

NATIONAL FUEL QUALITY STANDARDS

Measuring Cetane Number: options for diesel and alternative diesel fuels

Discussion Paper

Prepared by

**The Department of the
Environment and Heritage**

April 2004



Australian Government

Department of the Environment and Heritage

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1. INTRODUCTION

1.1 Cetane

Cetane Number is a measure of the readiness of a fuel to auto-ignite when injected into a diesel engine. It relates to the delay between when fuel is injected into the cylinder and when ignition occurs. Cetane Number is usually measured directly using a test engine.

In contrast, the Cetane Index is a mathematical estimation of the cetane number based on distillation temperatures and density. Cetane indices are applicable to petroleum distillates but not to biodiesel and other diesel alternatives.

1.2 Mandated Cetane Limit for Automotive Diesel

The *Fuel Standard (Automotive Diesel) Determination 2001* sets a Cetane Index limit of 46 (min). This limit came into effect on 1 January 2002.

A Cetane Index was specified for automotive or petroleum diesel rather than a Cetane Number because stakeholder feedback indicated that Cetane Number could not be easily measured. The Department was advised that the equipment required to measure Cetane Number, ie a cetane engine, was not available in Australia at the time. The simplicity of determining the Cetane Index has seen it dominate specifications and be routinely used for quality control.

1.3 Cetane Index not applicable to all Automotive Diesel

The addition of cetane enhancers to automotive diesel to improve cetane quality means that the cetane index is no longer applicable to that fuel. The index will give an estimation of base auto-ignition quality but will not indicate the effects of the cetane improver additives.

1.4 Mandated Cetane Limit for Biodiesel

In September 2003, the Government introduced a national fuel quality standard for biodiesel through the *Fuel Standard (Biodiesel) Determination 2003*. From 18 September 2004, the Determination will limit the cetane number of biodiesel to a minimum of 51.

1.5 Statement of the Issue

As noted above, the Department is aware of a lack of infrastructure and experience in Australia for testing Cetane Number, either of diesel or biodiesel. This will also be the case for other alternative diesel fuels such as diesohol (also called E-diesel) and diesel-water emulsions.

The Department is now seeking comment on options to balance the apparent lack of infrastructure and experience in testing the Cetane Number of these fuels with the need for both industry and government to test this fuel quality parameter.

1.6 Objectives of this paper

The objectives of this paper are to:

- identify any Australian testing facilities and infrastructure for determining the Cetane Number of diesel and diesel alternatives;
- identify alternatives to traditional Cetane Number testing methods such as ignition quality testing technology or the establishment of ‘cetane indices’ for alternative diesel fuels; and
- seek comment from stakeholders on appropriate methods of managing cetane as a fuel quality parameter.

This information will be used to inform future policy decisions on managing cetane through the *Fuel Quality Standards Act 2000*.

These issues are discussed further in terms of their impacts on the regulation of cetane properties of diesel and alternative diesel fuels and the implications for stakeholders.

Please Note: This is **not** a position paper. This is **not** a request for tender or a request for quotation.

1.7 Request for comment

The Department of the Environment and Heritage invites comment and seeks information from stakeholders on the issues raised in this paper.

Your comments are invited by **30 April 2004**.

Comments received will be treated as public information unless marked as confidential. It is intended that the feedback will be posted in a web forum on the Department website.

Please send comments, preferably electronically in Word format, to

email: fuel.quality@deh.gov.au

or

Clean Fuels and Vehicles Section
Department of the Environment and Heritage
GPO Box 787
CANBERRA ACT 2601

2 BACKGROUND

2.1 Fuel Quality Standards Act 2000

The Australian Government, through the Department of the Environment and Heritage, administers the *Fuel Quality Standards Act 2000* (the Act) which provides the legislative framework for setting national fuel quality standards.

The main objects of this Act are to:

- a) regulate the quality of fuel supplied in Australia in order to:
 - i. reduce the level of pollutants and emissions arising from the use of fuel that may cause environmental and health problems;
 - ii. facilitate the adoption of better engine technology and emissions control technology; and
 - iii. allow the more effective operation of engines; and
- b) ensure that, where appropriate, information about fuel is provided when the fuel is supplied.

This legislation provides the framework for the harmonisation of Australian fuel quality standards with international standards.

This legislation provides the Minister for the Environment and Heritage with the power to make determinations under section 21 of the Act in relation to fuel quality and fuel quality information standards. Determinations may be amended from time to time. Compliance by industry with standards made under the Act is compulsory and there are penalties attached to the offences under the Act.

