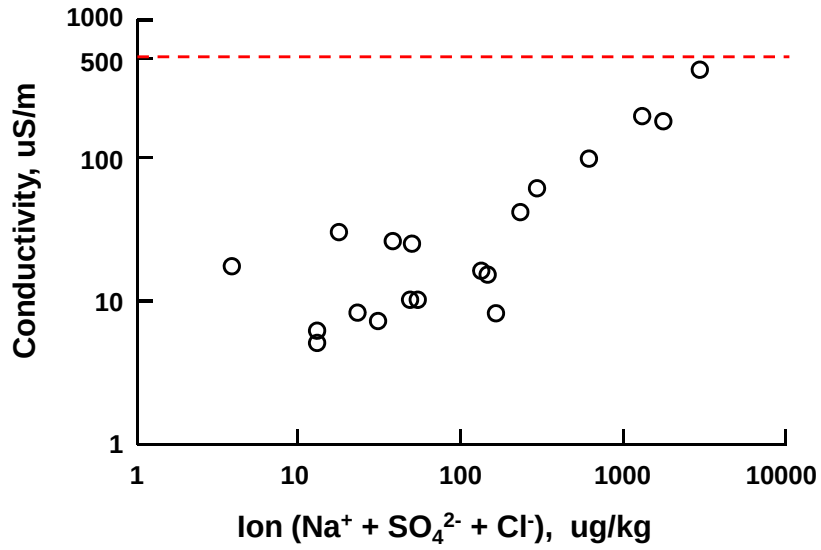
Notes regarding test methods:

Density measurements are accurate indicators of purity only if the fuel ethanol has insignificant amounts of other alcohols with similar density.

Electrical conductivity	500 max	µS/m	ASTM D1125 JIS K0130 Other: ABNT NBR 10547

Electrical conductivity correlates closely with the amount of metallic ions such as chloride, sulfate, sodium and iron in the fuel. A higher electrical conductivity means the fuel contains a higher amount of

corrosive and metallic ions that promote corrosion and failure in the vehicle fuel line and that also cause injector deposits. This limit is equivalent to 5 ppm for the sum of sodium, sulfate and chloride ions.



Notes regarding test methods:

New methods are under development.

Inorganic chloride	10.0 max	mg/l	EN 15484 or EN 15492 ASTM D7319, D7328 Other: ABNT NBR 10894/10895

Inorganic chloride is extremely corrosive and corrodes metals in vehicle fuel lines, even at low levels of contamination. This limit was selected for ethanol intended for blending into gasoline but a more stringent limit would be needed for ethanol used at essentially neat levels.

Controlling electrical conductivity will help minimize the presence of chloride ion.

Notes regarding test methods:

Inter-laboratory testing has failed to show statistical differences in precision at the specified levels in cases of disagreement between the results of EN 15484 and EN 15492.

Sulfate	4 max	mg/kg	EN 15492 ASTM D7318, D7319, D7328 Other: ABNT NBR 10894/12120

Sulfate is very corrosive and will corrode metals in the vehicle's fuel system, even at low levels of contamination. Sulfate also promotes deposits on injectors. Controlling electrical conductivity will help minimize the presence of sulfate. A maximum limit of 1 mg/kg is recommended for finished blends.

Copper	0.100 max	mg/kg (ppm)	EN 15488 ASTM D1688 modified, Method A JIS K0101 Other: ABNT NBR 10893

Metals accelerate oxidization of fuels and promote injector deposits. Ethanol production in materials made with copper may cause the metal to be introduced into the fuel. Controlling electrical conductivity will help minimize the presence of copper.

Notes regarding test methods:

Inductively Coupled Plasma (ICP) spectrometry can be used to measure copper, sodium, iron and phosphorus in one test.

