

TEST REPORT: 7191089091-CHM14-YL
02 SEP 2014



PSB Singapore

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SUBJECT

Literature Review of Non-Traditional Additives and Their Blending Effects

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DATE OF ORDER CONFIRMATION

05 Jun 2014

DESCRIPTION OF ORDER



Literature review were carried out of non-traditional additives, i.e. Sec-Butyl Acetate (SBA), N-Methylaniline (NMA), Acetone, Methylal and Methyl Acetate in focusing on their physiochemical properties, toxicity and blending effects. Relative governments regulations were also reviewed.

METHOD OF LITERATURE REVIEW

Collection and summarization of professional journals, books, database and internet accessible sources.

LIMITATIONS OF THIS LITERATURE REVIEW

This literature review is only focusing on a comparison of properties, toxicity, blending effects of selected non-traditional gasoline additives based on our accessible resources. Further research or investigation maybe necessary to provide more data especially lab testing and their prolong ecological effects in environment.

		LA-2007-0380-A LA-2007-0381-F LA-2007-0382-B LA-2007-0383-G LA-2007-0384-G LA-2007-0385-E LA-2007-0386-C LA-2010-0464-D	The results reported herein have been performed in accordance with the laboratory's terms of accreditation under the Singapore Accreditation Council - Singapore Laboratory Accreditation Scheme. Tests/Calibrations marked "Not SAC-SINGLAS Accredited" in this Report are not included in the SAC-SINGLAS Accreditation Schedule for our laboratory.
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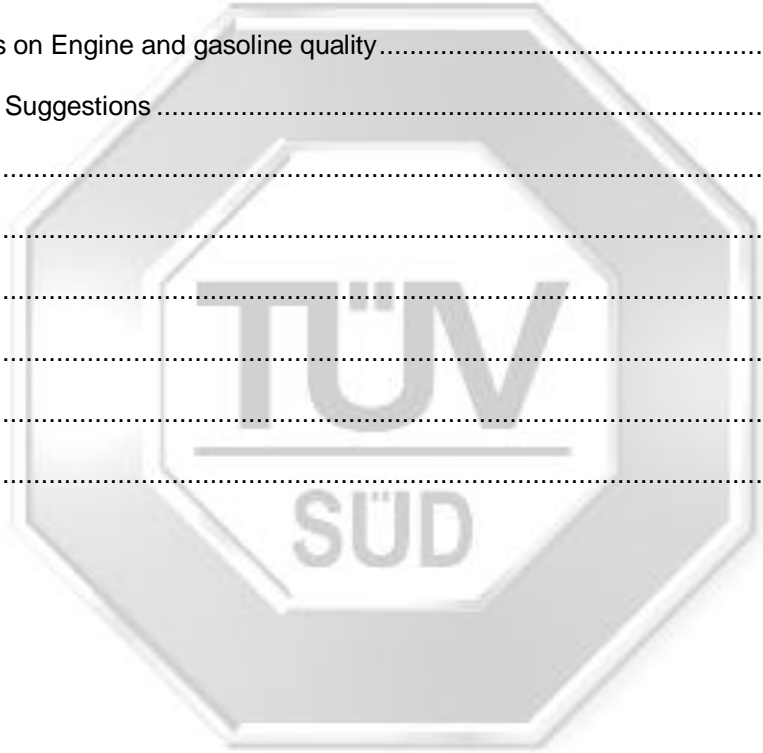
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Literature Review of Non-Traditional Additives and
Their Blending Effects

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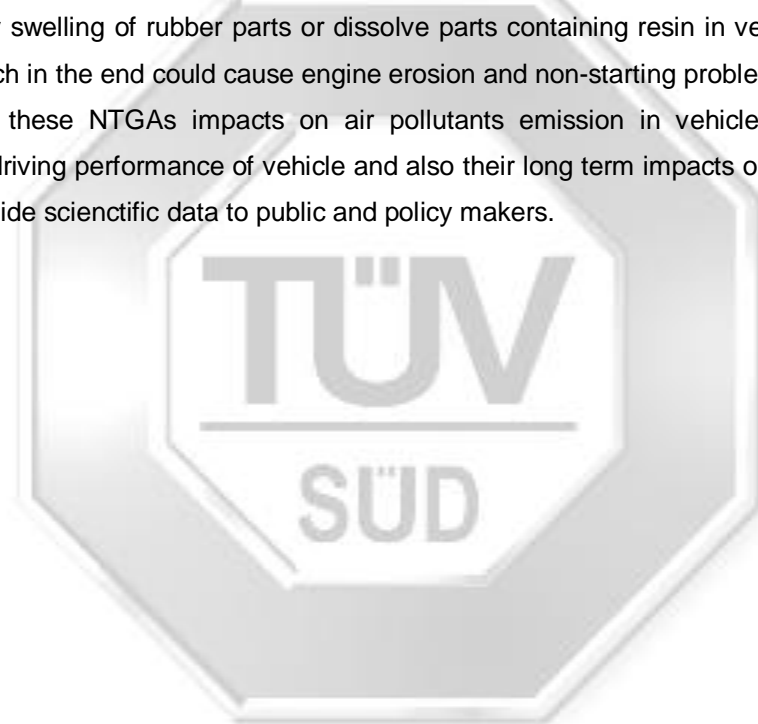


Literature Review of Non-Traditional Additives and Their Blending Effects

Executive Summary

Chemicals such as Sec-Butyl Acetate (SBA), N-Methylaniline (NMA), Acetone, Methylal and Methyl Acetate are non-traditional gasoline additives (NTGAs). Many countries do not recommend or already set ban on these chemicals blending into gasoline due to their unknown ecological impacts and risks to human beings. Further more, NMA is reported high toxic. These chemicals are good solvent and can cause apparently swelling of rubber parts or dissolve parts containing resin in vehicles engines such as seal ring which in the end could cause engine erosion and non-starting problems.

Further research on these NTGAs impacts on air pollutants emission in vehicle exhaust gas, corrosion of engine, driving performance of vehicle and also their long term impacts on environment are necessary to provide scientific data to public and policy makers.



