



# petrol & diesel

delivering quality

## resource document

Ministry of **Economic  
Development**



*Manatū Ōhanga*

A Review of the Petroleum Products Specifications Regulations

# contents

	<b>Abbreviations</b>	<b>5</b>
	<b>Summary</b>	<b>7</b>
<b>1.</b>	<b>Introduction</b>	<b>13</b>
1.1	Scope of the Review	14
1.2	Resource Document Structure	14
<b>2.</b>	<b>The Regulations</b>	<b>15</b>
2.1	History	15
2.2	Scope	15
<b>3.</b>	<b>New Zealand Fuel Market and Vehicle Fleet</b>	<b>17</b>
3.1	Fuel Market	17
3.1.1	Where Does New Zealand's Fuel Come From?	17
3.1.2	Where is New Zealand's Fuel used?	19
3.1.3	Fuel Suppliers	20
3.1.4	Regulatory vs. Internal Specifications	20
3.2	New Zealand's Vehicle Fleet	21
3.2.1	Vehicle Fleet Emissions	21
3.2.2	Fleet Make-up	22
3.2.3	Where do our vehicles come from?	23
3.2.4	Fleet Age and Turnover	25
3.2.5	Fleet Utilisation	25
3.3	Emission Standards	25
3.3.1	Emissions Control Capability of the New Zealand Fleet	26
3.3.2	Engine and Emission Control Technology	26
3.4	Non-road users of Petrol and Diesel	28
3.4.1	Marine	28
3.4.2	Other Users – Commercial	28
3.4.3	Other Users – Retail	28
3.4.4	Agricultural Use	28
<b>4.</b>	<b>Consumer Protection, Environmental Health and Safety Considerations</b>	<b>29</b>
4.1	Consumer Protection	29
4.1.1	Consumer Protection Legislation	29
4.1.2	Consumer Agencies	30
4.1.3	Consumer Issues	31
4.1.4	Fuel Quality Monitoring	31
4.2	Environment – Air Quality	32
4.2.1	Sources of Air Emissions Arising from the Use of Petrol and Diesel in New Zealand	32
4.2.2	Products of Combustion	34
4.2.3	Displacement Losses from Distribution (Evaporative Losses)	34
4.2.4	Evaporative Losses from Vehicles	35
4.2.5	Legal and Policy Framework	35
4.2.6	Air Quality Indicators for New Zealand	36
4.2.7	How Good is New Zealand's Local Air Quality?	36
4.2.8	Global Air Quality	37
4.3	Environment - Water Quality	38
4.3.1	Water Contamination Arising from the use of Petrol and Diesel in New Zealand	38
4.3.2	Legal and Policy Framework	39
4.3.3	Water Quality Indicators for New Zealand	39

# contents

4.3.4	How Good is New Zealand's Water Quality?	39
4.4	Health Effects	40
4.4.1	Fuel Distribution Occupations	40
4.4.2	Motor Trade Occupations	40
4.5	Hazardous Substances Legislation	40
4.5.1	Dangerous Goods Regulations	41
4.5.2	Toxic Substances Regulations	41
4.5.3	Hazardous Substances and New Organisms Act 1996 and Regulations	41
<b>5.</b>	<b>International Scene</b>	<b>42</b>
5.1	Vehicle Emission Standards	42
5.2	Fuel Quality and Emissions	43
5.2.1	Effects of Petrol Composition and Properties on Vehicle Emissions	43
5.2.2	Correlations between petrol quality and emissions	43
5.2.3	Effects of diesel composition and properties on vehicle emissions	43
5.3	International Fuel Quality Specifications	45
5.3.1	Japan	45
5.3.2	Australia	46
5.3.3	European Fuel Specifications	46
5.3.4	World-Wide Fuel Charter	47
5.3.5	United States of America	47
<b>6.</b>	<b>Key Issues</b>	<b>48</b>
6.1	Key Issues for the Fuel Supply Market	48
6.2	Key Issues for Fuel Use	48
6.3	Key Issues for Environment and Health	48
6.4	Timing	49
<b>7.</b>	<b>Properties of Petrol</b>	<b>50</b>
	<b>Properties Currently Specified</b>	<b>50</b>
7.1	Octane Number	50
7.2	Colour	53
7.3	Volatility and Distillation Parameters	53
7.4	Residue and Existent Gum	57
7.5	Copper Strip Corrosion	58
7.6	Sulphur	58
7.7	Oxidation Stability Induction Period	60
7.8	Lead	60
7.9	Total Aromatics	61
7.10	Benzene	63
7.11	Oxygenates	65
	<b>Properties Currently Not Specified</b>	<b>69</b>
7.12	Olefins	69
7.13	Manganese	70
7.14	Phosphorous	71
7.15	Density	72

