

# **SETTING NATIONAL FUEL QUALITY STANDARDS**

Paper 7

## **Discussion Paper on Diesel**

Prepared by

**Department of the Environment and Heritage**

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Department of the Environment and Heritage  
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Canberra ACT 2601

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The Department of the Environment and Heritage commissioned Duncan Seddon & Assoc Pty Ltd and SWB Consulting to prepare technical reports on diesohol, its use as a transport fuel, and its impact on vehicle emissions and engine operability. These reports have assisted in the development of this discussion paper. The views and opinions expressed in this publication do not necessarily reflect those of the Australian Government or the Minister for the Environment and Heritage.

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## PREFACE

The development of fuel quality standards for alternative fuels, such as diesohol, is an important part of the Government's continuing work to improve air quality and deliver cleaner fuels. This paper examines the options for regulating the quality of diesohol – a blend of diesel and ethanol – and we welcome your feedback.

Diesohol is a new fuel for Australia and is not currently used at a commercially significant level. It is not subject to any formal or accepted industry quality standards, either in Australia or internationally. For technical reasons, it appears that diesohol is likely to remain a niche fuel, for example, used in centrally refuelled fleets.

Transport is the most significant contributor to ambient air pollution in urban Australia. The 1997 Australian Academy of Technological Sciences and Engineering report *Urban Air Pollution In Australia*, commissioned by the Department of the Environment and Heritage, found that new, tighter vehicle emission standards were 'the long-term foundation for maintaining and improving air quality'. The Prime Minister, in his 1997 statement, *Safeguarding the Future: Australia's response to Climate Change* identified harmonisation with international vehicle emission standards as a goal of the Government – with a target date of 2006. The timetable for vehicle standards harmonisation was set, in May 1999, as part of the *Measures for a Better Environment* initiative under the New Tax System for Australia.

Australian Government environment, greenhouse, transport and industry agencies have, therefore, been working together with relevant industry sectors to improve the emissions performance of the transport fleet. The Government has already implemented new fuel quality standards for petrol and diesel, biodiesel and LPG under the national *Fuel Quality Standards Act 2000*. The Act provides the framework for the implementation of improved fuel quality, outlining the way fuel quality is specified and managed. These standards are a major achievement and contribute significantly to reduction of greenhouse gas emissions and air pollutants from Australian road transport.

Any proposal to improve, and mandate, the quality of fuels used in Australia, has the potential to impact on a wide range of stakeholders. Wide ranging stakeholder input will help achieve a balanced decision on the future of diesohol as a transport fuel. The Department looks forward to considering your views and asks you to make a submission to:

Clean Fuels and Vehicles Section  
Department of the Environment and Heritage  
PO Box 787  
Canberra ACT 2601

Fax: 02 6274 1640  
Email: [fuel.quality@ea.gov.au](mailto:fuel.quality@ea.gov.au)

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# 1 INTRODUCTION

The Australian Government regulates fuel quality through the *Fuel Quality Standards Act 2000* (FQS Act). The objectives of the FQS 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; and
  - (ii) facilitate the adoption of better engine technology and emission 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.

Fuel quality standards for petrol and automotive diesel came into effect on 1 January 2002, and standards for biodiesel and LPG came into effect on 18 September 2003 and 1 March 2004 respectively. The current diesel standard can be found at Appendix A, and more detailed information on standards is presented on the website of the Australian Government Department of the Environment and Heritage (the Department) at:

- <http://www.deh.gov.au/atmosphere/transport/index.html>.

This paper examines the options for setting a standard for diesohol - diesel-alcohol blends. SWB Consulting were commissioned by the Department to examine the key technical issues relating to these blends.

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”.

## 1.1 Objective of the paper

Diesohol is used in compression ignition engines but is not subject to any formal or accepted industry quality standards, either in Australia or internationally. This paper aims to:

- generate discussion around the options for formally regulating the quality of diesohol; and
- inform the Australian Government’s position on this issue.

This discussion paper should be used to inform stakeholders’ views about diesohol and its use as a transport fuel. It does not advocate the use of particular diesohol blends.

## 1.2 Structure of the paper

The information in this paper is arranged as follows -

- Section 2 summarises the issues for comment presented throughout the paper;
- **Part A** focuses on the background to managing fuel quality and the options for regulating diesohol:
  - Section 3 provides background to the fuel quality standards;
  - Section 4 outlines the key issues around the manufacture and use of diesohol; and
  - Section 5 provides a discussion of the different options for regulating diesohol,
- **Part B** examines the technical issues related to developing a fuel quality standard for diesohol:
  - Section 6 addresses those parameters that would be critical to manage; and
  - Section 7 addresses those parameters that are non-critical but may be necessary to manage.

**Note:** Option 5.4, the introduction of a diesohol standard under the FQS Act, assumes the development of one standard covering the two blending approaches covered in this paper.

## 1.3 Call for public submissions

In order to ensure that the most appropriate fuel quality standards are adopted in Australia, comments on the issues presented in this discussion paper are sought from all interested stakeholders and members of the public.

Comment on any matter presented in this paper is welcome. However, particular attention should be directed to questions highlighted as boxed text (summarised in Section 2).

Unless marked as ‘Confidential’, all submissions will be treated as public documents, posted on the Australian Government Department of the Environment and Heritage (DEH) website and provided to the Fuel Standards Consultative Committee (FSCC).

Written comments are requested by 7 July 2004 and should be sent electronically as an attached word document to: [fuel.quality@deh.gov.au](mailto:fuel.quality@deh.gov.au). Alternatively, submissions can be posted to:

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

## 2 ISSUES FOR COMMENT

Collated below are the main issues for which stakeholder comment is sought in relation to:

- Part A - the options for regulating diesohol; and
- Part B - the technical aspects to developing a fuel quality standard for diesohol.

### ***PART A – Options for regulating diesohol***

1. Stakeholders are asked to provide comment on:
  - the issue of vehicle warranties and the use of diesohol; and
  - if applicable, those properties of diesohol that may lead to the voiding of warranties.
2. Stakeholders are asked to provide comment on their preferred option for the regulation of diesohol:
  - a) no diesohol fuel quality standard (business as usual);
  - b) encourage a voluntary industry diesohol fuel quality standard;
  - c) encourage State and Territory diesohol fuel quality standards; and
  - d) introduce a national diesohol fuel quality standard under the FQS Act.
3. Stakeholders are asked to provide comment on the preliminary impact analysis of implementing a fuel quality standard for diesohol (presented in Section 5.4).

### ***PART B – Technical issues related to a fuel quality standard for diesohol***

#### Critical parameters

4. Stakeholders are asked to comment on:
  - the appropriateness of setting a maximum acid value (total) of 0.08 mg KOH/g; and
  - the appropriateness of test methods ASTM D974 and ASTM D664 for determining total acid value.
5. Stakeholders are asked to comment on:
  - the appropriateness of limiting alcohol to 15%;
  - an appropriate parameter for regulating alcohol content;
  - the appropriateness of using oxygen content as the parameter for regulating alcohol content;
  - an appropriate test method for determining alcohol content; and
  - an appropriate parameter for indirectly ensuring the quality of alcohol used to blend diesohol.
6. Stakeholders are asked to comment on:
  - an appropriate measure for cetane;
  - an appropriate minimum limit for cetane number; and
  - the appropriateness of test methods EN ISO 5165 and ASTM D613 for determining cetane number.
7. Stakeholders are asked to comment on:
  - the appropriateness of setting a maximum density limit of 860 kg/m<sup>3</sup>, to be reduced to 850 kg/m<sup>3</sup> on 1 January 2006;
  - the appropriateness of leaving minimum density open; and
  - the appropriateness of test method ASTM D1298 for determining density.
8. Stakeholders are asked to comment on:
  - the appropriateness of setting a standard for lubricity at a maximum wear of 0.460 mm at 60°C; and

- the appropriateness of test method IP 450 for determining lubricity.

9. Stakeholders are asked to comment on:

- the appropriateness of setting a maximum limit for PAHs at 11% m/m to come into effect on 1 January 2006; and
- an appropriate test method for determining the level of PAHs.