1. Purpose of the Literature Review

SBA, NMA, Acetone, Methylal and Methyl Acetate are organic compounds and important chemical materials in industry. They are widely used as solvent in lacquers, enamels, intermediate, resins, adhesives, paint strippers, protective coatings, glue removers etc. Due to their strong dissolving ability, expected swelling effect in rubber materials, a kind of popular material in making sealing ring and other parts in engine, and also some of them have acute toxic effect on human beings, they are not usually used as gasoline blending components.

Recently, there were numerous sales information in market of these chemicals as blending components in gasoline (*NTGAs sales information as gasoline additive*). Apparently, they had been sold and used for blending in fuels in some countries's market. It is high doubted that some massive non-startup accidents reported in media can be attributed to adding up these chemicals in gasoline. For example, engine extinguishing accidents were widely reported from year 2010 to 2013 in GuangXi, Shanghai, Henan, ZheJiang etc by china major media (*Annex A*). These accidents phenomenon are similar: sticky gum like substances sedimentation in air inlet, spark plug, engine cylinder and engine difficult to startup, shaking and weak in acceleration. Some reports pointed that NMA and Acetate type substances etc were analyzed in "problem gasoline".

In order to understand the characteristics of these chemicals in gasoline and their potential negative impact to engines, human health and the environment, literature review is necessary to consolidate these informations and present to consumers, policymakers and other stakeholders for further risk assessment or evaluations.

2. Review of Current Policies on NTGAs Blending in Gasoline

In fact, many country's authorities had realized these potential risks and already made provisions or regulations on these NTGAs and their application in gasoline blending.

China

China set ban on NTGAs in latest gasoline standard GB17930-2013 and in giant oil company.

China General Administration of Quality Supervision, Inspection and Quarantine and Standardization Administration issued latest gasoline standard GB17930-2013 for motor vehicles on 18 December 2013 and implemented on the same day. In the preface of GB17930-2013, it clearly stated that "Additives used in gasoline for motor vehicles should not contain recognized harmful substances and should be used by following up recommended safe dosage. Chemicals, such as methylal, aniline type compounds, halogens and those containing phosphorus and silicon etc should not be intentionally added in gasoline."

Noted that most of these NTGAs are oxygen contained. In GB17930, the oxygen content limit was set to be no more than 2.7% by mass percentage (*Annex B*).

One of China largest fuel oil supplier Sinopec released additional test parameters for gasoline purchased from third party company (*Annex C*). It was noted that in the table NMA, total Anilines, Sec-Methyl Acetae and Mehylal etc should not be detected or below detection limit by middle infrared analyzer. Gasoline smell should also be tested by professional and certificated staffs. Key parameters in Annex C were summarized in Table 1 below.

Table 1 Sinopec additional test standard of gasoline for non-sinopec suppliers

Items	Quality Requirement	Test Method
Smell	Normal	Judged by three certificated quality inspection professionals
Distillation range	Normal (not apparently excess in light components or heavy components)	GB/T 6536
Unwashed gum, mg/100mL	No more than 30 or 30-20 (gum after wash less than 2.5)	GB/T 8019

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Vapor pressure, kPa	No less than 45 (T>15 °C); No less than 55 (T=5-15 °C); No less than 65 (T< 5 °C)	GB/T 8017
Evaporation Index (DI value)	≤570; ≤565; ≤560	Calculation: DI=1.5*T10+3*T50+T90+11*oxygen%(mass)
N-Methylaniline (NMA)	Not detected	Middle Infrared Analyzer
p-toluidine	Not detected	Middle Infrared Analyzer
m-toluidine	Not detected	Middle Infrared Analyzer
o-Toluidine	Not detected	Middle Infrared Analyzer
Toal amine	Not detected	Middle Infrared Analyzer
Methylal	Not detected	Middle Infrared Analyzer and SH/T0663 alliance usage
Olefins, % by volume	≥8	GB/T 11132
methyl carbonate	Not detected	Middle Infrared Analyzer and SH/T0663 or SH/T 0713 alliance usage

United States

The NTGAs were not found in US EPA's List of Registered Gasoline Additives (*EPA, List of Registered Gasoline Additives*).

Fuel additives in the United States are regulated under section 211 of the Clean Air Act (as amended in January 1995). The Environmental Protection Agency (EPA) requires the registration of all fuel additives which are commercially distributed for use in highway motor vehicles in the United States, and may require testing and ban harmful additives. The US EPA also regularly reviews the health and net economic benefits of Clean Air Act policies.

Under section 211 of the Clean Air Act, all refiners and importers must register their fuel additives products with EPA before those products are offered for sale in US. Only gasoline and diesel fuel and fuel additives produced and commercially distributed for use in highway motor vehicles must be registered. The registration procedure includes submission of test report or data such as chemical composition, emission, toxicity etc., by following Title 40 CFR Part 79. All these tests must be

performed after the gasoline additives blending with base oil at the maximum concentration recommended by the additive manufacturer (*US Title 40 CFR Part 79*).

European Union

NTGAs are not in the list of recommended oxygenates in EU petro standard

By referring to EU EN 228:2012 and Directive 2009/30/EC, in automotive fuels of unleaded petrol – Requirements and test methods, these NTGAs were not found in the list. The oxygen content was set to a limit of 2.7% by mass percentage. All these NTGAs were not in the recommended oxygenates list (*Annex D*).

WWFC

NTGAs are not in the list of recommended oxygenates in WWFC catalog 4.

In the fifth edition of Worldwide Fuel Charter, the oxygen limit was set to be 2.7% by mass percentage in Catalog 4. In the footnotes, it mentioned “ where oxygenates are used, ethers preferred. Methanol is not permitted.” (*Annex E*)

Vietnam

Vietnam was reported to had set ban on SBA and acetone for gasoline blending.

It was reported that Vietnam had banned the use of SBA as an additive for gasoline after finding high levels of the substance in cargoes imported from Singapore. (*Platts, 2012*).

SBA is a strong solvent for industrial usage -- in products such as lacquers, enamels and plastics. Its use as an octane booster had never been documented. If used as gasoline additives, the impact of SBA on human health and motor vehicles were not known, hence banned by Vietnam.

It was reported that Vietnam already set ban on another NTGA, i.e. acetone, into gasoline on 2006 due to the unknwn health effect and potential harmful to vehicle engines (*Vietnet ban on acetone as gasoline additive*).