<b>8.</b>	<b>Properties of Diesel</b>	<b>73</b>
	Properties Currently Specified	73
8.1	Density	73
8.2	Appearance and Colour	75
8.3	Cetane Number and Cetane Index	76
8.4	Cold Flow Properties	78
8.5	Viscosity	80
8.6	Flash Point	81
8.7	Sulphur	81
8.8	Copper Strip Corrosion	84
8.9	Ash	85
8.10	Carbon Residue	85
8.11	Distillation – (T85)	86
	Properties Currently Not Specified	87
8.12	Polycyclic Hydrocarbons (PAH)	88
8.13	Oxidation Stability	89
8.14	Water Content and Total Contamination	89
8.15	Lubricity	90
8.16	Filter Blocking Tendency	90
8.17	Conductivity	90
<b>9.</b>	<b>Making the Regulations Work</b>	<b>91</b>
9.1	Why Do We Need the Regulations?	91
9.2	Fit for Purpose	91
9.3	Test Methods	92
9.4	Fines for Non-compliance	92
9.5	Labelling	92
9.6	Ensuring Fuel Consistency	92
9.6.1	Pool Averaging	93
9.6.2	Mandated Geographical Differences	93
9.7	Additives	93
9.8	Fuel for Retail Sale and All Other Fuel	94
9.9	Strategy for Ongoing Changes to the Regulations	95
<b>10.</b>	<b>Market and Cost Implications</b>	<b>96</b>
10.1	Competition and Security of Supply	96
10.2	Financial Implications of Proposed Changes	97
10.2.1	The Price of New Zealand Petrol and Diesel	97
10.2.2	Implications for Marsden Point Refinery	97
10.2.3	Costs from Australian Review	98
10.2.4	European Costings	98
10.2.5	Implications for New Zealand Petrol and Diesel Prices	98
	References	99
	Glossary	102
	Appendices	
	Appendix A How the Review was Undertaken	107
	Appendix B Petroleum Products Specifications Regulations 1998	111
	Appendix C Internal Combustion Engine Basic Operating Principles and Technology Trends	116
	Appendix D Vehicle Fleet Emissions Control Strategy	125
	Appendix E Air Contaminants	128

# abbreviations

<b>ACEA</b>	European Automobile Manufacturers Association	<b>HBFO</b>	Heavy Bunker Fuel Oil
<b>ADR</b>	Australian Design Rule	<b>HFO</b>	Heavy Fuel Oil
<b>AIP</b>	Australian Institute of Petroleum	<b>IARC</b>	International Agency for Research on Cancer
<b>ASTM</b>	American Society for Testing and Materials	<b>IP</b>	The Institute of Petroleum, London
<b>ATV</b>	All Terrain Vehicles	<b>ISO</b>	International Organisation for Standardisation
<b>BACT</b>	Best Available Control Technology	<b>JAMA</b>	Japan Automobile Manufacturers Association
<b>BS &amp; BSEN</b>	British Standard	<b>LEV</b>	Low Emission Vehicle
<b>CBU</b>	Completely built up (finished vehicle imported from overseas)	<b>LCV</b>	Light Commercial Vehicle
<b>CKD</b>	Completely knocked down (vehicle kitsets imported from overseas for local assembly)	<b>LFO</b>	Light Fuel Oil
<b>CNG</b>	Compressed natural gas	<b>LOAEL</b>	Lowest Observable Adverse Effect Level
<b>CO</b>	Carbon monoxide (local air pollutant)	<b>LPG</b>	Liquefied petroleum gas (vehicle fuel)
<b>CO<sub>2</sub></b>	Carbon dioxide (greenhouse gas)	<b>LTSA</b>	Land Transport Safety Authority
<b>CONCAWE</b>	The oil companies' European organisation for environment, health and quality	<b>LSD</b>	Low Sulphur Diesel
<b>DBL</b>	Diurnal breathing losses	<b>MED</b>	Ministry for Economic Development
<b>DIN</b>	The German Institute for Standardisation	<b>MfE</b>	Ministry for the Environment
<b>EC</b>	European Commission	<b>MIA</b>	Motor Industry Association
<b>ECA</b>	Environmental Capacity Analysis	<b>m/m</b>	mass/mass
<b>EEC</b>	European Economic Community	<b>MMT</b>	Methylcyclopentadienyl manganese tricarbonyl (an octane enhancer)
<b>EECA</b>	Energy Efficiency and Conservation Authority	<b>MOH</b>	Ministry of Health
<b>EGR</b>	Exhaust gas recirculation	<b>MON</b>	Motor Octane Number
<b>EMA</b>	Engine Manufacturers Association	<b>MOT</b>	Ministry of Transport
<b>EMS</b>	Engine management system	<b>MTBE</b>	Methyl tertiary butyl ether – an octane enhancer and petrol extender
<b>EPI</b>	Environmental Performance Indicators	<b>NO<sub>2</sub></b>	Nitrogen dioxide
<b>EU</b>	European Union	<b>NO<sub>x</sub></b>	Oxides of nitrogen (general term)
<b>EXOS</b>	Ex-Overseas vehicles (commonly referred to as "imports")	<b>NOAEL</b>	No Observed Adverse Effect Level
<b>FRNZ</b>	First registered in New Zealand	<b>NZOSL</b>	New Zealand Oil Services Limited
<b>G-DI</b>	Gasoline Direct Injection	<b>NZRC</b>	New Zealand Refining Company Limited
		<b>OCGE</b>	Office of the Chief Gas Engineer