10. Stakeholders are asked to comment on:

- their experience of storage stability of different diesohol blends;
- an appropriate target time for storage stability (e.g. six months);
- an appropriate test method or methods for determining storage stability;
- the appropriateness of the following test method for determining storage stability, if modified as required for Alcohol-in-Oil Emulsions - ASTM D3707 Standard Test Method for Storage Stability of Water-in-Oil Emulsions by the Oven Test Method; and
- the appropriateness of the following test method for determining storage stability, if modified as required for Alcohol-in-Oil Emulsions - ASTM D3709 Standard Test Method for Storage Stability of Water-in-Oil Emulsions Under Low to Ambient Temperature Cycling Conditions.

11. Stakeholders are asked to comment on:

- the appropriateness of setting a maximum limit for sulfur at 500 ppm, to be reduced to 50 ppm on 1 January 2006; and
- the appropriateness of test method ASTM D5453 for determining the level of sulfur.

12. Stakeholders are asked to comment on:

- a) the appropriateness of regulating viscosity; and
- b) if necessary:
  - an appropriate viscosity standard; and
  - the appropriateness of test method ASTM D445 for determining viscosity.

13. Stakeholders are asked to comment on:

- the appropriateness of a water and sediment limit of 500 ppm; and
- an appropriate test method for determining water and sediment.

#### Non-critical parameters

14. Stakeholders are asked to comment on:

- a) the appropriateness of regulating ash and suspended solids; and
- b) if necessary:
  - establishing a 100 ppm maximum limit for ash and suspended solids; and
  - the appropriateness of test method ASTM D482 for determining the level of ash and suspended solids.

15. Stakeholders are asked to comment on:

- a) the appropriateness of regulating carbon residue; and
- b) if necessary:
  - the appropriateness of establishing a maximum carbon residue (on 10% distillation residue) at 0.2 mass %; and
  - the appropriateness of test method ASTM D4530 for determining the level of carbon residue.

16. Stakeholders are asked to comment on:

- a) the appropriateness of regulating conductivity; and
- b) if necessary:
  - the appropriateness of setting a minimum conductivity at ambient temperature of 50 pS/m for all diesel; and
  - the appropriateness of test method ASTM 2624 for determining the level of conductivity.

17. Stakeholders are asked to comment on:

- a) the appropriateness of regulating copper corrosion; and
- b) if necessary:
  - the appropriateness of setting a maximum copper corrosion limit of Class 1 (3 hours at 50°C); and
  - the appropriateness of test method ASTM D130 for determining the level of copper corrosion.

18. Stakeholders are asked to comment on:

- a) the appropriateness of regulating distillation; and
- b) if necessary:
  - an appropriate Australian specification for distillation; and
  - an appropriate test method for determining distillation.

19. Stakeholders are asked to comment on:

- a) the appropriateness of regulating filter blocking tendency; and
- b) if necessary the appropriateness of setting a maximum filter blocking tendency of 2.0 as measured by test method IP 387.

20. Stakeholders are asked to comment on the appropriateness of not regulating flash point.

## **PART A – OPTIONS FOR REGULATING DIESEL FUEL**

### **3 BACKGROUND TO FUEL QUALITY STANDARDS**

#### **3.1 Guiding principles**

The principal drivers under the FQS Act for regulating fuel quality are for both environmental and vehicle operability reasons. Improvements to fuel quality are aimed at:

- reducing the environmental impacts of transport by providing fuels which facilitate the adoption of emerging vehicle engine and emission control technologies; and
- enabling the effective operation of vehicles.

Regulating fuel quality can also serve to establish and maintain consumer confidence. This is particularly important for fuels that are new to the marketplace and depend on gaining consumer support.

The guiding principles for the development of fuel quality standards are:

1. Fuel standards are intended to manage those fuel qualities/parameters that are known to have the potential to impact adversely on the environment.
2. Fuel standards should be compatible with relevant international or internationally accepted standards in order not to impede competition and trade.
3. Fuel standards should not impede competition and favour one technology over another.
4. Fuel standards are intended to be mandated and implemented on a national basis. In particular, fuel standards that are technology enabling must apply nationally. Local environmental circumstances may, however, dictate variation within the national standard to achieve environmental outcomes (Department of Industry Science and Resources, 1999).
  - Consideration will be given to State by State establishment of fuel standards that address airshed specific environmental conditions; however, in such cases a national standard may be determined as a default.
5. Fuel standards will apply to, and be enforced equally in respect of, imports as well as domestically produced fuels (Department of Industry Science and Resources, 1999).
  - Fuel standards must not impede competition, either between Australian refiners, or with imported refined product.
6. Fuel standards that directly address environmental or health issues will be determined on the basis of Australian-specific requirements. In such instances, harmonisation with European specifications may be neither necessary nor desirable.
7. The timetable for the introduction of new fuel standards will be based on Australian requirements. Harmonisation, in terms of timing, will not be based on European or any other regional timetable, except where there is a previous policy decision to this effect or the standard is technology enabling and the need for such harmonisation is clearly demonstrated.
8. Consideration will be given to setting standards that provide, as far as possible, flexibility in terms of compliance, providing:
  - flexibility provisions must not impede competition or trade; and
  - flexibility provisions must not add significantly to legislative/regulatory complexity or implementation/enforcement costs to Government.

### **3.2 Government policy – reducing vehicle emissions**

The Australian Government has an ongoing programme of introducing new vehicle emission standards to ensure that the environmental benefits of evolving emission control and fuel efficiency technologies are realised in Australia. New vehicle emission standards are established as Australian Design Rules (ADRs) under the *Motor Vehicles Standards Act 1989* and are subject to regular review.

The 1997 Australian Academy of Technological Sciences and Engineering (AATSE) report, *Urban Air Pollution in Australia*, identified transport activities as the most significant contributor to urban ambient air pollution in Australia, with road vehicles the dominant source of pollutants. The report also found that new vehicle emission standards were “the long term foundation for maintaining and improving air quality”, and recommended that Australia should move to adopt European vehicle emission regulations.

The Prime Minister, in his 1997 statement *Safeguarding the Future - Australia's Response to Climate Change*, identified harmonisation with these international vehicle emission standards as a goal of the Australian Government and nominated a target date of 2006. In response to the Prime Minister's statement, the Government established new vehicle emission standards for petrol and diesel vehicles in December 1999, to help achieve reductions in emissions of significant pollutants. Fuel quality standards for petrol and diesel were also established from 1 January 2002 to support the new emissions standards.

### **3.3 Future fuel quality and vehicle emission standards**

It is expected that vehicle emission and corresponding fuel quality standards will be progressively tightened in the future to align more closely with European standards. Standards have become increasingly stringent to address advancing vehicle and fuel refining technology, increasing vehicle fleet size and usage, and mounting concern about air pollution. Under the *Motor Vehicle Standards Act 1989*, diesel vehicle emissions standards equivalent to Euro 4 (ADR 79/01) are mandated for 2006 and will require fuel with a sulfur limit of 50 ppm.

The Motor Vehicle Environment Committee (MVEC) is currently undertaking a review of vehicle emissions and fuel standards for Australia in the post 2006 period. The review is jointly managed by the Australian Government Department of Transport and Regional Services and the Department of the Environment and Heritage on behalf of MVEC (information about the review is available at [www.ephc.gov.au/mvec/](http://www.ephc.gov.au/mvec/)).

## 4 DIESOHOL

### 4.1 Diesohol blending

Diesel and alcohol do not mix easily and formulating diesohol requires the use of additives to create stable blends. For example, although small proportions of ethanol can be dissolved in diesel at high ambient temperature, as the temperature falls there is a tendency for the solution to separate into two phases. There are two general approaches to making diesohol.

1. *Emulsions* - where the alcohol is hydrous (e.g. 95% ethanol and 5% water), blends are formulated using an emulsifier that retains the hydrated alcohol as a dispersed phase in the diesel. The emulsifying agent keeps microscopic droplets of hydrated alcohol in suspension. The hydrous alcohol and diesel are not in a true solution and agitation of the mixture is required to form the emulsion.
2. *Solutions* - where the alcohol is anhydrous (e.g. 100% ethanol), blends are formulated using a solvent or co-solvent which maintains the alcohol more like a solution in the diesel. The solvent is miscible with both diesel and anhydrous alcohol. The alcohol, diesel and solvent form a true solution or a micro-emulsion which can be easily blended. Blends of anhydrous alcohol and diesel are sensitive to being separated by water and demulsifying agents are also added to ensure any water that is present forms a separate phase.