3. Hazard and exposure of NTGAs

The hazard of chemicals can be classified as physical, human health and environmental etc. Many well-known authorizations or internal associations had done numerous research and classified into data base and opened to public, such as National Institute for Occupational Safety and Health (NIOSH), International Labour Organization, European Union, United Nations. The following table summarized the hazard and exposure level of SBA, NMA, acetone, methylal and methyl acetate.

Table 2 Hazard and exposure levels of SBA, NMA, acetone, methylal and methyl acetate*

Hazard types	SBA	NMA	Acetone	Methylal	Methyl Acetate
CAS No.	105-46-4	100-61-8	67-64-1	109-87-5	79-20-9
UN hazard class	3 (Flammable liquids)	6.1 (Poisonous material)	3 (Flammable liquids)	3 (Flammable liquids)	3 (Flammable liquids)
Flammable	High flammable	Combustible with toxic fumes	Highly flammable	Highly flammable	Highly flammable
Explosive	Yes	Yes	Yes	Yes	Yes
Physical danger: Mix with air, explosive risk	Inhalation danger	Inhalation danger	Inhalation danger	Inhalation danger	Inhalation danger. Distant ignition risk.
Chemical danger: Reactive, fire hazard risk	React with strong acids and oxidants	If heated or burning, can produce toxic fumes including nitrogen oxides and aniline); react violently with strong acids and oxidants.	Contact with strong oxidants, generates fire and explosion hazard, attacks plastics.	May explode on heating. Reacts vigorously with strong oxidants. This generates fire and explosion hazard.	Generates fire and explosion hazard when decompose. Strong reducing agent. Reacts violently with oxidants. Attacks many metals in the presence of water. Attacks plastics
Exposure route	inhalation	Inhalation, skin contact, ingestion,	inhalation	inhalation	inhalation
Short-term exposure risk	mildly irritating, harmful to central nervous system	effects on blood, may cause methaemoglobin	irritating to the eyes and respiratory tract	irritating to the eyes, skin and respiratory tract, harmful to	irritating to the eyes and respiratory tract. Harmful to central nervous system.

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				central nervous system	Exposure far above the OEL could cause death.
Long-term exposure risk	Skin dryness and cracking	No data	Skin dryness and cracking	Skin dryness and cracking	Skin dryness or cracking. Harmful to the optic nerve.
Inhalation risk	Harmful if inhalation of contaminated air	Harmful if inhalation of contaminated air	Harmful if inhalation of contaminated air	Harmful if inhalation of contaminated air	Harmful if inhalation of contaminated air
Occupational exposure limits: Threshold Limit Value (TLV) ²	200ppm (ACGIH)	0.05 ppm (skin) (ACGIH)	500 ppm (ACGIH)	1000 ppm (ACGIH)	200 ppm (ACGIH)
Occupational exposure limits: Maximum allowed concentration at workplace (MAK) ³	No data	0.5 ppm (2.2 mg/m ³)	No data	1000 ppm (3200 mg/m ³)	100 ppm (310 mg/m ³)
Occupational exposure limits: Peak limitation category ³	No data	II(2)	No data	II(2)	I(4)
Occupational exposure limits: Pregnancy risk group ³	No data	D	No data	D	C
Occupational exposure limits: Skin absorption ³	No data	H	No data	No data	No data
human carcinogen ⁴	No	No	Not classified (ACGIH 2009) No	No	No data
Toxicity to aquatic life	No data	Very toxic to aquatic life with long lasting effects.	EC50 - Daphnia magna (Water flea) - 13,500.00 mg/l - 48 h	No data	Danio rerio (zebra fish) - 250 - 350 mg/l - 96 h; EC50 - Daphnia magna (Water flea) - 700 - 1,000 mg/l - 24 h
Persistence and degradability ⁵	No data	Not readily biodegradable.	No data	No data	No data
Bioaccumulative potential ⁴	No data	Cyprinodontidae - 48 h - 250 µg/l Bioconcentration factor (BCF): 2.6	No data	No data	No data

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Reproductive toxicity	No data	No data	No data	No data	No data
Mobility in soil ⁵	No data	No data	No data	No data	No data

Data source:

- 1 The International Chemical Safety Cards (ICSC) database;
- 2 American Conference of Governmental Industrial Hygienists (ACGIH);
- 3 German Health Ministry;
- 4 levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC;
- 5 Sigma-aldrich MSDS

All these four types of NTGAs are high flammable or combustible liquid with irritation effects on eyes, skins. SBA, acetone, methylal and methyl acetate are classified as 3 in UN hazard classification, mean they are flammable liquid; while NMA is classified as 6.1 means it is a toxic substance. NMA is also harmful to aquatic life. By Comparing the occupational exposure limits or called threshold limit value (TLV), the values for SBA, acetone, methylal and methyl acetate are 200ppm, 500 ppm, 1000ppm and 200 ppm respectively, while the NMA has a very low value of 0.05 ppm (skin), meaning it is very toxic. To better understanding this, most popular gasoline additives such as MTBE has a TLV of 50 ppm, ETBE has a TLV of 5 ppm, TAME has a TLV of 20 ppm (ICSC). Normally gasoline has a TLV of 300 ppm (ACGIH).

NMA is a high toxic substance, thus mixing in gasoline may increase fuel's toxicity. SBA, acetone, methylal and methyl acetate have lower toxicity generally.

Some research also pointed out the NMA is high toxic and can cause damage to central nerve system and liver, kidney.

4. Effects of NTGAs on Engine and gasoline quality

The basic physical properties of SBA, NMA, acetone, methylal, methyl acetate and gasoline are listed below and compared with gasoline.