		<b>Units</b>	
<b>O<sub>3</sub></b>	Ozone		
<b>OECD</b>	Organisation for Economic Co-operation and Development	<b>cSt</b>	centistokes, unit of kinematic viscosity; alternatively mm <sup>2</sup> /sec
<b>OEM</b>	Original equipment manufacturer	<b>g</b>	gram
<b>PAH</b>	Polyaromatic hydrocarbons	<b>mg</b>	milligram, 10 <sup>-3</sup> grams
<b>PM<sub>10</sub></b>	Particulate matter of less than 10 µm diameter	<b>µg</b>	microgram, 10 <sup>-6</sup> grams
<b>PM<sub>2.5</sub></b>	Particulate matter of less than 2.5 µm diameter	<b>ng</b>	nanogram, 10 <sup>-9</sup> grams
<b>ppm</b>	Parts per million	<b>kg/m<sup>3</sup></b>	kilograms per cubic metre (unit of density)
<b>PULP</b>	Premium Unleaded Petrol	<b>kg/litre</b>	kilograms per litre (unit of density)
<b>PWC</b>	Personal Water Craft (commonly known as jet-skis)	<b>g/m<sup>3</sup></b>	grams per cubic metre, (unit of concentration) equivalent to mg/litre
<b>RMA</b>	Resource Management Act 1991		
<b>RVP</b>	Reid Vapour Pressure	<b>mg/litre</b>	milligrams per litre (unit of concentration) equivalent to ppm
<b>SD</b>	Standard Deviation		
<b>SHED</b>	Sealed Housing for Evaporative Determination	<b>µm</b>	micron, 10 <sup>-6</sup> m
<b>TSP</b>	Total Suspended Particulate	<b>ppm</b>	parts per million, equivalent to mg/litre
<b>ULEV</b>	Ultra Low Emission Vehicle		
<b>ULP</b>	Unleaded Petrol (refers to regular grade)		
<b>USEPA</b>	United States Environmental Protection Agency		
<b>VFECs</b>	Vehicle Fleet Emissions Control Strategy		
<b>VFEM</b>	Vehicle Fleet Emissions Model		
<b>VOC</b>	Volatile organic compound		
<b>VKT</b>	Vehicle kilometres travelled		
<b>WES</b>	Workplace Exposure Standard		
<b>VVT</b>	Variable valve timing		
<b>WHO</b>	World Health Organisation		

# summary

The review of the Petroleum Products Specifications Regulations has identified that a major upgrade of the specifications is justifiable to ensure our petrol and diesel quality standards are in line with international trends. These trends are towards specifications that deliver better vehicle performance and environmental outcomes. If our specifications do not change, New Zealand may not be able to obtain the newer technology, more fuel-efficient and environmentally friendly vehicles now entering international markets. However, timing issues, industry competitiveness and costs need to be considered alongside the advantages to be gained from better performance and higher health and environmental standards. A full list of the proposed amendments is summarised in the tables on pages 9-12.

## The most significant changes proposed to the petrol specifications include:

- Progressively reducing maximum benzene levels from 4.2% to 1% by volume.  
*Benzene is a known carcinogen. Our allowable limits are high compared to other international standards.*
- Progressively reducing maximum sulphur levels from 500 parts per million (ppm) to 50 ppm.  
*This amendment will codify current practice and facilitate the introduction of advanced engine technologies.*
- Prohibiting the use of MTBE in petrol with a contamination limit of 1% by volume.  
*MTBE mixes readily with water and has been known to taint groundwater at very low concentrations. This has led to its ban in parts of the United States.*
- Allowing ethanol blends up to 10%, subject to a testing and approval process.  
*Currently ethanol blends are not provided for. Many countries allow ethanol blends. A precautionary approach is proposed to ensure ethanol blended petrol meets New Zealand motoring requirements.*
- Prohibiting the addition of MMT (manganese).  
*This is not currently used. The automotive industry strongly opposes it as an additive.*
- Specifying and progressively reducing maximum levels of olefins from 25% by volume to 18%.  
*Olefin levels are currently not regulated. Olefins contribute to smog forming emissions and formation of toxic dienes.*
- Reducing maximum aromatics level in regular grade petrol to 40% by volume and progressively reducing maximum aromatics level in premium grade petrol from 48% to 42% by volume.  
*This is a means of limiting exhaust emissions of hydrocarbons.*
- Reducing maximum lead levels from 13 mg/litre to 5 mg/litre.

## The most significant changes proposed to the diesel specifications include:

- Progressively narrowing the allowable density range.  
*This will enable improved engine performance and will align New Zealand with international standards.*
- Progressively increasing the cetane number from 45 to 51.  
*This will improve engine performance, decrease nitrogen oxide and possibly carbon monoxide and hydrocarbon emissions, and decrease fuel consumption.*
- Progressively reducing maximum sulphur levels from 3,000 ppm to 50 ppm.  
*This will align us with international trends and enable the use of new technology vehicles with emissions control systems requiring very low sulphur levels. Reductions to 500 ppm will reduce particulate emissions from existing vehicles.*

- Specifying maximum levels of PAHs to 11% by mass from two to three years hence.  
*Levels of PAHs are not currently regulated. Limiting PAHs is desirable for health benefits and is in line with international trends.*
- Adding a new filterability test.  
*This will help to avoid the filter clogging problems experienced by diesel users in May-June this year.*