Organic impurities	10 max (1 max)	mg/l (% m/m)	JIS JAAS001 – 6.4

For non-denatured ethanol, the presence of organic impurities indicates contamination. The fuel ethanol can pick up contamination from dirty trucks (lorries), storage tanks and other vessels, and such contamination may hurt vehicle operation. The type of hydrocarbon found should not exceed 10 carbon atoms (C10); additional alcohols and ketones also should not be present. Blenders and distributors should take precautions and follow local rules to limit hydrocarbons and other sources of contamination during distribution.

Notes regarding test methods:

The JAAS method measures alcohols and ketones in addition to non-oxygenated hydrocarbons.

Phosphorus	0.50 max	mg/l	EN 15487 ASTM D3231

Phosphorus may enter ethanol through plant uptake of agricultural chemicals. Phosphorus is a powerful catalyst poison and will cause exhaust emissions to increase.

Sulfur	10 max	mg/kg or ppm	EN 15486[2] ASTM D5453 (< 20 ppm) JIS K2541

Most ethanol does not contain sulfur, but certain production methods may introduce sulfur compounds into the fuel. Denaturing the ethanol with a high sulfur gasoline will also add sulfur. Sulfur poisons catalysts, which causes exhaust emissions to increase. As a result, many governments limit the amount of sulfur in the ethanol and/or the finished blends to ensure compatibility with emission control systems and to meet local emission standards. Regulators may require testing of both ethanol and the finished blend.

[2] These methods have special provisions for ethanol which are not incorporated in the usual petroleum test methods such as EN ISO 20846 and EN ISO 20884.

Notes regarding test methods:

ASTM D2622 is an acceptable method for samples containing more than 20 mg/kg sulfur.

EN 15485, EN 15486: In cases of dispute concerning sulfur content, inter-laboratory testing has not identified statistical differences in precision at the specified levels. These methods have special provisions for ethanol that are not incorporated into the usual petroleum test methods (e.g., EN ISO 20846, Petroleum products—Determination of low sulfur content of automotive fuels—Ultraviolet fluorescence method (ISO 20846:2004) and EN ISO 20884, Petroleum products—Determination of low sulfur content of automotive fuels—Wavelength-dispersive X-ray fluorescence spectroscopy (ISO 20884:2004)).

Heavy metals	Non-detectable; No intentional addition	Other: ICP-AES

Fuel ethanol should contain no heavy metals, which poison catalysts and cause exhaust emissions to increase. In case of denatured ethanol, this limit may be unnecessary.

Notes regarding test methods:

A general guide for performing trace element analysis by ICP can be found in ASTM D7260.

Non-volatile material*	5 max	mg/100 ml	prEN 15691 ASTM D381 JIS JAAS001 – 6.3 Other: ABNT NBR 8644

*Similar to evaporative residue and existent unwashed gum. See notes regarding test methods, below.

Non-volatility material may contain heavy components that result from contamination in the distribution system. These components contribute to deposits.

For un-denatured E100, this limit may be used as an alternative to the limit for existent washed gum.

Notes regarding test methods:

The three procedures differ but are essentially trying to measure the same property, namely, the residue remaining after the ethanol is evaporated. The US (ASTM D381) and Brazilian (NBR 8644) procedures are similar, but the US washes the sample with heptane and Brazil measures unwashed gum. The EU procedure (prEN 15691), which is still in development and designed specifically for ethanol intended for blending with gasoline, determines the total dry residue by a gravimetric method. For non-volatiles at 10 mg/100 ml, the precision of this method is R = 4.78; for non-volatiles at 20 mg/100 ml, the precision is R=5.48. The JIS method, which is commonly used to measure food ethanol, has excellent precision.

For all the methods, an appropriate sample size must be used to ensure accurate results.

pHe	6.5 - 9		ASTM D6423
Methods that produce "pHe-like" results			
	6 – 8		EN 15490 JIS JASO M361-6.10 Other: ABNT NBR 10891

The pHe value measures acidity and alkalinity, both of which can increase corrosion. A higher value means the fuel contains more alkaline components, and a lower value means it contains more acidic components. A value of 7 indicates neutrality, and the fuel must be as close to neutral as possible.