Table 3 Basic physical properties of NTGAs and gasoline

	SBA	NMA	Acetone	Methylal	Methyl Acetate	Gasoline (EU 228:2012)
Boiling point:	112°C	194-196°C	56°C	42°C	57°C	22-52% < 70 °C; 46-72% < 100 °C; 75% < 150 °C; final boiling point) 210 oC; Distillation residue < 2%
Melting point:	-99°C	-57°C	-95°C	-105°C	-98°C	-
Relative density (water = 1):	0.87	0.99	0.8	0.86	0.93	0.72-0.78
Solubility in water, g/100ml at 20°C:	0.8	none	miscible	33	24.4	-
Vapour pressure, kPa at 20°C:	1.33	39.9	24	44	21.7	45-100
Relative vapour density (air = 1):	4.0	3.7	2.0	2.6	2.6	-
Relative density of the vapour/air-mixture at 20°C (air = 1):	1.04	1.0	1.2	1.7	1.3	-
Flash point:	17°C	79.5°C	18°C	-	13°C	-
Explosive limits, vol% in air:	1.7-9.8	-	2.2-13	1.6-17.6	3.1-16	-
Octanol/water partition coefficient as log Pow:	1.51	1.7	0.24	0	0.18	-
Auto-ignition temperature:	-	-	465°C	237°C	455°C	-
Viscosity:	-	-	0.34 mm ² /s at 40°C	-	-	-
Octane number						>95 (RON); >85 (MON)

SBA

SBA's vapour pressure is 1.33 kPa at 20 °C, which is far below gasoline's normal range of 45-100 kPa. If too much SBA is blended into gasoline, it may decrease gasoline vapour pressure to below lower limit, which can cause too much evaporation loss and decrease fuel economy. High volatility may also cause hot driveability problems.

Adding 8% SBA in 93# gasoline can increase octane number by 1-2 units. However, apparent swelling effect can be noticed when soaking machine gun 6 hours. The longer time soaked, the more serious swelling effect will be, which may cause machine gun malfunction in gas station and accident in motor vehicles (Zheng xiangdong, 2013).

NMA

Liu studied aniline type additive blending effect in gasoline (Liu Jingdong, 2012) and found that adding aniline type additive can significantly improve gasoline octane number, but also cause increasement in actual gum, shorten induction period and has swelling effects on seal ring. Higher actual gum will cause higher carbon deposit in engine; too short induction period can cause decrease in gasoline stability and poor antiknock property. The swelling of sealring may cause leakage of oil from pipes. Table 4 listed part of the result. For example, adding 5% aniline type additive into gasoline increased actual gum by 200%, decreased induction period by at least 50% and increased the swelling effect by 1300%. The addition of NMA will cause heavier copper strip erosion, which indicating it will cause engine erosion.

Table 4 Blending effect of aniline type additive on gasoline quality and seal ring

Items	Blank	Add 3% Aniline type additive	Add 5% aniline type additive
RON	87	97	99
MON	83	90	90.5
Actual gum (mg/100ml)	1	3	3
Induction period (min)	>810	520	380
Seal ring swelling	0.2	1.5	2.8

(butadiene - acrylonitrile rubber)-after 48 hours			
Seal ring swelling (butadiene - acrylonitrile rubber)-after 96 hours	0.3	3.1	4.2

The NMA contains nitrogen in its molecular formula, when burning the nitrogen will react with oxygen and release nitrogen oxides in to environment. Some study showed that 0.3 g NOx will be released into air for every 1 g NMA burning and if adding 1% aniline type additive into gasoline, the NOx emission in exhaust gas will doubled, which will cause serious air pollution..

Other research pointed that NMA concentration higher than 5% can cause sedimentation in anti-knock sensors (in engine combustion chamber) and failure in octane number reading (Zheng xiangdong, 2013).

Acetone

Acetone is a good solvent for many plastics and some synthetic fibers including resins and rubber, which are usually used in engine parts. The addition of acetone in gasoline will increase the risk of engine damage due to these parts swelling and dissoving.

Methylal

Methylal's relative density is 0.86 g/cm³, higher than gasoline. It has octane number of 83-84, which is lower in most octane number boosters. But due to its lower price, oil manufacture often uses it as gasoline blending components together with NMA to lower gasoline cost (Zheng xiangdong, 2013). Methylal is also a good solvent and has swelling effects on plastics.

Methyl Acetate

Methyl acetate is mainly used as solvent glues, paints, and nail polish removers. Blending of methyl acetate in gasoline can increase octane number by 3-4 fold, but also increases the vapor pressure, desnity and decreases drivability. (H.A. Dabbagh et al, 2013). The report of methyl acetate effects on engine is rare.

5. Conclusions and Suggestions

- The NTGAs of SBA, acetone, methylal and methyl acetate have lower toxicity, while NMA is high toxic;
- All of these NTGAs are good solvent. They are either proven or expected to have swelling effects on engine parts containing rubber and can dissolve resin due to their high solubility on plastic and fibers; Their such properties may cause engine damage or oil supply system failure.
- All these NTGAs are currently not allowed or set ban for gasoline blending in many countries such as China, Vietnam, United States and Europe due to unknown risks to human health and potential damage to vehicle systems. Further research on these aspects are recommended.



References

NTGAs sales information as gasoline additive:

<http://detail.1688.com/offer/1137514701.html>
<http://china.guidechem.com/trade/pdetail1519218.html>
<http://czbaolong0519.cn.chemnet.com/show/pdetail--1650535.html>
http://test.peswiki.com/index.php?title=Directory:Acetone_as_a_Fuel_Additive
<http://auto.anhuinews.com/system/2012/03/14/004833651.shtml>
<http://www.china-nengyuan.com/product/12081.html>
<http://china.npicp.com/tradeinfo/offerdetail/10-350-0-4666846.html>

EPA, List of Registered Gasoline Additives

Weblink: <http://www.epa.gov/otaq/fuels/registrationfuels/web-gas.htm>

US Title 40 CFR Part 79

Weblink: <http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&SID=15aa2dd04f0e4e89f963d0dcff2b2b2&rgn=div5&view=text&node=40:17.0.1.1.8&idno=40#40:17.0.1.1.8.3.1.2>

Platts, 2012: <http://www.platts.com/latest-news/oil/singapore/vietnam-bans-the-use-of-secondary-butyl-acetate-7148176>

Vietnet ban on acetone as gasoline additive: <http://www.ccin.com.cn/ccin/news/2006/09/22/8107.shtml>

Liu Jingdong, 2012, *China petroleum and chemical quantity and standard*, Issue 12, Page 38

Liu Ling, 2013, *Oil depot and gas station*, vol 20, no. 3, page 32-34.