2.2 Current compliance activities

The Department uses an independent contracted laboratory to undertake petrol, diesel and biodiesel fuel quality analysis for monitoring, compliance and enforcement of the Act. This laboratory currently sends biodiesel samples overseas for cetane number analysis, as there are no known cetane engine facilities in Australia. Despite the cost associated with this, it is a suitable short-term arrangement as there are currently only a small number of commercial suppliers of biodiesel in Australia. However with more production due to start and supplies to increase in the near future, testing of cetane number overseas does not appear a cost-effective long-term option.

2.3 Cetane

Cetane is an integral environmental and operability parameter in diesel fuels. The *Fuel Standard (Automotive Diesel) Determination 2001* came into effect in January 2002 and sets a cetane index limit of 46(min). The *Fuel Standard (Biodiesel) Determination 2003* came into effect in September 2003. The determination sets a cetane number limit of 51(min) and this parameter is due to come into effect on 18 September 2004.

In compression ignition diesel engines the cetane number is the measure of ignition promotion, an indication of the smoothness of combustion. In a spark ignited gasoline engine the ignition quality of gasoline is measured by the octane number, which is a rating of ignition delay.¹ Higher cetane numbers indicate shorter times between injection of the fuel and its ignition. Higher cetane numbers have been associated with reduced engine roughness and with lower starting temperatures for engines. Good ignition from a high cetane number assists in easy starting, starting at low temperature, low ignition pressures, and smooth operation with lower knocking characteristics. Low cetane fuel with poor ignition qualities causes misfiring, tarnish on pistons, engine deposits, rough operation and higher knocking (thus noise level).²

Cetane Number should not be confused with the Cetane Index. The Cetane Index predicts the Cetane Number from equations derived for petroleum distillates and is not applicable to diesel containing cetane additives, biodiesel or other alternative diesel fuels.

2.4 Impact on engine performance

Cetane number requirements for diesel vehicles depend on engine design, size, nature of speed and load variations, and on starting and atmospheric conditions. High cetane number fuels enable an engine to be started more easily at lower air temperatures, reduce white smoke exhaust, and reduce diesel knock. With a low cetane number fuel, engine knock noise and white smoke can be observed during engine warm-up, especially in severe cold weather. If this condition is allowed to continue for any prolonged period, harmful fuel derived deposits will accumulate within the combustion chamber. While an engine may appear to operate satisfactorily on low cetane number fuel, after prolonged use, severe mechanical damage (e.g. piston erosion) can result.

An increase in natural cetane can contribute towards reduced fuel consumption. To avoid excessive dosage of diesel fuel with cetane additives, the World Wide Fuel Charter (WWFC) recommends that the difference between the cetane index and the cetane number be no greater than 3.² (Generally large quantities of additive are not added for economic reasons, as the additive is expensive).³ This has also been general practice to prevent having the general character of the fuel too far from that implied by a certain cetane number. Starting and white smoke emissions appear to be related primarily to ignition delay, and so cetane improved fuels generally perform as well as natural fuels of the same cetane number.⁴

2.5 Environmental and health effects

Experiments documented by the European Program on Emissions, Fuels and Engine Technologies (EPEFE) study show a direct relationship between exhaust emissions and cetane number of diesel fuel. An increase in cetane number resulted in a decrease in carbon monoxide and hydrocarbon emissions (notably in light duty engines), nitrogen

¹ Midwest Biofuels. Biodiesel Cetane Number Engine Testing Comparison Cetane Index Number. Midwest Biofuels, USA, 1994.

² AAMA et al, 1998, WWFC

³ Pers comm., Peter Nash, Asia Pacific Petroleum Services, March 2000.

⁴ CONCAWE Report No. 99/55.

oxides emissions (notably in heavy duty engines), as well as benzene, 1,3 butadiene, formaldehyde and acetaldehyde emissions from light duty engines.⁵

While the EPEFE study found that particle emissions increased from light duty vehicles as the cetane number increased (no significant effect was seen in heavy duty engines) other research has suggested that an increase in cetane number can lead to lowered particle emissions.⁶

According to the EPEFE study, cetane number and density of diesel fuel are the two most influential of the fuel parameters in relation to managing emissions from light duty diesel vehicle engines. It also found that after polyaromatic hydrocarbons, cetane number is the most influential parameter in relation to managing emissions from heavy-duty diesel engines.