Notes regarding test methods:

ASTM D6423 is the empirical method that defines pHe. Regarding the other listed methods which produce "pHe-like" results, note that pH is not defined for non-aqueous solvents, and all pH-like measurements in non-aqueous solvents are purely empirical measurements defined by the measuring equipment and details of the test procedure. As a consequence, such methods are expected to return different results on the same sample. ASTM method is under review.

Acidity (as acetic acid)	0.007 max	% m/m	EN 15491 ASTM D1613 Other: ISO 1388/2; ABNT NBR 9866

Blenders must limit the acidity of the ethanol blendstock to control the acidity in the finished gasoline blend.

Appearance	clear and bright, no visible impurities	Visual inspection

Fuel should be clear in appearance and free of visible water and sediment. The presence of these materials generally indicates poor fuel handling practices. Water and sediment can shorten filter life or plug fuel filters, which can lead to engine fuel starvation.

Notes regarding test methods:

CEN is working to develop a method for measuring appearance, along with ethanol purity, higher saturated (C3, C5) mono-alcohol content and methanol content.

Color	Visual inspection

Color may vary according to local rules.

Additional Properties

Consult the Worldwide Fuel Charter for recommended limits and test methods for additional properties—such as octane and volatility—that require control in the finished E10 blend.

Notes

Denaturant

Limits are determined by national or local regulation. Where a local government requires producers to denature the fuel ethanol, the only permitted denaturants are gasoline (conforming to EN 228, ASTM D4814 or JIS K2202); ethyl tert-butyl ether (ETBE); methyl tert-butyl ether (MTBE); tert-butyl alcohol (TBA); isobutanol (2-methyl 1-propanol); and isopropanol (2-propanol). Any or all of these denaturants may be used alone or together, except that isobutanol and isopropanol separate easily from solution, so it is advisable to use them in combination with another denaturant. The final gasoline-ethanol blend should also meet EN 228, D4814 or JIS K2202.

Good Housekeeping Practices

Given the known potential for ethanol to absorb water, suppliers shall ensure that water does not contaminate the ethanol fuel under the expected range of climatic and fuel distribution conditions. Additional useful information can be found in "Guidelines For Blending And Handling Motor Gasoline Containing Up To 10% V/V Ethanol," CONCAWE, Report No. 3/08, April 2008.

Labeling

Vehicle and engine manufacturers design their products for compatibility with different concentrations of ethanol. Most current production vehicles with spark ignition engines are compatible with gasoline containing up to 10% ethanol; some in-use vehicles and engines, however, may be incompatible with this blend. Check owner guide for manufacturer recommendations. Some manufacturers offer vehicles for use with high level ethanol blends, such as those containing 85% ethanol. Concerns about ethanol compatibility and quality increase as the ethanol content increases. The WWFC recommends dispenser labeling that identifies the amount of ethanol content and advises the consumer to check manufacturer recommendations.

Summary of Guidelines

Property	*Value*	*Units*	*Test Methods*
Ethanol plus C3-C5 saturated alcohols (anhydrous)	99.2 min	% m/m	EN 15721 ASTM D5501 Other: JAAS001-6.2
C3-C5 saturated alcohols (anhydrous)	2 max	% m/m	EN 15721
Methanol	0.5 max	% m/m	EN 15721 ASTM D5501
Water	0.3 max	% m/m	EN 15489 ASTM E203 JIS K8101
Density	report	kg/m^3	ASTM D 4052 Other: ABNT NBR 5992
Electrical conductivity	500 max	µS/m	ASTM D 1125 JIS K0130 Other: ABNT NBR 10547
Inorganic chloride	10.0 max	mg/l	EN 15484 or EN 15492 ASTM D7319, D7328 Other: ABNT NBR 10894/10895
Sulfate	4 max	mg/kg	EN 15492 ASTM D7318, D7319, D7328 Other: ABNT NBR 10894/12120
Copper	0.100 max	mg/kg (ppm)	EN 15488 ASTM D1688 modified, Method A JIS K 0101 Other: ABNT NBR 10893
Organic impurities	10 max (1 max)	mg/l (% m/m)	JIS JAAS001 –6.4
Phosphorus	0.50 max	mg/l	EN 15487 ASTM D3231
Sulfur	10 max	mg/kg or ppm	EN 15486[3] ASTM D5453 (< 20 ppm) JIS K2541
Heavy metals	Non-detectable; No intentional addition		Other: ICP-AES
Non-volatile material	5 max	mg/100 ml	prEN 15691 ASTM D381 JIS JAAS001–6.3 Other: ABNT NBR 8644