Most blends of diesohol are typically made with 10-15% alcohol, 85-90% automotive diesel and a blending agent.

### 4.2 Diesohol industry

Diesohol has been the subject of a number of trials both domestically and internationally. Current use in Australia however only occurs on a small scale. It is difficult to determine the potential size of the diesohol market, although due to storage and handling issues related to reduced flash point, it is generally acknowledged that diesohol is likely to remain a niche fuel – targeted around use in centrally refuelled fleets (McCormick and Parish, 2001). The reduction in flash point (due to the addition of alcohol) means that diesohol has different safety requirements than diesel. It needs to be handled like petrol and consequently the current diesel storage and handling infrastructure is not appropriate for diesohol. Centrally refuelled fleets have significant control over storage and handling, and the cost of installing the appropriate infrastructure only needs to be met once – unlike in a retail situation where infrastructure costs would be multiplied across a number of supply points. It is therefore considered more likely for diesohol to find a market in these centrally refuelled fleets.

The total Australian domestic diesel sales were approximately 13,888 ML in 2002-03 (Department of Industry, Tourism and Resources, 2003), and it would be expected that the fleet market would account for a significant proportion of diesel fuel use. Diesohol could potentially displace some of this market.

The main focus of diesohol trials in Australia has been on hydrous ethanol blends formulated using an emulsifier developed by APACE Research. The APACE emulsifier, a proprietary product, has recently been used in several trials of diesohol in Queensland. It has also been used for a number of previous trials – both domestically and overseas.

Internationally, there are a number of other companies that produce additives to facilitate the blending of diesohol. These companies include (potentially among others) - AAE

Technologies, Akzo-Nobel, Betz-Dearborn, and the Pure Energy Corporation. Most of the interest from these companies has been on blending anhydrous ethanol with diesel.

Other potential players in the diesohol industry include producers and importers of diesel, ethanol and methanol producers, and more broadly, stakeholders from the biofuels industry.

### **4.3 Impacts of diesohol use**

Diesohol, while used in compression ignition engines as an alternative to diesel, behaves quite differently to diesel. The alcohol component in the fuel:

- changes the combustion characteristics of the fuel;
- alters tail-pipe emissions and engine operability; and
- changes the storage and handling requirements in comparison to diesel.

Presented below is a general summary of the results of a number of diesohol trials. Results vary from trial to trial depending on the testing methodology and blend of fuel used. For example, it is likely that there will be some variation in emission outcomes with varying blends of diesohol. However, it is possible to outline the general trends arising from the use of diesohol.

#### *4.3.1 Emissions*

Testing indicates that when compared to diesel, diesohol significantly reduces emissions of particulate matter (PM), has little effect on oxides of nitrogen (NO<sub>x</sub>), and depending on the particular diesohol, can decrease or increase emissions of hydrocarbons (HC) and carbon monoxide (CO). There is little information about the impact of diesohol on emissions of air toxics – although there are indications that emissions of aldehydes decrease when compared to diesel. Total greenhouse gas life-cycle emissions may also be less for diesohol than diesel.

#### Particulate matter (PM)

It has been shown that the addition of oxygenates such as ethanol to diesel fuel is an effective method for reducing PM emissions from diesel vehicles (Cheng *et al*, 2002). For example, Swedish trials of a 15% hydrous ethanol diesohol blend reported reductions of PM emissions in the order of 35-50% when compared to the base diesel (Westerholm *et al*, 1997). PM emissions have been linked with a range of negative health effects, and the diesel fleet in Australia is the major source of vehicle produced particles in urban areas (National Environment Protection Council, 1998). Reductions in PM emissions are consequently seen as one of the major benefits arising out of the use of diesohol.

#### Oxides of Nitrogen (NO<sub>x</sub>)

While it is understood that there is typically a trade-off between PM and NO<sub>x</sub> emissions – where a reduction in one will result in an increase in the other – most trials of diesohol report significant reductions in PM concurrently with minor reductions in NO<sub>x</sub>. For example, Shih (1998) in Cole *et al* (2001) noted a reduction in NO<sub>x</sub> with the addition of ethanol to diesel, especially at low loads or low speeds. McCormick and Parish (2001) suggest that as long as the cetane of the diesohol is the same as the blending diesel then there should be no significant change (i.e. increase) in NO<sub>x</sub> emissions.

#### Hydrocarbons (HC) and carbon monoxide (CO)

Certain trials of diesohol report increases in emissions of both HC and CO when compared to the base diesel. For example, Kass *et al* (2001) found that HC and CO emissions increased for both 10 and 15% anhydrous ethanol blends – with the 10% blend resulting in the greatest increase. However, Westerholm *et al* (1997) found no change in HC and CO emissions when comparing diesel with a 15% hydrous ethanol blend, and McCormick and Parish (2001) report a study by Yanowitz *et al* (1999) in which CO emissions are reduced with the use of diesohol.

There is a general lack of discussion about the capability of diesel engines running on diesohol to meet the relevant vehicle emission standards (e.g. Euro 3 or Euro 4). Given that PM emissions are expected to decrease and NO<sub>x</sub> emissions are expected to remain essentially the same, the main concern would centre around HC and CO. Again, there is little discussion about the impact that emission control technologies may have on any potential increases in HC and CO emissions. However, both Kass *et al* (2001) and McCormick and Parish (2001) suggest that, if necessary, a diesel oxidation catalyst would be likely to reduce these emissions to acceptable levels.

#### Air toxics

Few trials of diesohol have looked at potential changes to emissions of air toxics. However, Scott *et al* (1995) found in trials of a 15% hydrous ethanol blend, that total aldehyde emissions were reduced under 25% and 100% load, but increased at idle. Information about the impact of diesohol on other toxics such as benzene and toluene was not available.

#### Greenhouse gases

Beer *et al* (2000) reported an estimated 6-7% reduction in the total greenhouse gas life-cycle emissions for diesohol when compared to diesel.

#### **4.3.2 Vehicle operability**

The addition of alcohol to diesel results in a minor reduction in fuel economy and maximum power, and can have some impact on engine fuel systems.

#### Fuel economy and maximum power

Alcohol has a considerably lower energy content than diesel. For example, the lower calorific value of anhydrous ethanol is 20.6 MJ/L, 19.41 MJ/L for hydrous ethanol with a 5% water content, and approximately 35.70 MJ/L for diesel (Beer *et al*, 2000). The reduced energy content of alcohols translates to reduced fuel economy and maximum power from diesohol blends when compared to diesel. Based on calorific values alone, a 7.3% reduction in power would be expected for diesohol blended with 15% hydrous ethanol. According to APACE Research, this reduction is only 3-4% in practice because the alcohol in the fuel acts to delay the timing of ignition – resulting in increased thermal efficiency, especially under full load conditions (Beer *et al*, 2000). Further reductions in maximum power and fuel economy would be expected as the proportion of alcohol increased.

#### Vapour pressure

Due to the increased vapour pressure of diesohol, there is the potential for vapour locks to form in the vehicle fuel pumping systems. For example, vapour lock issues were reported in trials of diesohol in buses conducted by the NSW EPA (Joseph, 1996). It has been suggested that minor adjustments to conventional diesel engines can overcome this problem.

## Component compatibility

It is well known that certain engine components may not be compatible with alcohols – e.g. nitrile rubber seals. It is recommended by APACE Research that these be replaced prior to the use of diesohol. It is also recommended that fuel filters be replaced soon after the initial use of diesohol as the alcohol can act to loosen engine deposits. Any adjustments made to fuel systems to accommodate the use of diesohol should not affect a vehicle's interchangeability with diesel.

As with all fuels, there are a number of fuel quality parameters that may also impact on vehicle operability if not appropriately managed. A discussion of the relevant environmental and operability parameters of diesohol is presented in Part B.