3 MEASURING CETANE

3.1 Automotive diesel

Cetane number is measured on a test engine and reflects the effects of any cetane improver additives. A simpler proxy for the purposes of quality control of diesel fuel without cetane improver additives is the cetane index. This index provides an indication of the 'natural' cetane of the fuel. It is derived through a calculation process based on the fuel density and distillation parameters. It gives an estimation of the base auto-ignition quality of the fuel, but does not indicate the effects of cetane improver additives.⁷

Prior to the introduction of the automotive diesel standard under the Act, the Australian Standard *AS3570-1998 Automotive diesel fuel* was referred to by industry. This standard set a limit for cetane number of 45(min) and referred to test method ASTM D613 Standard Test Method for Cetane Number of Diesel Fuel Oil. This test method determines the rating of diesel fuel oil in terms of an arbitrary scale of cetane numbers using a standard single cylinder, four-stroke cycle, variable compression ratio, indirect injected diesel engine.⁸ The standard was voluntary with no legislative backing. The standard did not specify a cetane index.

However, at the time of setting the national diesel standard under the Act, Australian refiners reported against cetane index of their fuel as opposed to cetane number. Justification for this practice was based on:

- cetane index being relatively easy to measure through a correlation of crude properties;

⁵ EPEFE, 1995, Chapter 6, p.7.

⁶ IPCS, 1996, Environmental Health Criteria 171, Diesel Fuel and Exhaust Emissions.

⁷ Mittlbach, M. Diesel derived from vegetable oils, VI: Specification and Quality Control of Biodiesel. Bioresource Technology 1996. 56:7-11.

⁸ [http://www.astm.org/cgi-bin/SoftCart.exe/STORE/filtrexx40.cgi?U+mystore+xsct4503+-L+D613NOT:\(STATUS:<NEAR/1>:REPLACED\)+/usr6/htdocs/astm.org/DATABASE.CART/REDLINE_PAGES/D613.htm](http://www.astm.org/cgi-bin/SoftCart.exe/STORE/filtrexx40.cgi?U+mystore+xsct4503+-L+D613NOT:(STATUS:<NEAR/1>:REPLACED)+/usr6/htdocs/astm.org/DATABASE.CART/REDLINE_PAGES/D613.htm)

- cetane number measurement involving a more costly laboratory based test, which was claimed as being notoriously unreliable in terms of both bench test reliability and reproducibility; and
- it was argued by industry that the method used to calculate cetane index (ASTM D4737 – Test Method for Calculated Cetane index by Four Variable Equation (IP 380)) provided good estimates of the ‘natural’ cetane or combustion characteristics of the fuel.⁹

As stated above, the *Fuel Standard (Automotive Diesel) Determination 2001* came into effect in January 2002 and, to be consistent with refinery practice a cetane index limit of 46(min) was set. The determination refers to test methods ASTM D976 – Standard Test Methods for Calculated Cetane Index of Distillate Fuels and ASTM D4737 – Standard Test Method for Calculated Cetane index by Four Variable Equation.

Issue for Comment

Are you aware of any equipment available in Australia that may be used to test diesel to ASTM D613 (Standard Test Method for Cetane Number of Diesel Fuel Oil)?

This test method requires use of a standard single cylinder, four-stroke cycle, variable compression ratio, indirect injected diesel engine.

3.2 Biodiesel

The cetane number of biodiesel depends on the distribution of fatty acids in the original oil or fat from which it was produced. The longer the fatty acid carbon chains and the more saturated the molecules, the higher the cetane number.¹⁰

Biodiesel, from various feedstocks, tend to have higher cetane numbers than diesel so would therefore tend to improve operation of the engine when compared to diesel based on this parameter alone.

When initial consultation was undertaken in developing the biodiesel standard, biodiesel proponents advised the Department that they were supportive of a national quality standard and that they were currently able to or would have the ability to meet international standards for biodiesel at the time (i.e. German DIN, European EN and/or US ASTM biodiesel quality standards). Cetane number limits in these standards range from 47(min) to 51(min). Indications that quality specifications could be met was understood to mean that producers could assure the quality of their biodiesel, i.e. they had the ability to test for each parameter or could procure services for testing of each parameter.

⁹ Setting National Fuel Quality Standards – Paper 2 – Proposed Standards for Fuel Parameters (Petrol and Diesel) – Environment Australia, May 2000. Section 5.5.

¹⁰ Van Gerpen J. et al. Determining the Influence of Contaminants on Biodiesel Properties. Iowa State University for The Iowa Soybean Promotion Board. 1996.

However feedback from the *Setting National Fuel Quality Standards Paper 6 – National Standard for Biodiesel – March 2003* discussion paper revealed that there is apparently no cetane engine in Australia¹¹. The subsequent consultation paper, the *Proposed Standard for Fuel Parameters (Biodiesel) Commonwealth Position Paper, August 2003* stated that:

“Testing for Cetane number requires a Cetane engine. The Department of the Environment and Heritage has been informed that there is no cetane engine in operation in Australia. A cetane engine costs approximately \$0.5 million, and requires substantial experience to operate properly and consistently. The Commonwealth proposes to delay this specification until September 2004 to allow for this requirement to be met by industry.”¹²

Issue for Comment

Are you aware of any equipment available in Australia that may be used to test the Cetane Number of biodiesel to ASTM D613 (Standard Test Method for Cetane Number of Diesel Fuel Oil) or EN ISO 5165 (Petroleum products – Determination of the ignition quality of diesel fuels – cetane engine method)?