[3] These methods have special provisions for ethanol which are not incorporated in the usual petroleum test methods such as EN ISO 20846 and EN ISO 20884.

Property	*Value*	*Units*	*Test Methods*
pHe	6.5 – 9		ASTM D6423
"pHe-like"	6 – 8		EN 15490 JIS JASO M361-6.10 Other: ABNT NBR 10891
Acidity (as acetic acid)	0.007 max	% m/m	EN 15491 ASTM D1613 Other: ISO 1388/2; ABNT NBR 9866
Appearance	Clear and bright, no visible impurities		Visual inspection
Color	local requirement		Visual inspection

Summary of Test Methods

(see main text for additional notes)

Property	Units	CEN/ISO[4]	ASTM	JIS	Other
Ethanol + C3-C5 (anhydrous)	% m/m	EN 15721	D5501	JAAS001-6.2 (C2-C5)	
C3-C5 saturated alcohols (anhydrous)	% m/m	EN 15721			
Methanol	% m/m	EN 15721	D5501		
Water	% m/m	EN 15489	E203	K8101	
Density	kg/m^3		D4052		ABNT/NBR 5992
Electrical conductivity	µS/m		D1125	K0130	ABNT/NBR 10547
Inorganic chloride	mg/l	EN 15484 or EN 15492[5]	D7319 D7328		ABNT/NBR 10894/10895
Sulfate	mg/kg	EN 15492	D7318 D7319 D7328		ABNT/NBR 10894/12120
Copper	mg/kg (ppm)	EN 15488	D1688 modified, Method A	K0101	ABNT/NBR 10893
Organic impurities	mg/l (or % m/m)			JAAS001–6.4	
Phosphorus	mg/l	EN 15487	D3231		
Sulfur	mg/kg or ppm	EN 15486[6]	D5453 (<20ppm)	K2541	
Heavy metals					ICP-AES[7]
Non-volatile material[8]	mg/100ml	prEN 15691	D381	JAAS001-6.3	ABNT NBR 8644
pHe			D6423		
“pHe-like”*		EN 15490*		JASO M361-6.10*	ABNT NBR 10891*
Acidity (as acetic acid)	% m/m	EN 15491	D1613		ISO 1388/2 ABNT NBR 9866
Appearance		visual inspection			
Color		visual inspection			

*Results may differ significantly from pHe.

[4] When testing by ISO methods, the ethanol before denaturing shall meet the limits specified. The test methods have been shown to be applicable to ethanol in an inter-laboratory test programme: “Ethanol Test Methods – Inter-laboratory Study, CEN/TC 19/WG 27, “Elemental Analysis of petroleum products,” available from NEN, P.O. Box 5059, NL-2600 GB Delft, the Netherlands. Precision data from the programme are incorporated in the test method.

[5] In cases of dispute concerning sulfur or inorganic chloride content, inter-laboratory testing has not identified statistical differences in precision at the specified levels.

[6] These methods have special provisions for ethanol which are not incorporated in the usual petroleum test methods such as EN ISO 20846 and EN ISO 20884.

[7] A general guide for performing trace element analysis by ICP can be found in ASTM D7260.

[8] Also applies to evaporative residue and existent washed gums.