Dong Jun, 2013, *Shandong chemical industry*, vol 42, no 5, pages 63-67

Zheng dongqian, 2013, *Oil depot and gas station*, vol 22, no. 6, pages 18-21

H.A. Dabbagh et al, 2013, *Fuel* 104 (2013) 216–223.



A handwritten signature in black ink, appearing to read 'Lei'.

DR. YANG LEI
EXECUTIVE CONSULTANT
CHEMICAL CENTRE

A handwritten signature in black ink, appearing to read 'Yan Thim'.

CHOONG YAN THIM
SENIOR PRODUCT MANAGER
ENVIRONMENTAL MONITORING
CHEMICAL & MATERIALS



Annex A

Media Reports

List of china major internet media reports on “problem gasoline” and “engine extinguish accidents”

1. <http://finance.sina.com.cn/chanjing/b/20120309/103111551251.shtml>
2. <http://finance.sina.com.cn/consume/gfpl/20130429/095915313636.shtml>
3. <http://news.hexun.com/2012/xihuo/>
4. http://auto.qq.com/a/20120223/000247_1.htm
5. <http://business.sohu.com/20120228/n336074767.shtml>



Annex B

China Gasoline Standard GB 17930-2013

Remark:

1. Data source GB 17930-2013
2. Implementation:
Transitional period of technical requirements in Table 2 is by December 31st of 2013, technical requirements in Table 1 are to be abolished from January 1, 2014;
Transitional period of technical requirements in Table 3 is by December 31st of 2017, technical requirements in Table 2 are to be abolished from January 1, 2018.

Table 1 Technical specifications and testing methods of gasoline for motor vehicles (III)

Items	Quality specifications			Testing methods
	90#	93#	97#	
Antiknock property: Research Octane Number (RON) Antiknock index (RON +MON) /2	Minimum Minimum	90 85	93 88	97 Report GB/T 5487 GB/T 503 GB/T 5487
Lead content ^a , g/L	Maximum	0.005		GB/T 8020
Boiling range distribution: 10% evaporation temperature; °C 50% evaporation temperature; °C 90% evaporation temperature; °C End boiling point; °C Residue, % (volume percentage)	Maximum Maximum Maximum Maximum Maximum	70 120 190 205 2		GB/T 6536
Evaporation pressure, kPa November 1 st to April 30 th , May 1 st to October 31 st ,	Maximum Maximum	88 72		GB/T 8017
Gum content (mg/100mL) Gum content before washing (before detergent addition) Gum content after washing	Maximum Maximum	30 5		GB/T 8019
Induction period, min.	Minimum	480		GB/T 8018
Sulphur content ^b , mg/kg	Maximum	150		SH/T 0689

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Mercaptan (qualified if meeting either of the requirements below) :		
Mercaptan-sulphur (Doctor Test) Mercaptan-sulphur content, % (mass percentage) Maximum	Pass 0.001	SH/T 0174 GB/T 1792
Copper strip corrosion (50°C, 3h), Grade Maximum	1	GB/T 5096
Water soluble acid or alkaline	None	GB/T 259
Mechanical impurity and moisture	None	eyeballing ^c
Benzene content ^d , % (Volume percentage) Maximum	1.0	SH/T 0713
Aromatics content ^e , % (Volume percentage) Maximum	40	GB/T 11132
Olefins ^e , % (Volume percentage) Maximum	30	GB/T 11132
Oxygen content, % (mass percentage) Maximum	2.7	SH/T 0663
Methanol content ^a , % (mass percentage) Maximum	0.3	SH/T 0663
Manganese content ^f , g/L Maximum	0.016	SH/T 0711
Iron content ^a , g/L Maximum	0.01	SH/T 0712
<p>a. Addition of iron or lead contained additives and methanol in gasoline for motor vehicles are not allowed;</p> <p>b. Also can use GB/T 380, GB/T 11140, SH/T 0253, SH/T 0742, ASTM D7039, Arbitration test should be based on result tested by using SH/T 0689;</p> <p>c. Add sample to 100 ml glass measuring cylinder and observe, the sample should be transparent, no suspending or precipitated mechanical impurities and moisture, arbitration test should be based on result of GB/T 511 and GB/T 260.</p> <p>d. Also can use SH/T 0693, arbitration test should use SH/T 0713;</p> <p>e. For 97# gasoline for motor vehicles, the maximum allowed aromatics is 42% by volumetric percentage under the condition that total content of olefins and aromatics are controlled below the maximum value in this table; testing method can also use NB/SH/T 0741, arbitration test should use GB/T 11132;</p> <p>f. Manganese content refers to total manganese content which manganese is only in the form of methylcyclopentadienyl manganese tricarbonyl (MMT), other types of manganese are not allowed to be added in;</p> <p>g. NB/SH/T0741 is acceptable. Arbitration test should be based on result of GB/T 11132.</p>		

Table 2 Technical specifications and testing methods of gasoline for motor vehicles (IV)

Items	Quality specifications			Testing methods	
	90#	93#	97#		
Antiknock property: Research Octane Number (RON) Antiknock index (RON +MON) /2	Minimum Minimum	90 85	93 88	97 Report	GB/T 5487 GB/T 503 GB/T 5487
Lead content ^a , g/L	Maximum	0.005			GB/T 8020
Boiling range distribution: 10% evaporation temperature, °C 50% evaporation temperature, °C 90% evaporation temperature, °C End boiling point, °C Residue, % (volume percentage)	Maximum Maximum Maximum Maximum Maximum	70 120 190 205 2			GB/T 6536
Evaporation pressure ^b , kPa November 1 st to April 30 th , May 1 st to October 31 st ,	Maximum Maximum	42-85 40-68			GB/T 8017
Gum content (mg/100mL) Gum content before washing (before detergent addition) Gum content after washing	Maximum Maximum	30 5			GB/T 8019
Induction period, min.	Minimum	480			GB/T 8018
Sulphur content ^c , mg/kg	Maximum	50			SH/T 0689
Mercaptan (qualified if meeting either of the requirements below) : Mercaptan-sulphur (Doctor Test) Mercaptan-sulphur content, % (mass percentage) Maximum		Pass 0.001			SH/T 0174 GB/T 1792
Copper strip corrosion (50°C, 3h), Grade	Maximum	1			GB/T 5096
Water soluble acid or alkaline		None			GB/T 259