### ***4.3.3 Storage and handling***

The main issues around the storage and handling of diesohol are safety concerns relating to the low flash point of the fuel when compared to diesel, and its long term storage stability.

#### Flash point

Flash point is defined as the minimum temperature at which the vapour pressure of a liquid is sufficient to produce a flammable mixture above the liquid surface in a vessel. The addition of even small amounts of alcohol to diesel (in the order of 5%) reduces the flash point of the fuel to that of the alcohol. Diesohol has a typical flash point of 11°C in the case of methanol blends and 13°C for ethanol blends – compared to a minimum of 61.5°C for automotive diesel in Australia. This reduction in flash point means that diesohol needs to be treated in the same manner as petrol – a Class 3 combustible fluid for the purposes of Australian Standard, AS 1940 – 1993, Storage and Handling of Flammable and Combustible Liquids. Current commercial infrastructure for the storage and handling of diesel is therefore not considered appropriate for diesohol. Due to the economic constraints of installing the appropriate infrastructure, a view has been expressed that the market for diesohol may be limited to centrally refuelled fleets, where there can be considerable control over fuel handling (McCormick and Parish, 2001).

The reduced flash point and increased vapour pressure of diesohol may also have implications for its transport. Neat ethanol can produce a flammable mixture in a vehicle fuel tank under a wide range of temperatures. Diesohol appears to have similar vapour pressures as neat ethanol and flammability in fuel tanks may be an issue (McCormick and Parish, 2001). Furthermore, certain applications may not be suitable for the use of diesohol – e.g. as a substitute for marine diesel where high flash points are necessary to minimise the possibilities of fires onboard boats.

## Storage stability

The stability of different diesohol blends in a range of different conditions has not been well studied. However, it has been noted that diesohol made with anhydrous alcohol can be sensitive to phase separation in the presence of water, and with decreasing temperatures (Waterland *et al*, 2003). Manufacturers claim that emulsified blends made with hydrous alcohol are more stable in the presence of water (McCormick and Parish, 2001). Storage stability is discussed further in Part B.

### **4.4 Vehicle warranties**

Engine manufacturers warranty their engines for “materials and workmanship”. An engine company will cover the rectification of a fault with an engine part or with engine operation within the prescribed warranty period, if the fault is due to an error in manufacturing or assembly. Typically, an engine company will define what fuel the engine was designed for and will recommend the use of that fuel to their customers in their owner's manuals.

Engine companies do not warranty fuel, whether petrol, diesel or diesohol. Engine problems arising directly from the use of fuel (and not a fault in materials and workmanship) are the responsibility of the fuel supplier and not the engine manufacturer.

1. Stakeholders are asked to provide comment on:
  - the issue of vehicle warranties and the use of diesohol.

## 5 OPTIONS FOR ACTION

In order for vehicles to be able to meet emissions standards, set out under the *Motor Vehicle Standards Act 1989*, the fuels they use need to be of an appropriate quality to facilitate the effective operation of engines and emission control technologies. Diesohol produced and sold in Australia is not subject to any regulated minimum quality requirements. While the production of diesohol currently only occurs at a small scale – there is the potential for the market to grow significantly.

In the absence of a standard, inferior quality diesohol may enter the market, potentially leading to negative environmental and health impacts, vehicle operational problems and consumer confidence issues. Diesohol quality could be managed through a variety of means including a voluntary industry standard, State and Territory standards, or a standard under the FQS Act. Regulation of diesohol, particularly through a standard under the FQS Act, may be an appropriate mechanism to ensure that the environmental and operability outcomes arising from the use of the fuel are satisfactory. However, regulation may also impose a regulatory burden on both fuel suppliers and government, and may also restrict entry into the market place.

It is this balance between the elements of benefit and cost (discussed in the following Sections) that needs to be considered in the potential setting of a fuel quality standard for diesohol. Within this context, four options for the treatment of diesohol blends are presented. These include:

1. no diesohol fuel quality standard (business as usual);
2. encourage a voluntary industry diesohol fuel quality standard;
3. encourage State and Territory diesohol fuel quality standards; and
4. introduce a diesohol fuel quality standard under the FQS Act.

|                                                                                                        |
|--------------------------------------------------------------------------------------------------------|
| 2. Stakeholders are asked to provide comment on their preferred option for the regulation of diesohol. |
|--------------------------------------------------------------------------------------------------------|

### 5.1 No diesohol fuel quality standard

Under this option, diesohol would continue to be produced and sold in Australia without regulation.

#### *Advantages and Disadvantages*

While problems associated with diesohol quality have not been an issue to date, diesel and alcohol are easily attainable and there is the potential for inferior quality blends to be manufactured and made available on the Australian market.

Without regulation, there is the potential for certain parameters to not meet accepted environmental limits. For example, in order for diesel vehicles to meet vehicle emission standards, they require diesel fuel with a sulfur limit of 500 ppm. Without regulation, diesohol may enter the market that does not meet this limit and cause unacceptable emission outcomes.

Furthermore, poor quality diesohol has the potential to negatively impact on vehicle operability. For example, the addition of alcohol to diesel can reduce cetane (a measure of ignition quality) below accepted levels. While easily managed through the addition of cetane improvers, this

brings with it an associated economic cost, which may not be met without a standard. Low cetane fuel with poor ignition qualities causes misfiring, tarnish on pistons, engine deposits, rough operation and poor emission outcomes.

Consumer and community confidence is important for the successful development of any industry. Lack of regulation would not provide certainty about the quality of fuel.

As stated above, regulation comes with a cost to both industry and governments. Maintaining business as usual would allow participants in the industry to operate without any associated compliance costs, and government would not need to meet the cost of monitoring and enforcement.

## **5.2 Voluntary industry diesohol fuel quality standard**

Under this option, diesohol would also continue to be produced and sold in Australia without regulation. However, the industry would apply a voluntary fuel quality standard.

### *Advantages and Disadvantages*

The diesohol industry in Australia is not well developed and an appropriate voluntary standard, applicable to both blending approaches, would be difficult to establish and maintain. Given the ease of accessibility of diesel and alcohol and the lack of a structured industry, it is unlikely that a voluntary industry standard would be able to deliver the necessary outcomes. Inferior quality diesohol would have the potential to enter the Australian market, potentially leading to negative environmental and health impacts, vehicle operational problems and consumer protection issues.

Competition problems may arise when producers either decline to be parties to such an agreement or, on occasion, to operate outside the agreement.

A voluntary agreement would have a substantial benefit in that if industry effectively self-regulates, administrative and compliance costs on the wider community and government would be reduced.

## **5.3 State and Territory diesohol fuel quality standards**

Almost all the States and Territories currently have regulation relating to fuel quality, storage or handling. For example, the New South Wales and Victorian Governments regulate fuel volatility in those states. In addition, States have existing consumer affairs legislation that could be used to prosecute retailers that misrepresent the quality of their fuel (e.g. *NSW Fair Trading Act 1987*, *Victoria Fair Trading Act 1999*).

Current State fuel quality legislation is not nationally consistent and there are currently no State or Territory regulations regarding diesohol quality. The Department of the Environment and Heritage is not aware of any jurisdiction's intention to introduce such legislation.

### *Advantages and Disadvantages*

State-specific regulation has the potential to result in different standards for each jurisdiction. This may give rise to competition issues, by creating barriers to interstate markets and raising compliance costs.

The use of State-specific regulation would not consistently ensure the nationwide availability of high quality diesohol.

#### **5.4 Introduce a diesohol fuel quality standard under the FQS Act**

Under this option, an Australian fuel quality standard for diesohol (covering both blending approaches) would be introduced that specified certain parameters to ensure the availability of fuel that:

- reduced the level of pollutants arising from the use of the fuel that may cause environmental and health problems;
- facilitated the adoption of better vehicle technologies;
- allowed more effective operation of engines; and
- consistently met consumer expectations.

Technical information relating to a fuel quality standard for diesohol is presented in Part B of this paper.

3. Stakeholders are asked to comment on the discussion presented below as it relates to their interests.

### *Advantages and Disadvantages*

A diesohol fuel quality standard would introduce a 'level playing field' for current and future Australian diesohol producers, promoting competition on an even footing. A diesohol fuel quality standard will result in a consistent minimum quality of diesohol and promote increased consumer confidence in the product. To the extent that diesohol complying with the standard displaced inferior quality diesohol, consumers would experience fewer operability problems, reduced repair costs and less downtime while vehicles are repaired.