## General Changes proposed to Regulations

- Inclusion of a general clause requiring that all fuel be “fit for purpose”.  
*This will make it clear that a primary objective of the Regulations is to ensure that fuel supplied is “fit for purpose” (refer Section 9.2).*
- Increase fines for non-compliance to \$30,000 for an individual and \$100,000 for a corporate body.  
*The maximum fine for non-compliant fuel is currently \$10,000. This change would mean fine levels consistent with the Fair Trading Act. This change would require an amendment to the Ministry of Energy Abolition Act (refer Section 9.4).*
- Requirement that fuel dispensers at retail service stations be clearly labelled.  
*This is to minimise the risk of misfuelling (refer Section 9.5).*
- “Boutique” grades of petrol must meet the octane ratings and other special properties advertised, as well as all other properties specified in the Regulations.  
*“Boutique” grades are those grades of petrol not marketed as regular or premium petrol (refer Section 9.5).*
- Add a new definition of additive.  
*Additives are allowed in petrol and diesel. The definition will clearly signal that additives are intended to improve fuel performance or fuel distribution (refer Section 9.7).*



## Changes to Petrol Specifications Under Consideration

Immediate changes will be implemented as soon as the new Regulations can be issued. This is anticipated to be around mid-2002.

Stage 1 changes will be implemented in 2-3 years' time (2003 - 2004)

Stage 2 changes will be implemented 5-6 years' time (2006 - 2007)

Property	Current Limits	Immediate	Stage 1	Stage 2	Discussion
Research octane number (RON)	Premium 95.0 min	Regular 91.0 min	No change to RON and MON requirements for Regular and Premium grades.		Refer to Section 7.1
Motor octane number (MON)	85.0 min	82.0 min			
Colour	Not to be mistaken for a harmless substance	Delete from regulations.			Refer to Section 7.2
Percentage volume evaporated at 70°C (E70)	25 minimum 45 maximum	22 minimum 45 maximum			Refer to Section 7.3
Percentage volume evaporated at 100°C (E100)	45 minimum 67 maximum	No change			Refer to Section 7.3
Percentage volume evaporated at 180°C (E180)	90 maximum	No change	Change to E150, 75 maximum		Refer to Section 7.3
End point (°C)	220 maximum	No change	215 maximum	210 maximum	Refer to Section 7.3
Flexible Volatility Index [RVP (kPa) + (0.7 × E70)] (Specifications cover broad range of summer and winter grades)	77.5 minimum 115.0 maximum	Remove minimum FVI limit, replace with RVP limits (see below). Retain current maximum FVI limit, review later.			Refer to Section 7.3
Reid Vapour Pressure (kPa) [New property]		85 maximum (Summer) 90 maximum (Spring & Autumn) 95 maximum (Winter) Test method ASTM D 323	75 maximum (Summer) 85 maximum (Spring & Autumn) 95 maximum (Winter)	65 maximum (Summer) 80 maximum (Spring & Autumn) 95 maximum (Winter)	Refer to Section 7.3
Residue (percentage volume)	2 maximum	No change			Refer to Section 7.4
Existent gum (solvent washed) (mg/100 ml)	5 maximum	No change			Refer to Section 7.4
Copper strip corrosion (2 hours at 100°C)	Class 1 maximum	Change to 3 hours at 50°C Class 1 maximum.			Refer to Section 7.5
Sulphur (percentage mass)	0.05 maximum [equivalent to 500 ppm]	150 mg/kg (ppm) maximum Specify ASTM D 5453 (Ultraviolet fluorescence) as test method for sulphur.		50 mg/kg (ppm)	Refer to Section 7.6

## Changes to Petrol Specifications Under Consideration

Property	Current Limits	Immediate	Stage 1	Stage 2	Discussion
Oxidation stability induction period (minutes)	240 minimum	360 minimum			Refer to Section 7.7
Lead (grams per litre)	0.013 maximum (13 mg/litre)	0.005 maximum (5 mg/litre)			Refer to Section 7.8
Total aromatic compounds (including Benzene) (percentage volume)	48 maximum	Premium or higher grades			Refer to Section 7.9
		No change		42 maximum	
		Regular grade (defined as petrol with RON < 95)			
		40 maximum			
Benzene (% mass)	5 maximum	4 maximum (percentage volume)	3 maximum (percentage volume)	1 maximum (percentage volume)	Refer to Section 7.10
Oxygenates (percentage mass)  (Does not apply where the added oxygenate is methyl tertiary butyl ether (MTBE). Up to 11 percent volume MTBE may be added.)	0.1 maximum	Retain limit for total oxygenates, excluding MTBE and ethanol.  Allow 1% maximum (percentage by volume) for MTBE (as contaminant).  Consider allowing 10% maximum (percentage by volume) for ethanol on a test basis, subject to an approval process.			Refer to Section 7.11
Olefins (percentage volume)	Not currently regulated	25 maximum To apply to all petrol  Test method ASTM D 1319	21 maximum	18 maximum	Refer to Section 7.12
Manganese	Not currently regulated	0.25 mg/litre maximum To apply to all petrol  Test method ASTM D 3831 (Atomic Absorption Spectroscopy)			Refer to Section 7.13
Phosphorous	Not currently regulated	0.20 mg/litre maximum To apply to all petrol  Test method ASTM D 3231			Refer to Section 7.14
Density	Not currently regulated	No change			Refer to Section 7.15

## Changes to Diesel Specifications Under Consideration

Immediate changes will be implemented as soon as the new Regulations can be issued. This is anticipated to be around mid-2002.