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Mechanical impurity and moisture	None	Eyeballing ^d
Benzene content ^c , % (Volume percentage) Maximum	1.0	SH/T 0713
Aromatics content ^f , % (Volume percentage) Maximum	40	GB/T 11132
Olefins ^f , % (Volume percentage) Maximum	28	GB/T 11132
Oxygen content, % (mass percentage) Maximum	2.7	SH/T 0663
Methanol content ^a , % (mass percentage) Maximum	0.3	SH/T 0663
Manganese content ^g , g/L Maximum	0.008	SH/T 0711
Iron content ^a , g/L Maximum	0.01	SH/T 0712

- a Addition of iron or lead contained additives and methanol in gasoline for motor vehicles are not allowed;
- b Also can use SH/T 0794, arbitration test should use GB/T 8017;
- c. Also can use GB/T 11140, SH/T 0253, ASTM D7039, Arbitration test should be based on result tested by using SH/T 0689;
- d. Add sample to 100 ml glass measuring cylinder and observe, the sample should be transparent, no suspending or precipitated mechanical impurities and moisture, arbitration test should be based on result of GB/T 511 and GB/T 260.
- e Also can use SH/T 0693, arbitration test should use SH/T 0713;
- f. For 97# gasoline for motor vehicles, the maximum allowed aromatics is 42% by volumetric percentage under the condition that total content of olefins and aromatics are controlled below the maximum value in this table; testing method can also use NB/SH/T 0741, arbitration test should use GB/T 11132;
- g. Manganese content refers to total manganese content which manganese is only in the form of methylcyclopentadienyl manganese tricarbonyl (MMT), other types of manganese are not allowed to be added in;

Table 3 Technical specifications and testing methods of gasoline for motor vehicles (V)

Items	Quality specifications			Testing methods	
	89#	92#	95#		
Antiknock property: Research Octane Number (RON) Antiknock index (RON +MON) /2	Minimum Minimum	89 84	92 87	95 90	GB/T 5487 GB/T 503 GB/T 5487
Lead content ^a , g/L	Maximum	0.005		GB/T 8020	
Boiling range distribution: 10% evaporation temperature, °C 50% evaporation temperature, °C 90% evaporation temperature, °C End boiling point, °C Residue, % (volume percentage)	Maximum Maximum Maximum Maximum Maximum	70 120 190 205 2		GB/T 6536	
Evaporation pressure ^b , kPa November 1 st to April 30 th , May 1 st to October 31 st ,	Maximum Maximum	45-85 40-65 ^c		GB/T 8017	
Gum content (mg/100mL) Gum content before washing (before detergent addition) Gum content after washing	Maximum Maximum	30 5		GB/T 8019	
Induction period, min.	Minimum	480		GB/T 8018	
Sulphur content ^d , mg/kg	Maximum	10		SH/T 0689	
Mercaptan (qualified if meeting either of the requirements below) : Mercaptan-sulphur (Doctor Test) Mercaptan-sulphur content, % (mass percentage) Maximum		Pass 0.001		SH/T 0174 GB/T 1792	
Copper strip corrosion (50°C, 3h), Grade	Maximum	1		GB/T 5096	
Water soluble acid or alkaline		None		GB/T 259	

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Mechanical impurity and moisture	None	Eyeballing ^e
Benzene content ^f , % (Volume percentage) Maximum	1.0	SH/T 0713
Aromatics content ^g , % (Volume percentage) Maximum	40	GB/T 11132
Olefins ^g , % (Volume percentage) Maximum	24	GB/T 11132
Oxygen content, % (mass percentage) Maximum	2.7	SH/T 0663
Methanol content ^a , % (mass percentage) Maximum	0.3	SH/T 0663
Manganese content ^a , g/L Maximum	0.002	SH/T 0711
Iron content ^a , g/L Maximum	0.01	SH/T 0712
Density ^h , 20 °C, kg/m ³	720-775	GB/T 1884, GB/T 1885

- a Addition of iron or lead or manganese contained additives and methanol in gasoline for motor vehicles are not allowed;
- b Also can use SH/T 0794, arbitration test should use GB/T 8017;
- c This limit range is applicable to the whole year in Guang Dong, Guang Xi and Hai Nan provinces.
- d Also can use GB/T 11140, SH/T 0253, ASTM D7039, Arbitration test should be based on result tested by using SH/T 0689;
- e Add sample to 100 ml glass measuring cylinder and observe, the sample should be transparent, no suspending or precipitated mechanical impurities and moisture, arbitration test should be based on result of GB/T 511 and GB/T 260.
- f Also can use SH/T 0693, arbitration test should use SH/T 0713;
- g For 95# gasoline for motor vehicles, the maximum allowed aromatics is 42% by volumetric percentage under the condition that total content of olefins and aromatics are controlled below the maximum value in this table; testing method can also use NB/SH/T 0741, arbitration test should use GB/T 11132;
- h SH/T 0604 can be used to test density, arbitration test method should use GB/T 1884 and GB/T 1885.

Table A.1 Technical specifications and testing methods of 98# gasoline for motor vehicles (V)

Items	Quality specifications	Testing methods
Antiknock property: Research Octane Number (RON)	Minimum	
Antiknock index (RON +MON) /2	Minimum	98 93
		GB/T 5487 GB/T 503 GB/T 5487
Lead content ^a , g/L	Maximum	0.005
		GB/T 8020
Boiling range distribution:		
10% evaporation temperature, °C	Maximum	
50% evaporation temperature, °C	Maximum	
90% evaporation temperature, °C	Maximum	70
End boiling point, °C	Maximum	120
Residue, % (volume percentage)	Maximum	190 205 2
		GB/T 6536
Evaporation pressure ^b , kPa	Maximum	
November 1 st to April 30 th , May 1 st to October 31 st ,	Maximum	45-85 40-65 ^c
		GB/T 8017
Gum content (mg/100mL)		
Gum content before washing (before detergent addition)	Maximum	30
Gum content after washing	Maximum	5
		GB/T 8019
Induction period, min.	Minimum	480
		GB/T 8018
Sulphur content ^d , mg/kg	Maximum	10
		SH/T 0689
Mercaptan (qualified if meeting either of the requirements below) :		
Mercaptan-sulphur (Doctor Test)		
Mercaptan-sulphur content, % (mass percentage)		Pass
Maximum		0.001
		SH/T 0174 GB/T 1792
Copper strip corrosion (50°C, 3h), Grade	Maximum	1
		GB/T 5096
Water soluble acid or alkaline		None
		GB/T 259