To the extent that the introduction of a diesohol standard increased consumption of diesohol and displaced diesel, benefits would accrue to the wider community in avoided health costs and increased amenity from improved air quality. These benefits would be dependent on a standard managing those parameters that had the greatest impact on air quality. As outlined previously, emissions of particulate matter have been shown to decrease in the order of 35-50% when vehicles use diesohol as compared to diesel (Westerholm *et al*, 1997). A study undertaken by the European Commission (1998) estimated that the avoided health costs associated with reducing one tonne of particulate emissions (PM<sub>10</sub>) in a city of around one million inhabitants to be A\$224,600.

An enforceable minimum quality standard will also result in a product of consistent quality, increasing consumer confidence in diesohol and potentially leading to increased sales. A nationally consistent and high quality product resulting from a diesohol fuel quality standard may also lead to greater confidence in and acceptance of the product by vehicle manufacturers. Whilst engine warranty issues relating to the use of diesohol are not yet clear, an enforced diesohol fuel quality standard offers the strongest opportunity to obtain warranty clarification and provide the greatest level of consumer protection.

Establishing a fuel quality standard for diesohol will incur some cost to government in administration of the standard and monitoring compliance with the FQS Act.. This revenue would not be available to the community for other activities. As previously noted, current diesohol production in Australia is very small and the additional cost is not anticipated to be significant. In the event that new test methods and/or laboratory equipment are required to test diesohol parameters, these costs would flow through to the regulator.

There would be costs for producers associated with an enforceable fuel standard. The FQS Act imposes record keeping and annual reporting requirements on suppliers of fuel. Annual reports must include information on fuel quality including details of any testing undertaken. Records are to be kept for two years and include information such as type and quantity of fuel produced, details of any testing done on the fuel and stock reconciliation records. There may also be testing and sampling costs associated with producing diesohol to a standard. Any increased costs for producers as a result of having to meet a standard may be passed onto consumers.

There is also a risk that a standard may indirectly restrict entry into the market place. The more difficult it is to meet a standard, the more difficult it would be to supply fuel that meets the requirements of the FQS Act.

## **PART B – TECHNICAL ISSUES RELATED TO A DIESEHOL STANDARD**

Should a diesohol fuel quality standard be developed under the FQS Act, a number of decisions would need to be made about which parameters to regulate, what the appropriate limits for these parameters are, and what test methods should be prescribed.

A balanced approach to developing this standard would need to be taken, where only those parameters that are appropriate are regulated. This will be important to maximise the benefits of a standard while at the same time minimising any potential costs to industry and government. To that extent, Section 6 discusses those parameters that are considered critical to manage in ensuring diesohol quality in the short term, and Section 7 discusses those parameters that either do not directly affect operability, or are considered non-critical to manage at this stage.

### **6 CRITICAL PARAMETERS**

A number of parameters are considered to be critical to ensure the quality of diesohol. These parameters are considered to be the most important in terms of managing overall environmental and operability performance. These parameters are:

- acidity;
- alcohol quality and content;
- cetane;
- density;
- lubricity;
- polyaromatic hydrocarbons;
- storage stability;
- sulfur;
- viscosity; and
- water and sediment.

#### **6.1 Acidity**

The *Discussion Paper on Operability Fuel Parameters (Petrol and Diesel)*, prepared by the Department of Industry, Science and Resources (2001), notes that the management of organic acids in diesel is necessary to avoid corrosion of vehicle fuel systems. Acidity is typically measured in terms of both strong acidity and total acidity. Strong acidity is a measure of particularly corrosive acidic elements whilst total acidity is a measure of both these components as well as the less corrosive acidic components.

Acidity is not currently controlled for diesel. However, the European Automobile Manufacturers Association *et al* through the World-Wide Fuel Charter of 2002, recommend a maximum total acidity of 0.08 mg KOH/g for diesel fuel but do not specify a limit for strong acidity. Given the importance of managing acidity in alcohols, it may be appropriate to set a maximum total acidity limit for diesohol of 0.08 mg KOH/g.

The World-Wide Fuel Charter recommends ASTM D974 as the test method for total acid number, and test method ASTM D664 is also used.

4. Stakeholders are asked to comment on:

- the appropriateness of setting a maximum acid value (total) of 0.08 mg KOH/g; and
- the appropriateness of test methods ASTM D974 and ASTM D664 for determining total acid value.

## 6.2 Alcohol quality and content

Alcohol quality or content are not regulated through the diesel standard but will be important to manage for diesohol. As discussed under other parameters, the alcohol component to the fuel relates directly to fuel quality and engine performance. Major issues related to alcohol quality and content (as discussed elsewhere in this paper) include impacts on:

- storage stability;
- lubricity;
- maximum power and fuel efficiency;
- corrosiveness;
- cetane; and
- conductivity.

Most of the published data on diesohol performance relate to 10% or 15% ethanol/diesel blends. Because of the lack of suitable data for higher percentage alcohol blends, it may be appropriate to limit alcohol content to 15%.

A method for regulating alcohol content would be through oxygen content. However, an appropriate oxygen limit, that takes into account the oxygen content of water in the case of hydrated alcohol and any additives (such as cetane improvers), and an appropriate test method, would need to be determined.

Regulating the quality of alcohol used in diesohol blends may be important. It may be possible to indirectly regulate alcohol quality by specifying limits for parameters of diesohol. It should be noted that the Department of the Environment and Heritage will separately investigate the need for a standard for fuel ethanol.

5. Stakeholders are asked to comment on:

- the appropriateness of limiting alcohol to 15%;
- an appropriate parameter for regulating alcohol content;
- the appropriateness of using oxygen content as the parameter for regulating alcohol content;
- an appropriate test method for determining alcohol content; and
- an appropriate parameter for indirectly ensuring the quality of alcohol used to blend diesohol.

### 6.3 Cetane

Cetane is a measure of auto-ignition quality which is important for the effective operation of diesel engines. It is dependent on fuel composition, and relates to the delay between when fuel is injected into the cylinder and when ignition occurs. Good ignition from high cetane 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) – and can consequently result in poor emissions outcomes.

Cetane can be expressed as a cetane number or through a cetane index. Cetane number is physically measured on a test engine, whereas cetane index is calculated from a formula, which uses the density, mid-boiling point and other characteristics of diesel fuel as input data. Due to the chemically different nature of diesohol, the use of cetane index is not possible for diesohol.

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 fuels (U.S. Department of Energy, 1991). 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. The biodiesel determination sets a minimum cetane number of 51 (to come into effect on 18 September 2004).

Cetane number appears to be the appropriate measure for diesohol as it reflects the addition of cetane improvers. However, previous advice has indicated that the testing of cetane number in Australia is not possible because of the lack of testing equipment. Fuel samples would need to be sent overseas for testing – at some cost. The Department is currently assessing the options for measuring cetane for a range of diesel alternatives.

The current prescribed test methods for the cetane number of biodiesel are EN ISO 5165 or ASTM D613.

6. Stakeholders are asked to comment on:

- an appropriate measure for cetane;
- an appropriate minimum limit for cetane number; and
- the appropriateness of test methods EN ISO 5165 and ASTM D613 for determining cetane number.

## 6.4 Density

Density relates to the energy content of fuel in such a way that the higher the density of the fuel the higher its energy content per unit volume. However, higher density also relates to higher aromatic content. The World-Wide Fuel Charter (2002) notes that reducing density is desirable as it translates to reduced harmful emissions – e.g. of particulates. From a purely emissions perspective, there is some evidence to support an open ended minimum density specification for diesel fuels (Environment Australia, 2000). However, the World-Wide Fuel Charter (2002) also notes that diesel engines are set to a standard density range, and too low a density may lead to sub-optimal engine performance.

The diesel determination sets a density range of 820 – 860 kg/m<sup>3</sup>, to be reduced to 820 – 850 kg/m<sup>3</sup> on 1 January 2006.