Stage 1 changes will be implemented in 2-3 years' time (2003 - 2004)

Stage 2 changes will be implemented 5-6 years' time (2006 - 2007)

Property	Current Limits	Immediate	Stage 1	Stage 2	Discussion
Density at 15°C kg per litre	0.860 maximum 0.810 minimum	860 kg/m <sup>3</sup> maximum 820 kg/m <sup>3</sup> minimum Change to standard units (kg/m <sup>3</sup> )	850 kg/m <sup>3</sup> maximum 820 kg/m <sup>3</sup> minimum	845 kg/m <sup>3</sup> maximum 820 kg/m <sup>3</sup> minimum	Refer to Section 8.1
Appearance at 15 °C	Clear and bright	No change			Refer to Section 8.2
Colour (ASTM colour)	3.0 maximum	No change			
Cetane Number  OR  Cetane Index	45 minimum   47 minimum				Refer to Section 8.3
Cetane Number		49 minimum	51 minimum		Refer to Section 8.3
Cetane Index		47 minimum			Refer to Section 8.3
Cloud Point (CP) (°C) – Summer	4 maximum	Change Cloud Point test to ASTM D 5773 (Constant Cooling Rate)  Specify seasonal and geographical limits for CP and CFPP to be met at the point of sale (see main text)			Refer to Section 8.4
Cloud Point or Cold Filter Plugging Point (CFPP) (°C) – Winter	-6 maximum				
<ul style="list-style-type: none"> <li>• Applies at time of manufacture in New Zealand or, for imports, date of discharge into port storage at a New Zealand port. Summer: 1 September to end February. Winter: 1 March to 31 August.</li> <li>• Sales for marine use may be summer grade at any time of the year</li> </ul>					
Viscosity (centistokes at 40(°C)	1.5 minimum  5.0 maximum	1.5 minimum  4.5 maximum  Standardise units (mm <sup>2</sup> /s)	2.0 minimum  4.5 maximum		Refer to Section 8.5
Flash point (°C)	61 minimum	Make applicable to all diesel sold or supplied not just for retail sale			Refer to Section 8.6
Sulphur (percentage mass)  (Limit for sulphur does not apply to sale for marine use)	0.30 maximum [equivalent to 3000 ppm]	Under consideration  Specify ASTM D 5453 (Ultraviolet fluorescence) as test method for sulphur	500 mg/kg (ppm) maximum	50 mg/kg (ppm) maximum	Refer to Section 8.7
Copper strip corrosion (3 hours at 100°C)	Class 1 maximum	Change to 3 hours at 50°C			Refer to Section 8.8

## Changes to Diesel Specifications Under Consideration

Property	Current Limits	Immediate	Stage 1	Stage 2	Discussion
Ash (percentage mass)	0.01 maximum	No change			Refer to Section 8.9
Carbon residue – Ramsbottom on 10 percent volume Residuum (percentage mass)	0.20 maximum	Replace with MCR test IP 398 (ASTM D 4530) and 0.10 maximum.			Refer to Section 8.10
Distillation – 85 percent volume recovered to (°C)	350 maximum	Remove T85 specification and replace with T95 specification of 370°C maximum	Reduce T95 to 360 °C maximum		Refer to Section 8.11
Polyaromatic hydrocarbons (PAH)	Not currently regulated	No limit proposed at this stage.	11 percent maximum by mass, to apply to all diesel  Test by ASTM D 5186 (Supercritical Fluid Chromatography Method) or IP 391 (High Performance Liquid Chromatography Method)		Refer to Section 8.12
Oxidation Stability	Not currently regulated	25 g/m <sup>3</sup> maximum Test by ASTM D 2274 (Accelerated Method)			Refer to Section 8.13
Water content	Not currently regulated	200 mg/kg maximum. Test method to be determined.			Refer to Section 8.14
Total contamination	Not currently regulated	24 mg/kg maximum. Test by ASTM D 2276			
Lubricity	Not currently regulated	460 µm maximum HFRR wear scar diameter at 60°C Test by IP 450			Refer to Section 8.15
Filter Blocking Tendency	Not currently regulated	1.41 maximum Test by IP 387			Refer to Section 8.16
Conductivity	Not currently regulated	Do not propose to regulate at this stage			Refer to Section 8.17

This Resource Document comprises a detailed discussion of the Petroleum Products Specifications Regulations 1998 and the context in which they exist. The regulations set out minimum standards affecting the performance of fuel, enabling consumers to purchase petrol and diesel to a quality standard appropriate for New Zealand's vehicle fleet and climatic conditions. They also include provisions limiting components that could be harmful to the environment or public health.

The regulations are being reviewed to ensure that consumers have access to petrol and diesel that comply with accepted and up to date quality, safety and environmental standards. The review has two main objectives:

- To clarify the purpose of the regulations; and
- To determine whether the specifications are meeting present needs and are relevant for the medium to long term, and whether we need a strategy to amend the specifications over time.