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Mechanical impurity and moisture	None	Eyeballing ^e
Benzene content ^f , % (Volume percentage) Maximum	1.0	SH/T 0713
Aromatics content ^g , % (Volume percentage) Maximum	40	GB/T 11132
Olefins ^g , % (Volume percentage) Maximum	24	GB/T 11132
Oxygen content, % (mass percentage) Maximum	2.7	SH/T 0663
Methanol content ^a , % (mass percentage) Maximum	0.3	SH/T 0663
Manganese content ^a , g/L Maximum	0.002	SH/T 0711
Iron content ^a , g/L Maximum	0.01	SH/T 0712
Density ^h , 20 °C, kg/m ³	720-775	GB/T 1884, GB/T 1885

- a Addition of iron or lead or manganese contained additives and methanol in gasoline for motor vehicles are not allowed;
- b Also can use SH/T 0794, arbitration test should use GB/T 8017;
- c This limit range is applicable to the whole year in Guang Dong, Guang Xi and Hai Nan provinces.
- e. Also can use GB/T 11140, SH/T 0253, ASTM D7039, Arbitration test should be based on result tested by using SH/T 0689;
- e. Add sample to 100 ml glass measuring cylinder and observe, the sample should be transparent, no suspending or precipitated mechanical impurities and moisture, arbitration test should be based on result of GB/T 511 and GB/T 260.
- f Also can use SH/T 0693, arbitration test should use SH/T 0713;
- g. For 98# gasoline for motor vehicles, the maximum allowed aromatics is 42% by volumetric percentage under the condition that total content of olefins and aromatics are controlled below the maximum value in this table; testing method can also use NB/SH/T 0741, arbitration test should use GB/T 11132;
- h. SH/T 0604 can be used to test density, arbitration test method should use GB/T 1884 and GB/T 1885.

Annex C

Sinopec's additional test parameters of gasoline purchased from other companies

Data source: Dong Jun, Shandong Chemical Industry, Vol 42, Issue 5, Page 63-67

表 1 外采汽油追加检测指标

项目	质量指标	试验方法
气味	无异常	由三名持证质检员判断
馏程	无异常(轻组分多 或重组分多)	GB/T 6536
未洗胶质/(mg/100mL)	≤30	
	30~20 洗后 胶质≤2.5	GB/T 8019
蒸汽压/kPa	≥45 (温度>15℃)℃ ≥55 (5℃≤温度≤15℃) ≥65 (温度<5℃)	GB/T 8017
蒸发指数 DI 值	≤570 ≤565 ≤560	计算公式: $DI = 1.5 \cdot T_{10} + 3 \cdot T_{50} + T_{90} + 11 \cdot \text{氧含量}\%$ (质量分数)
N-甲基苯胺	未检出	中红外机
对甲苯胺	未检出	中红外机
间甲苯胺	未检出	中红外机
邻甲苯胺	未检出	中红外机
总胺类	未检出	中红外机
甲缩醛	未检出	中红外机及 SH/T 0663 联合使用
烯烃含量/% (体积分数)	≥8	GB/T 11132
碳酸二甲酯	未检出	中红外机与 SH/T 0663 或 SH/T 0713 联合使用

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Annex D

EN 228:2012 Automotive fuels – Unleaded petrol – Requirements and test methods				
Property	Units	Limits		Test Method
		Min	Max	
Research octane number, RON		95,0	-	EN ISO 5164/ ASTM D2699/IP237
Motor octane number, MON		85,0	-	EN ISO 5163/ ASTM D2700/IP236
Lead content	mg/l	-	5,0	EN 237/ASTM D3341
Density (at 15°C)	kg/m ₃	720,0	775,0	EN ISO 3675/D1298/ IP 160 EN ISO 12185/D4052
Sulfur content	mg/kg g	-	10,0	EN ISO 13032 /ISO13032 EN ISO 20846/ASTM D5453
Manganese content Until 31.12.2013 From 01.01.2014	mg/l	-	6,0 2,0	EN 16135/ASTM D 3831 EN 16136
Oxidation stability	minutes	360	-	EN ISO 7536/ASTM D525/ IP 40 ASTM D 7525
Existent gum content (solvent washed)	mg /100 ml	-	5	EN ISO 6246/ASTM D381
Copper strip corrosion (3h at 50 °C)	rating	Class 1		EN ISO 2160/ASTM D130/ IP 154
Appearance	-	Clear and bright		Visual inspection
Hydrocarbon type content - olefins - aromatics	% (V/V)	- -	18,0 35,0	EN 15553/ASTM D1319/ IP156 EN ISO 22854/ASTM D6839
Benzene content	% (V/V)	-	1,00	EN 238/ASTM D4053/ASTM D6277 EN 12177/ASTM D3606 EN ISO 22854/ASTM D6839

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Unleaded petrol with a maximum oxygen content of 3,7 % (m/m)									
Oxygen content	% (m/m)	-						3,7	EN 1601/ASTM D5599
Oxygenates content	% (V/V)	-						3,0	
- methanol		-						10,0	EN 13132/ ASTM D4815 EN ISO 22854/ ASTM D6839
- ethanol								12,0	
- iso-propyl alcohol								15,0	
- iso-butyl alcohol								15,0	
- tert-butyl alcohol								22,0	
- ethers (5 or more C atoms)								15,0	
- other oxygenates									
Vapour pressure (VP)	kPa, min kPa, max	Limits						EN 13016-1/ ASTM D5191	
		Class A	Class B	Class C/C1	Class D/D1	Class E/E1	Class F/F1		
		45,0 60,0	45,0 70,0	50,0 80,0	60,0 90,0	65,0 95,0	70,0 100,0		
% evaporated at 70 °C , E70	% (V/V), min	22,0	22,0	24,0	24,0	24,0	24,0	EN ISO 3405/ ASTM D86	
	% (V/V), max	50,0	50,0	52,0	52,0	52,0	52,0		
% evaporated at 100 °C , E100	% (V/V), min	46,0	46,0	46,0	46,0	46,0	46,0	EN ISO 3405/ ASTM D86	
	% (V/V), max	72,0	72,0	72,0	72,0	72,0	72,0		
% evaporated at 150 °C , E150	% (V/V), min	75,0	75,0	75,0	75,0	75,0	75,0	EN ISO 3405/ ASTM D86	
Final Boiling point FBP	°C, max	210	210	210	210	210	210	EN ISO 3405/ ASTM D86	
Distillation residue	% (V/V), max	2	2	2	2	2	2	EN ISO 3405/ ASTM D86	
Vapour lock index (VLI), (10VP + 7 E70)	index, max	-	-	C -	D -	E -	F -		
Vapour lock index (VLI), (10VP + 7 E70)	index, max			C1 1064	D1 1164	E1 1214	F1 1264		