The density of alcohol is lower than diesel and will lead to a drop in density for diesohol. For example, the density of anhydrous ethanol is approximately 790 kg/m<sup>3</sup> (hydrous ethanol is slightly higher than anhydrous) and blending with diesel would lead to an expected decrease in density. A 15% ethanol blend with diesel at the low end of the permissible density range would thus result in a product with a density of approximately 815.5 kg/m<sup>3</sup>. It may be appropriate to manage the density of diesohol through a maximum limit (in line with diesel) but leave the minimum limit open.

The prescribed test methods for determining density for diesel are ASTM D1298 and ASTM D4052. It is intended to consolidate this into the one test method – ASTM D1298 – to determine compliance in the future.

7. Stakeholders are asked to comment on:

- the appropriateness of setting a maximum density limit of 860 kg/m<sup>3</sup>, to be reduced to 850 kg/m<sup>3</sup> on 1 January 2006;
- the appropriateness of leaving minimum density open; and
- the appropriateness of test method ASTM D1298 for determining density.

## 6.5 Lubricity

Diesel fuel lubricates various moving parts of diesel pumps and injectors, and to avoid excessive wear the fuel must have some minimum amount of lubricity. Lubricity is measured using the High Frequency Reciprocating Rig (HFRR) test procedure which simulates the amount of the wear characteristics of diesel fuels. The diesel determination sets a maximum wear at 60°C of 0.460 mm.

The lubricity of diesohol may differ depending on the blending approach. For example, some additives are purported to increase lubricity. Given the importance of lubricity to diesel engine performance, it may be appropriate to maintain the same lubricity standard for diesohol as for diesel.

The prescribed test method for the lubricity of diesel is IP 450.

8. Stakeholders are asked to comment on:

- the appropriateness of setting a standard for lubricity at a maximum wear of 0.460 mm at 60°C; and
- the appropriateness of test method IP 450 for determining lubricity.

## 6.6 Polyaromatic hydrocarbons

Polyaromatic hydrocarbons (PAHs) are known to be a human carcinogen and increasing levels of aromatics can lead to decreased engine performance. The fuel quality standard for diesel sets the maximum limit for PAHs at 11% m/m to come into effect on 1 January 2006.

The amount of PAHs in diesohol will depend primarily on the specifications of the base diesel. Alcohol and the additives used to create diesohol blends contain no PAHs and diesohol would be expected to contain proportionally less aromatics than the base diesel. Regulating PAHs for diesohol would therefore provide an indication of the quality of the base diesel.

A prescribed test method for measuring PAHs in diesel will be determined prior to 1 January 2006.

9. Stakeholders are asked to comment on:

- the appropriateness of setting a maximum limit for PAHs at 11% m/m to come into effect on 1 January 2006; and
- an appropriate test method for determining the level of PAHs.

## 6.7 Storage stability

Long term storage stability of fuels is an important aspect of fuel quality. For diesel, oxidation stability is an indicator of long term storage stability as it measures the resistance of the fuel to oxidation under accelerated oxidation conditions. Under these conditions, the tendency of the fuel to oxidize and form gums correlates with long term storage stability. However this parameter would not be a suitable indicator for the storage stability of diesohol as stability of the emulsion or co-solvent mixtures is the more critical parameter.

A number of factors determine the stability of diesohol. These include (but are not restricted to) type of blending system, solubility of the phases in each other, particle size of the non-continuous phase (generally the smaller the more stable the blend), temperature, and type of mixing process.

It would be expected that a diesohol blend produced with emulsifiers and containing hydrated alcohol would have a higher tolerance to the presence of water than diesohol which contains anhydrous alcohol held in solution with co-solvents. In the former case, the presence of emulsifiers means that a small quantity of free water is more likely to be “captured” and held in a relatively stable form with little detriment to the fuel. However, in the latter case, not only will introduced water result in “free” visible water, but it could also initiate phase separation, where one phase will be predominantly diesel fuel/co-solvent and another phase predominantly alcohol/water. This outcome will be dependent on a number of factors, including the amount of water, type of co-solvent and the relative hydrophilic/hydrophobic nature of all the constituents.

Temperature is also a major factor in diesohol stability and as temperature decreases, the tendency for phase separation to occur increases as alcohol level increases.

There appears to be currently no one test to identify the storage stability of diesohol blends. However, because of the importance of storage stability as a fuel quality parameter, it may be important to resolve this issue.

10. Stakeholders are asked to comment on:

- their experience of storage stability of different diesohol blends;
- an appropriate target time for storage stability (e.g. six months);
- an appropriate test method or methods for determining storage stability;
- the appropriateness of the following test method for determining storage stability, if modified as required for Alcohol-in-Oil Emulsions - ASTM D3707 Standard Test Method for Storage Stability of Water-in-Oil Emulsions by the Oven Test Method; and
- the appropriateness of the following test method for determining storage stability, if modified as required for Alcohol-in-Oil Emulsions - ASTM D3709 Standard Test Method for Storage Stability of Water-in-Oil Emulsions Under Low to Ambient Temperature Cycling Conditions.

## 6.8 Sulfur

The contribution of sulfur in diesel fuels to exhaust particulate emissions has been well established - with a general linear relationship between fuel sulfur levels and this regulated emission. The sulfur limit for automotive diesel is 500 ppm, to be reduced to 50 ppm on 1 January 2006. These sulfur levels are required to enable current and future emissions control technologies to operate effectively.

As with PAHs, the amount of sulfur in diesohol will depend primarily on the properties of the base diesel. While some additive packages may contain sulphonate surfactants, these should not significantly affect the overall sulfur content of the fuel. In fact, diesohol blends would be expected to have lower concentrations of sulfur than the base diesel.

In order to ensure that sulfur is maintained at the appropriate level, it may be appropriate to maintain the same limits as set out in the diesel standard. As with PAHs, regulating sulfur for diesohol would provide an indication of the quality of the base diesel.

The prescribed test methods for sulfur in the diesel standard are ASTM D1266, ASTM D2622, ASTM D4294, ASTM D5184, ASTM D5185, ASTM D5453, or IP336. It is intended to consolidate these into one test method - ASTM D5453 – which will be used to determine compliance in the future.

11. Stakeholders are asked to comment on:

- the appropriateness of setting a maximum limit for sulfur at 500 ppm, to be reduced to 50 ppm on 1 January 2006; and
- the appropriateness of test method ASTM D5453 for determining the level of sulfur.

## 6.9 Viscosity

Viscosity indicates a fluid's resistance to flow. Viscosity of diesel fuel is important for the operation of fuel injection equipment.

Fuel with low viscosity can result in excessive wear in some injection pumps and in power loss due to pump injector leakage. Spray may not atomise sufficiently, impairing combustion and power output, and decreasing fuel economy (Standards Australia, 1998, AS 3570 - automotive diesel). This can have adverse effects on emissions performance.

Too high a viscosity can cause poor combustion and loss of power and economy. The poor atomisation of high viscosity fuels can lead to overspray in the injection process causing problems for the cylinder walls by washing away lubricating oil, resulting in excessive wear and also increasing the dilution of the lubricating oil in the engine. For rotary fuel injection pumps, seizure during start up can be experienced in excessively cold weather.

The fuel quality standard for diesel sets a viscosity range of 2.0 to 4.5 cSt at 40°C, and the standard for biodiesel sets a viscosity range of 3.5 to 5.0 mm<sup>2</sup>/s (1.0 cSt = 1.0 mm<sup>2</sup>/s).

The viscosity of diesohol appears to depend on the proportion of alcohol blended and the type of additives used. Alcohol itself has a lower viscosity than diesel, but additives can have a counteracting effect causing diesohol to have a higher viscosity than the base diesel.

The prescribed test method for the viscosity of diesel and biodiesel is ASTM D445.

12. Stakeholders are asked to comment on:

a) the appropriateness of regulating viscosity; and

b) if necessary:

- an appropriate viscosity standard; and
- the appropriateness of test method ASTM D445 for determining viscosity.