Petrol and diesel specifications were first regulated in 1988 at the time of deregulation of petrol and diesel retailing. The specifications have been amended since this time to prohibit the use of lead as an additive and to restrict the addition of aromatics in petrol. However, the present review is the first time the Regulations have been considered in total.

When issued in 1988, the fuel specifications were considered good by world standards.

Since then, there have been significant developments both domestically and internationally in fuel engine technologies, in fuel production processes and in our understanding of the health and environmental issues that surround petrol and diesel use. Other jurisdictions, notably Europe, the United States of America, Australia and Japan, have adopted in recent years more stringent specifications to achieve higher quality, safety, health and environmental outcomes.

#### Who is Involved in the Review

The Petrol and Diesel – Delivering Quality review is being led by the Ministry of Economic Development, in association with the Ministry for the Environment, the Ministry of Transport, the Ministry of Health and the Ministry of Consumer Affairs.

The review complements the Vehicle Fleet Emissions Control Strategy work undertaken by the Ministry of Transport, the Ministry for the Environment's work on ambient air quality, climate change and the National Energy Efficiency Strategy, and the Ministry of Health's work on benzene.

This Resource Document is complemented by the Discussion Document: Petrol and Diesel – Delivering Quality – A Review of the Petroleum Products Specifications Regulations, available online from [www.med.govt.nz](http://www.med.govt.nz) or as a printed document on request from the Ministry of Economic Development.

Public submissions on the proposed recommendations, outlined in both documents, are sought, and should be forwarded to the Ministry of Economic Development by 15 October 2001. The Discussion Document contains a cut-out submission form and details on how to have your say.

## 1.1 Scope of the Review

Appendix A describes the terms of reference for the review and this Resource Document, the underlying principles that have informed the review, and the process by which the review has been conducted so far.

In brief the review and this Resource Document examine:

- What is the purpose of the current Regulations and are these still appropriate?
- Are the specifications meeting current needs and are they relevant for the medium to long term?
- Does New Zealand need a strategy for changing the Regulations and/or specifications over time?

Particular emphasis has been placed on:

- Consumer, environmental, health and safety issues and the most appropriate way of addressing them;
- The effect of the Regulations on consumer access to petroleum fuel products and the impact, if any, on the presence of a competitive market for petroleum fuel;
- Whether the specifications create barriers to the development of new products and/or the adoption of new technology;
- Whether the specifications reflect international trends; and
- Related work programmes in other government departments.

The review does not cover:

- Alternative fuels such as LPG, CNG, bio-diesel. It does however consider the use of petrol/ethanol blends, which is discussed in Section 7.
- Life-cycle energy analysis. Changes to fuel specifications may require additional processing energy at a refinery, increasing emissions of CO<sub>2</sub>. A full life-cycle analysis of the effect of the proposed changes on CO<sub>2</sub> emissions has not been conducted.
- Traffic congestion. The causes of traffic congestion and ways of managing congestion have not been discussed. References to work carried out by the Ministry of Transport that describe in detail the impacts of congestion on emissions are provided.
- Road and fuel pricing policy. The financial impacts of any recommendations are discussed in Section 10; however, this discussion does not extend to ways of financing any recommended changes in the specifications nor to road and fuel pricing policy and practice.

## 1.2 Resource Document Structure

This Resource Document is a more detailed companion to the Discussion Document.

**Section 1** (this section) provides a brief background and outlines the scope of the review.

**Section 2** describes the history and scope of the Regulations.

**Section 3** describes the New Zealand fuel market and the New Zealand vehicle fleet.

**Section 4** describes the policy and physical context for the three main areas that are the focus of the regulations: consumer protection, environmental impacts, and health and safety.

**Section 5** describes what is happening internationally in relation to fuel and vehicle development and relates this to the situation in New Zealand.

**Section 6** summarises the key issues taken into consideration in reviewing the current Regulations and specifications.

**Section 7** contains a property by property analysis of the specifications for petrol (regular and premium grade) and recommendations for change.

**Section 8** contains a property by property analysis of the specifications for diesel and recommendations for change.

**Section 9** makes recommendations on possible amendments to the Regulations.

**Section 10** discusses the market and cost implications of the proposed changes.

**Section 11** contains a full list of references.

Additional information is provided in the **appendices** to this document.

## 2.1 History

The distribution and sale of petrol and diesel in New Zealand was deregulated in 1988. Prior to that, retail prices and margins had been set by the government. Fuel quality specifications were set by agreement between the government, the oil industry and the motor vehicle manufacturers.

Deregulation created the opportunity for additional players to enter the market and it was considered that regulatory controls on the quality of diesel and petrol supplied and sold in New Zealand should be established. The purpose of these was to protect the interests of consumers and provide minimum standards covering fuel performance, safety and environmental effects.

Specifications for petroleum fuels were first promulgated in the Ministry of Energy (Petroleum Product Specifications) Regulations 1988, which came into effect on 1 January 1989. The basic structure of the regulations is still the same, with only a few changes over the last 12 years:

- 1994 – Changes to E70 limits (refer Section 7.3) following cold starting problems encountered with one particular shipment of imported fuel (which met the limits then current).
- 1994 – Amendments to require regular unleaded petrol to be supplied from 1 July 1995 and to phase out the supply of premium leaded petrol during 1996.
- 1995 – Replacement of the 1988 Regulations with the Petroleum Products Specifications Regulations 1995. This consolidated changes associated with the introduction of premium unleaded petrol (PULP) together with minor changes for regular grade petrol and for diesel.
- 1996 – Limits and test methods established for total aromatics levels in PULP, following difficulties which arose with the introduction of this grade (again related to fuel that met the limits then current).
- 1998 – Replacement of the 1995 Regulations with the Petroleum Products Specifications Regulations 1998 which came into force in October 1998, and are still current. Limits on total aromatics for both grades of petrol were harmonised and specific colour requirements for petrol were removed.