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Unleaded petrol with a maximum oxygen content of 2,7 % (m/m)									
Oxygen content	% (m/m)	-						2,7	EN 1601/ASTM D5599 EN 13132/ ASTM D4815 EN ISO 22854/ ASTM D6839
Oxygenates content	% (V/V)	-						3,0	
- methanol - ethanol		-						5,0	
- iso-propyl alcohol - iso-butyl alcohol - tert-butyl alcohol - ethers (5 or more C atoms) - other oxygenates		}			Volume blending restricted to 2,7% (m/m) maximum oxygen content				
Vapour pressure (VP)	kPa, min kPa, max	Limits						EN 13016-1/ ASTM D5191	
		Class A	Class B	Class C/C1	Class D/D1	Class E/E1	Class F/F1		
		45,0 60,0	45,0 70,0	50,0 80,0	60,0 90,0	65,0 95,0	70,0 100,0		
% evaporated at 70°C, E70	% (V/V), min	20,0	20,0	22,0	22,0	22,0	22,0	EN ISO 3405/ ASTM D86	
	% (V/V), max	48,0	48,0	50,0	50,0	50,0	50,0		
% evaporated at 100 °C, E100	% (V/V), min	46,0	46,0	46,0	46,0	46,0	46,0	EN ISO 3405/ ASTM D86	
	% (V/V), max	71,0	71,0	71,0	71,0	71,0	71,0		
% evaporated at 70°C, E150	% (V/V), min	75,0	75,0	75,0	75,0	75,0	75,0	EN ISO 3405/ ASTM D86	
Final Boiling point FBP	°C, max	210	210	210	210	210	210	EN ISO 3405/ ASTM D86	
Distillation residue	% (V/V), max	2	2	2	2	2	2	EN ISO 3405/ ASTM D86	
Vapour lock index (VLI), (10VP + 7 E70)	index, max	-	-	C -	D -	E -	F -		
Vapour lock index (VLI), (10VP + 7 E70)	index, max			C1 1050	D1 1150	E1 1200	F1 1250		

Annex E

Worldwide Fuel Charter, 2013, WWFC, Category 4

Fuel quality category 4 is for market with advanced requirements for emission control. For example, market requiring US Tier 2, US Tier3 (pending), US 2007/2010 Heavy Duty On-Highway, US Non-Road Tier 4, California LEV II, EURO 4/IV, EURO 5/V, EURO 6/VI, JP 2009 or equivalent emission standards.

PROPERTIES	UNITS	LIMIT	
		Min.	Max.
'91 RON' ⁽¹⁾	Research Octane Number	91.0	
	Motor Octane Number	82.5	
'95 RON' ⁽¹⁾	Research Octane Number	95.0	
	Motor Octane Number	85.0	
'98 RON' ⁽¹⁾	Research Octane Number	98.0	
	Motor Octane Number	88.0	
Oxidation stability	minutes	480	
Sulphur	mg/kg ⁽²⁾		10
Trace metal ⁽³⁾	mg/kg		1 or non-detectable, whichever is lower
Oxygen ⁽⁴⁾	% m/m		2.7 ⁽⁵⁾
Olefins	% v/v		10.0
Aromatics	% v/v		35.0
Benzene	% v/v		1.0
Volatility		See Tables, page 8	
Sediment (total particulate)	mg/l		1
Unwashed gums ⁽⁶⁾	mg/100 ml		30
Washed gums	mg/100 ml		5
Density	kg/m ³	715	770
Copper corrosion rating			Class 1
Silver corrosion rating			Class 1
Appearance		Clear and bright; no free water or particulates	
Fuel injector cleanliness, Method 1, or	% flow loss		5
Fuel injector cleanliness, Method 2	% flow loss		10
Particulate contamination, size distribution	Code rating		18/16/13 per ISO 4406
Intake-valve sticking	pass/fail	Pass	
Intake valve cleanliness II			
Method 1 (CEC F-05-A-93), or	avg. mg/valve		30
Method 2 (ASTM D5500), or	avg. mg/valve		50
Method 3 (ASTM D6201)	avg. mg/valve		50
Combustion chamber deposits ⁽⁶⁾			
Method 1 (ASTM D6201), or	% of base fuel		140
Method 2 (CEC-F-20-A-98), or	mg/engine		2500
Method 3 (TGA FLTM BZ154-01)	% mass @ 450°C		20

Footnotes:

- ⁽¹⁾ Three octane grades are defined for maximum market flexibility; availability of all three is not needed.
- ⁽²⁾ The unit mg/kg is often expressed as ppm.
- ⁽³⁾ Examples of trace metals include, but are not limited to, Cu, Fe, Mn, Na, P, Pb, Si and Zn. Another undesirable element is Cl. No trace metal should exceed 1 mg/kg. No intentional addition of metal-based additives is allowed.
- ⁽⁴⁾ Where oxygenates are used, ethers are preferred. Methanol is not permitted.
- ⁽⁵⁾ By exception, up to 10% by volume ethanol is allowed if permitted by existing regulation. Blendstock ethanol should meet the E100 Guidelines published by the WWFC Committee. Fuel pump labelling is recommended for gasoline-ethanol blends to enable customers to determine if their vehicles can use the fuel.
- ⁽⁶⁾ To provide flexibility (for example, to enable the use of detergency additives that increase unwashed gum levels), the fuel may comply with either the Unwashed Gum limit or the Combustion Chamber Deposits limit.

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