## 6.10 Water and sediment

Water is very insoluble in diesel fuel (<0.1%) and the presence of free water can lead to a number of engine operability/fuel supply system problems such as component corrosion and fuel system blockages. Sediment in diesel fuel can lead to blockages in the fuel injection system. Similar problems would be expected with diesohol (both emulsion and co-solvent technologies) and it is therefore desirable for diesohol to have the same free water and sediment limits as diesel fuel, 500 ppm.

The amount of water in diesohol will depend on the alcohol content and the degree of hydration of the alcohol as well as the storage and handling of the diesohol. Diesohol that is blended using hydrous alcohol will have a much higher water content than that set under the diesel determination. For example, a 15% hydrous ethanol blend may contain approximately 7,500 ppm water. However, this water is associated with the dispersed alcohol phase of the emulsion and may not be considered 'free' water. Hydrous alcohol blends are resistant to separation caused by contact with water. When diesohol is produced with anhydrous alcohol it forms a solution, which can be susceptible to phase separation as temperature decreases, and/or in the presence of water.

Distillation methods (as used for diesel) are inappropriate for determining water content because of the carry-over of alcohol, and at the time of writing the report, no test method for determining free water in diesohol has been determined. It may be possible to adapt ASTM centrifuge methods for determining water and sediment in crude oil and fuel oils (ASTM D4007 and D1796), but there appears to be insufficient information available to fully assess this proposal.

Given the importance of managing water content of fuel, an appropriate test method for determining free water may need to be developed.

13. Stakeholders are asked to comment on:

- the appropriateness of a water and sediment limit of 500 ppm; and
- an appropriate test method for determining water and sediment.

## 7 NON-CRITICAL PARAMETERS

A number of parameters are considered non-critical to the immediate development of a fuel quality standard for diesohol. The following section presents a discussion of:

- parameters that are regulated for diesel but may not be appropriate for diesohol; and
- those parameters that are relevant to diesohol but may not be necessary to regulate in the short term to ensure fuel quality.

Where indicated, stakeholders are still asked to comment on the appropriateness of regulating these parameters, the appropriate limits and test methods.

Non-critical parameters include:

- the additives used to manufacture diesohol;
- ash and suspended solids;
- carbon residue;
- colour;
- conductivity;
- copper corrosion;
- distillation;
- filter blocking tendency;
- flash point.

### 7.1 Additives

As noted previously, the successful blending of diesohol requires the use of various additives. The potential influence of these additives on fuel quality could be effectively managed through other fuel parameters – e.g. a sulfur limit would ensure that the additives did not add excessive sulfur to the fuel.

Furthermore, additives would need to meet the requirements of the National Industrial Chemicals Notification and Assessment Scheme (NICNAS). NICNAS ensures that new industrial chemicals entering Australia are assessed for their health and environmental effects before they are used or released to the environment, and makes recommendations for safe use. Those chemicals that have been in use for a longer time are assessed on a priority basis in response to specific concerns about their effects on people's health or the environment or both.

### 7.2 Ash and suspended solids

Ash forming materials (incombustible mineral material) may be present in diesel fuel in two forms - as suspended solids or as hydrocarbon soluble organo-metallic compounds.

Ash forming materials present as suspended solids may contribute to fuel injector and fuel pump wear, which are critical issues in engines needed to meet tighter emission standards. Ash forming materials present as soluble organo-metallic compounds have little effect on wear of these components but, like suspended solids, can contribute to combustion chamber deposits, most critically on fuel injector tips, which can then influence emissions performance (Standards Australia, 1998, AS 3570 - automotive diesel).

The diesel determination sets a maximum limit for ash and suspended solids at 100 ppm. Alcohols are likely to have lower levels than this and are unlikely to increase the levels of ash and suspended solids. Given that it is proposed to indirectly regulate the quality of the base diesel through limiting PAHs and sulfur, it may not be necessary to manage ash and suspended solids for diesohol, or if deemed necessary then to regulate it in the same manner as diesel.

The prescribed test method for ash and suspended solids in the automotive diesel determination is ASTM D482.

14. Stakeholders are asked to comment on:

- a) the appropriateness of regulating ash and suspended solids; and
- b) if necessary:
  - establishing a 100 ppm maximum limit for ash and suspended solids; and
  - the appropriateness of test method ASTM D482 for determining the level of ash and suspended solids.

### 7.3 Carbon residue

Carbon residue gives a measure of the carbon-forming tendencies of diesel when heated under prescribed conditions. While not directly correlated with the formation of deposits in fuel injectors and combustion chambers, this property is considered to be an indication of deposit-forming tendency. The diesel determination sets a maximum carbon residue (on 10% distillation residue) at 0.2 mass %.

The addition of alcohol is unlikely to increase this parameter. As with ash and suspended solids, it may not be necessary to manage this parameter for diesohol, or if deemed necessary then to regulate it in the same manner as diesel.

The prescribed test method for carbon residue in the diesel determination is ASTM D4530.

15. Stakeholders are asked to comment on:

- a) the appropriateness of regulating carbon residue; and
- b) if necessary:
  - the appropriateness of establishing a maximum carbon residue (on 10% distillation residue) at 0.2 mass %; and
  - the appropriateness of test method ASTM D4530 for determining the level of carbon residue.

### 7.4 Colour

The colour of diesel is managed to detect contamination with fuel oil and provide a check on stability. Colour may not be an appropriate parameter to manage for diesohol because the

colour of the fuel will depend on the blending technology. Blends made with hydrous alcohol are opaque, while blends made with anhydrous alcohol are clear.

## 7.5 Conductivity

The management of the conductivity of diesel is necessary to avoid electrostatic charge build-up and spark formation during the pumping and loading of tankers. Additives are typically used to increase the conductivity of diesel sold as transport fuel. The diesel standard for minimum conductivity at ambient temperature is 50 pS/m (only applies at terminals, refineries and major distribution centres).

The conductivity of diesohol is significantly higher than diesel. This in itself may not cause problems. However, where diesel (with a low conductivity) and diesohol are used interchangeably within the same vehicle – there may be the potential for the rapid discharge of built up static charge. This may occur in a situation where diesel has built up static due to inadequate bonding or earthing, and diesohol with its high conductivity is added to the vehicle – a situation referred to as ‘Switch Loading’ in the bulk petroleum products transport sector. However, the conductivity parameter for diesel should prevent such a scenario from occurring and it may not be necessary to regulate conductivity for diesohol.

The prescribed test method for conductivity in the diesel determination is ASTM 2624.

16. Stakeholders are asked to comment on:

- a) the appropriateness of regulating conductivity; and
- b) if necessary:
  - the appropriateness of setting a minimum conductivity at ambient temperature of 50 pS/m for all diesohol; and
  - the appropriateness of test method ASTM 2624 for determining the level of conductivity.

## 7.6 Copper corrosion

The copper corrosion measure is an indicator of the possible corrosion of copper, brass or bronze fuel system components. Diesohol may be more corrosive than straight diesel – due to the effects of the alcohol. However, the fuel quality standard for diesel sets a copper corrosion limit at a maximum of Class 1 (3 hours at 50°C). Given that acidity, another measure of corrosion, is proposed to be regulated, it may not be necessary to regulate copper corrosion.

The prescribed test method for copper corrosion in the diesel determination is ASTM D130.

17. Stakeholders are asked to comment on:

- a) the appropriateness of regulating copper corrosion; and
- b) if necessary:
  - the appropriateness of setting a maximum copper corrosion limit of Class 1 (3 hours at 50°C); and
  - the appropriateness of test method ASTM D130 for determining the level of copper corrosion.

## 7.7 Distillation

Distillation is a reference to the volatility profile of fuel. The distillation or boiling range is a consequence of the chemical composition of the fuel meeting other fuel property requirements such as viscosity, flash point, cetane number and density.

The distillation curve of diesel fuel indicates the amount of fuel that will boil off at a given temperature. The curve can be divided into three parts: the light end, which affects startability; the region around the 50% evaporated point, which is linked to other fuel parameters such as viscosity and density; and the heavy end, characterised by the T90, T95 and final boiling points. The heavy end has received the most attention with respect to its effect on tailpipe emissions (European Automobile Manufacturers Association *et al*, 2002). The fuel quality standard for diesel sets distillation T95 at 370°C (max), to be reduced to 360°C (max) on 1 January 2006.