## 2.2 Scope

A full copy of the Petroleum Products Specifications Regulations 1998 is contained in Appendix B. In summary, the Regulations cover the following:

Clause	Content	Notes
1	Title and commencement	
2	Interpretation	<p>“Diesel” means a refined petroleum distillate having a viscosity and distillation range intermediate between those of kerosene and light lubricating oil, whether or not it contains additives, intended for use as fuel in internal combustion engines ignited by compression.</p> <p>“Petrol” means a refined petroleum distillate, normally boiling within the limits of 30°C to 220°C, whether or not it contains additives, intended for use as a fuel in spark-ignition internal combustion engines.</p> <p>“Retail sale” means a sale to an end user who has no written supply agreement or written contract with the supplier in respect of the sale.</p>

Clause	Content	Notes
3	Requirements relating to fuel sold by retail	<p>Petrol sold by retail sale must comply with all of the limits specified in Schedules 1 and 2 and diesel with all the limits specified in Schedule 3, except fuel which is to be used</p> <p>a) as an aviation fuel; or  b) for motor car racing; or  c) for powerboat racing and jet boats; or  d) for motorcycle racing.</p> <p><i>(This Review has therefore not considered fuel intended for these uses).</i></p>
4	Requirements relating to all fuel	<p>“All fuel” must comply with specified limits only. For petrol, those limits are those for sulphur, lead, benzene and total aromatics; for diesel, only the limit for sulphur must be met.</p> <p>This clause effectively allows the supply of alternative specification fuel to end users who have written supply agreements or contracts (commonly referred to as commercial users).</p> <p>The uses that are listed as exclusions in Clause 3 also apply for all fuel.</p>
5	Test procedures	Specifies requirements for sampling fuel for testing.
6	Sampling	Requires suppliers to allow samples of fuel to be taken or provide quality certification of a product.
7	Accreditation	Requires sampler/tester to be ISO accredited or equivalent.
8	Withdrawal of fuel from sale etc.	Distributor can be required to withdraw fuel from sale or supply
9	Offences	Specifies offences and a maximum fine of \$10,000 on conviction.
10.	Revocations	Revokes previous regulations.

Schedule 1 Requirements for Regular Grade Petrol

Schedule 2 Requirements for Premium Grade Petrol

Schedule 3 Requirements for Diesel

A property by property discussion of the requirements detailed in the Schedules is provided in Sections 7 and 8 of this document.



This section looks at our sources of petrol and diesel and patterns of use – where our fuel comes from and where it is used. These factors are important when considering the implications of any changes to the Regulations, as far as determining our particular requirements and how best to meet them. This section also considers the characteristics of the New Zealand vehicle fleet and the patterns of non-automotive use of fuels.

## 3.1 Fuel Market

New Zealand uses around 2.2 million tonnes of petrol per annum (2,900 million litres), of which about 75% is regular grade. The corresponding diesel consumption is around 1.9 million tonnes per annum (2,400 million litres) (MED, 2001a). As a comparison, the Australian market is currently around 13.5 million tonnes of petrol and 6 million tonnes of diesel per annum (EA, 2000a). The relative volumes of diesel and petrol for the two countries are significantly different.

Petrol consumption in New Zealand has been fairly static over the last 5 years, with annual growth averaging less than 1%, and the proportion of premium grade slowly declining. There has been a fairly steady growth in diesel consumption however, averaging around 5% over the last 5 years.

### 3.1.1 Where does New Zealand's fuel come from?

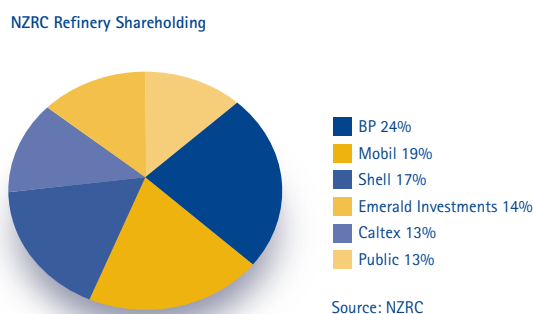
Petrol and diesel supplied in New Zealand comes from two sources:

- Crude oil refined at the Marsden Point Refinery; and
- Direct imports of finished product

#### Marsden Point Refinery

The Marsden Point Refinery is owned and operated by the New Zealand Refining Company (NZRC) and has been operating since 1964. A major expansion was completed in 1986. NZRC is a publicly listed company on the New Zealand Stock Exchange; the current shareholding is shown in Figure 3.1.