3.3 Diesohol

Diesel-alcohol blends are known by a number of names – including E-diesel, M-diesel, Oxy-diesel and diesohol. This paper uses the term diesohol, which is defined in the *Fuel Quality Standards Regulations 2001* (the Regulations) as a “blend primarily comprising diesel and an alcohol”. Diesohol is used in compression ignition engines as an alternative diesel fuel.

The cetane number of neat alcohols is very low (8 for ethanol and 3 for methanol) and as such they are extremely poor compression ignition engine fuels¹³. The cetane number of diesel in contrast is usually around the high 40’s – low 50’s. The cetane number of diesohol is dependent on the ignition quality of the base diesel, the percentage of the alcohol in the blend, and the addition of cetane improver additives.

Cetane will be important to manage for diesohol, especially given the potential for alcohols to reduce cetane.

Cetane number, as opposed to cetane index, appears to be the appropriate measure for diesohol as it reflects the addition of cetane improvers.

¹¹ AIP submission <http://www.deh.gov.au/atmosphere/biodiesel/submissions/pubs/aip.pdf> p9 - 3.1.

¹² *Proposed Standard for Fuel Parameters (Biodiesel) Commonwealth Position Paper, August 2003*

¹³ U.S. Department of Energy, 1991

3.4 Diesel-Water emulsions

Diesel-water emulsions are another alternative diesel fuel. The fuel generally consists of approximately 82-85% by volume diesel, 13-15% by volume water and 2% by volume proprietary additive.

One of the proprietors of this type of fuel states that “to achieve best performance it is suggested that the base diesel fuel have a > 48 cetane level.”¹⁴

Issue for Comment

Are you aware of appropriate test methods for determining the cetane number of diesel and/or emulsified diesel?

Issue for Comment

Do you have any information on alternatives to 'traditional' Cetane Number testing methods, such as ignition quality testing?

Issue for Comment

Is it practical or desirable to manage cetane by developing indices for alternative diesel fuels and diesel with cetane additives?

¹⁴ “Delivering fresher air by the gallon – PuriNOx™ performance systems”, Lubrizol Corporation 2000.

4 OPTIONS FOR DETERMINING CETANE NUMBER

Detailed below are some preliminary options for determining the Cetane Number of diesel and alternative diesel fuels. Likely advantages and disadvantages of each option are presented.

Please Note: The following options are **not** Government positions or proposals. The Department of the Environment and Heritage seeks your comment on appropriate methods of managing cetane as a fuel quality parameter. The Department recognises that there may be other options that warrant consideration that are not discussed here and invites stakeholders to provide any further information.

1. Send samples overseas for cetane number analysis

Likely advantages:

Suitable short term solution whilst production and supply levels are low.
Assurance that diesel and diesel alternatives meet cetane specifications.

Likely disadvantages:

Not feasible in the long term due to cost.
Expensive, especially for smaller alternative diesel producers.
Lengthy reporting timeframe on results.
Delays in releasing fuel to market.

2. Buy cetane engine

Likely advantages:

Long term solution.
Comparable to overseas analysis.
Allows local analysis of cetane number with cost and time savings.

Likely disadvantages:

Cost (approx. \$500,000¹⁵), ongoing maintenance and operating costs.
Requires trained staff with high-level expertise.
Reliability and accuracy of results.
Ownership arrangements.
Expertise for operation.

¹⁵ AIP submission <http://www.deh.gov.au/atmosphere/biodiesel/submissions/pubs/aip.pdf> p9 - 3.1.

3. Buy new/alternative cetane testing technology

Likely advantages:

Cheaper and easier to use than cetane engine.
Allows local analysis of cetane number with cost and time savings.

Likely disadvantages:

Laboratory staff require training.
Compatibility with established test methods.

4. Develop cetane indices

Likely advantages:

Potentially cheaper in the long term than testing cetane number using combustion process.

Likely disadvantages:

May not be achievable.
If achievable may take a long time to develop.
Specialist knowledge of fuel may be chemistry required.
Limited expertise and experience in Australia on alternative diesel fuel quality chemistry and analysis.

Issue for Comment
What is the appropriate means of determining the cetane number of Australian diesel and alternative diesel fuels or a surrogate in place of the direct measurement of cetane number?