The distillation curve of diesohol will be affected by the presence of the alcohol which will boil off at a single temperature. As such it may not be appropriate to regulate distillation for diesohol.

18. Stakeholders are asked to comment on:

- a) the appropriateness of regulating distillation; and
- b) if necessary:
  - an appropriate Australian specification for distillation; and
  - an appropriate test method for determining distillation.

## 7.8 Filter blocking tendency

Filter blocking tendency measures the ability of diesel fuels to be filtered. Efficiently operating filters are important for overall engine performance, and consequently emissions performance. The diesel determination sets a 2.0 maximum for filter blocking tendency as measured by the prescribed test method IP 387.

The Department has been advised that there is no technical argument or evidence which suggests that there is a deterioration in filter blocking tendency for diesohol compared to diesel. It therefore may not be necessary to manage this parameter for diesohol, or if deemed necessary then to regulate it in the same manner as diesel.

19. Stakeholders are asked to comment on:

- a) the appropriateness of regulating filter blocking tendency; and
- b) if necessary the appropriateness of setting a maximum filter blocking tendency of 2.0 as measured by test method IP 387.

## 7.9 Flash point

Alcohol has a much higher vapour pressure than diesel, and diesohol blends typically reflect the vapour pressure of the base alcohol when the alcohol exceeds 5% of the volume. An increase in vapour pressure corresponds with a decrease in flash point (the lowest temperature at which a product gives off just sufficient vapour to form a flammable mixture with air under standard conditions). For example, the fuel quality standard for diesel sets a minimum flash point of 61.5°C but the flash point of ethanol-diesel blends is characteristically 13°C.

The flash point of fuels is an important parameter related to safe storage and handling. The reduced flash point of diesohol means that it must be treated in the same manner as petrol – which is a Class 3 combustible fluid for the purposes of Australian Standard, AS 1940-1993, Storage and Handling of Flammable and Combustible Liquids, and has a Packaging Group Category PGII under the Australian Dangerous Goods Code.

The regulatory control of storage and handling in bulk storage is currently undertaken by the States and Territories. Consequently, it may not be necessary to set a specification for flash point.

20. Stakeholders are asked to comment on the appropriateness of regulating flash point.

## REFERENCES

Australian Academy of Technological Sciences and Engineering (AATSE) (1997) *Urban Air Pollution in Australia*.

Beer, T; Grant, T; Morgan, G; Lapszewicz, J; Anyon, P; Edwards, J; Nelson, P; Watson, H and Williams, D (2000) *Comparison of Transport Fuels - Final report (EV45A/2/F3C) to the Australian Greenhouse Office on the Stage 2 study of Life-cycle Emissions Analysis of Alternative Fuels for Heavy Vehicles*.

Cheng, AS (Ed); Dibble, RW and Buchholz, BA (2002) *The Effect of Oxygenates on Diesel Engine Particulate Matter*. SAE Technical Paper Series: 2002-01-1705.

Cole, RL; Poola, RB; Sekar, R; Schaus JE and McPartlin P (2001) *Effects of Ethanol Additives on Diesel Particulate and NO<sub>x</sub> Emissions*. SAE Technical Paper Series: 2001-01-1937.

Department of Industry Science and Resources (1999) *Downstream Petroleum Products Action Agenda*.

Department of Industry, Science and Resources (2001) *Setting National Fuel Quality Standards - Paper 4 - Discussion Paper on Operability Fuel Parameters (Petrol and Diesel)*.

Department of Industry, Tourism and Resources (2003) *Australian Petroleum Statistics*. Issue No. 83 June 2003.

Environment Australia (2000) *Setting National Fuel Quality Standards - Paper 2 - Proposed Standards for Fuel Parameters (Petrol and Diesel)*.

European Automobile Manufacturers Association; Alliance of Automobile Manufacturers; Engine Manufacturers Association; and Japan Automobile Manufacturers Association (2002) *World-Wide Fuel Charter*.

European Commission (1998) *European Commission ExternE Transport Project. Technical Final Report DG12*. Brussels.

Joseph, S (1996) *The Testing of Diesohol Fuel Buses*. Department of the Environment, Sport and Territories.

Kass, MD; Thomas, JF; Storey, JM; Domingo, N; Wade, J and Kenreck, G (2001) *Emissions from a 5.9 Litre Diesel Engine Fueled with Ethanol Diesel Blends*. SAE Technical Paper Series: 2001-01-2019.

McCormick, RL and Parish R (2001) *Advanced Petroleum Based Fuels Program and Renewable Diesel Program. Milestone Report: Technical Barriers to the Use of Ethanol in Diesel Fuel*. National Renewable Energy Laboratory.

National Environment Protection Council (1998) *Ambient Air Quality – National Environment Protection Measure and Revised Impact Statement for Ambient Air Quality*. National Environment Protection Council Service Corporation.

Scott, WT; Brown, SDA; Kadayifci, MZ and Mitchell, AW (1995) *Exhaust and Noise Emission Testing of Diesel and Diesohol Fuelled Buses*. Report No. MV-A-29. NSW EPA – Mobile Sources Section.

Standards Australia (1998) *Australian Standard for Automotive Diesel Fuel, AS 3570 – 1998*. Standards Australia, North Sydney, NSW.

U.S. Department of Energy, Biofuels Systems Division, Office of Alternative Fuels (1991) *Properties of Alcohol Transportation Fuels Alcohol Fuels Reference Work #1*. Prepared by: Fuels and Transportation Division, Meridian Corporation.

Waterland, LR; Venkatesh, S and Unnasch, S (2003) *Safety and Performance Assessment of Ethanol/Diesel Blends (E-Diesel)*. National Renewable Energy Laboratory.

Westerholm, R; Christensen, A; Tornqvist, M; Ehrenberg, L and Haupt, D (1997) *Chemical and biological characterisation of exhaust emissions from ethanol and ethanol blended diesel fuels in comparison with neat diesel fuels. KFB Report*. Kommunikations Forsknings Beredningen (Swedish Transport and Communications Research Board) Stockholm.

## APPENDIX A – AUTOMOTIVE DIESEL STANDARD

| Parameter                                 | Standard                                                                                       | Date of effect |
|-------------------------------------------|------------------------------------------------------------------------------------------------|----------------|
| Sulfur                                    | 500 ppm                                                                                        | 31 Dec 2002    |
|                                           | 50 ppm                                                                                         | 1 Jan 2006     |
| Cetane Index                              | 46 (min) index                                                                                 | 1 Jan 2002     |
| Density                                   | 820 to 860 kg/m <sup>3</sup>                                                                   | 1 Jan 2002     |
|                                           | 820 to 850 kg/m <sup>3</sup>                                                                   | 1 Jan 2006     |
| Distillation T95                          | 370°C (max)                                                                                    | 1 Jan 2002     |
|                                           | 360°C (max)                                                                                    | 1 Jan 2006     |
| Polyaromatic hydrocarbons (PAHs)          | 11% m/m (max)                                                                                  | 1 Jan 2006     |
| Ash and suspended solids                  | 100 ppm (max)                                                                                  | 1 Jan 2002     |
| Viscosity                                 | 2.0 to 4.5 cSt @ 40°C                                                                          | 1 Jan 2002     |
| Carbon Residue (10% distillation residue) | 0.2 mass % max                                                                                 | 16 Oct 2002    |
| Water and sediment                        | 0.05 vol % max                                                                                 | 16 Oct 2002    |
| Conductivity                              | 50 pS/m (Min) @ambient temp (only applies at terminals/refineries/ major distribution centres) | 16 Oct 2002    |
| Oxidation Stability                       | 25 mg/L max                                                                                    | 16 Oct 2002    |
| Colour                                    | 2 max                                                                                          | 16 Oct 2002    |
| Copper Corrosion (3 hrs @50°C)            | Class 1 max                                                                                    | 16 Oct 2002    |
| Flash point                               | 61.5°C min                                                                                     | 16 Oct 2002    |
| Filter blocking tendency                  | 2.0 max                                                                                        | 16 Oct 2002    |
| Lubricity                                 | 0.460 mm (max) (only for diesel containing less than 500ppm sulfur)                            | 16 Oct 2002    |