Figure 3.1 : Marsden Point Refinery Shareholding



The Refinery is a tolling operation, that is, it charges a toll on each litre of fuel produced. It processes crude oil on behalf of the refinery users (who are also shareholders) but the NZRC does not own the oil or the products. The processing fee is related to regional refining margins (ie. crude and product price differentials), which are affected by available refining capacity and regional economic performance. The Marsden Point Refinery effectively competes against other refineries in the region, with Singapore product costs being a benchmark, though other factors such as transport costs and strategic considerations also come into play.

These ownership arrangements are somewhat unusual in the refining business. It is more common for oil companies

to own their own refineries, as in Australia, where each of the four major oil companies has two refineries. This is an important consideration when looking at options for any changes to fuel quality and in understanding the differences between New Zealand and Australia.

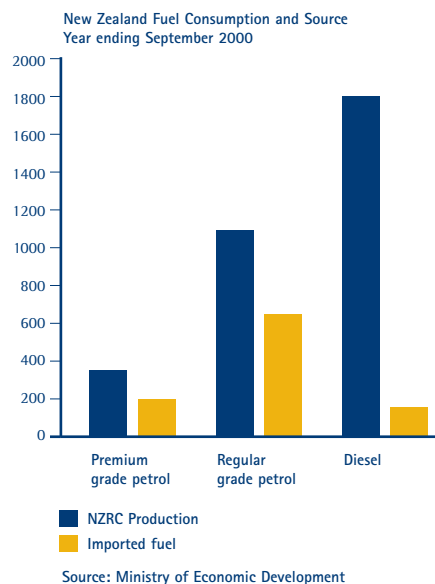
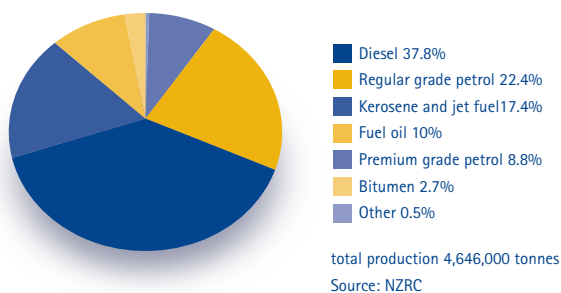
The Marsden Point Refinery processes around 5 million tonnes of feedstocks each year (mostly crude oils, but also some residues and semi-refined streams). It is essentially a “middle distillate” refinery, configured primarily for the production of jet fuel and diesel, rather than petrol. In the early 1980s, a synthetic petrol plant was built at Motonui to produce 25% of New Zealand’s petrol requirements from natural gas. The refinery expansion project in the mid-1980s was designed to complement this by producing predominantly distillates (kerosene and diesel). The Motonui plant is now owned by Methanex and no longer produces petrol, therefore New Zealand has a shortfall in petrol production.

The Marsden Point Refinery produces around 95% of New Zealand’s jet fuel requirements and 90% of its diesel, but only about 65% of its petrol. The balance of the petrol and diesel requirement is imported directly as finished product. In addition to automotive fuels and jet fuel, the refinery produces fuel oils (LFO, HFO and HBFO) as well as bitumen. The range and split of fuels produced by the Refinery is shown in Figure 3.2. Annual consumption and sources of petrol and diesel are shown in Figure 3.3.

Figure 3.2 : Marsden Point Refinery  
Ending Production, Year 2000

Figure 3.3 : Consumption of Petrol and Diesel by Source  
Year Sept 2000

NZRC Refinery Production by Tonnes, Year 2000



### Sources of Crude Oil

Crude oil feedstocks for the Marsden Point Refinery come from a range of sources. The selection of crudes for processing reflects the Refinery’s configuration as primarily a producer of middle distillates and its ability to produce high quality products from relatively low quality (and price) feedstocks (high sulphur crudes and residues). These feedstocks typically fall into the following main categories:

Table 3.1: Marsden Point Refinery Feedstocks

Feedstock	Characteristics	Typical proportion of total feedstock (by tonnage)
Middle East crudes	Medium to high sulphur, high residue	45%
Far East crudes	Lower sulphur, waxier, richer in middle distillates and more expensive	35%
Residues	Upgraded by vacuum distillation	8%
Condensates	Kapuni, Maui and imported condensates – sources of naphtha	13%

New Zealand crudes may be processed at the Refinery or exported depending on the buyer and the market price.

The sulphur content of petrol produced at Marsden Point is very low, as the catalytic reforming process used for producing petrol requires sulphur to be removed from the feed stream. However, significant quantities of imported petrol blendstocks are required to blend with the Refinery product to meet octane and aromatics limits, and these are the primary source of any sulphur in the petrol produced in New Zealand. Last year, these blendstocks made up around 11% by volume of the Refinery's total petrol production. These blendstocks include catalytically cracked spirit (petrol), low aromatics PULP, alkylate, reformat and isomerate from overseas refineries.

By comparison with most Australian refineries, Marsden Point has a significant hydrocracking capacity (a process which converts heavy streams to lighter kerosene and gas oil (diesel)) with capability to process heavy, sour (high sulphur) crudes. The Refinery's current capacity for hydrodesulphurisation of diesel is limited and is insufficient to meet the low sulphur levels (500 ppm) now becoming common in many countries, for all the diesel it produces. While the low sulphur diesel currently being sold in Christchurch is produced at the Refinery there is insufficient capacity to meet all New Zealand's requirements at this level. This is discussed in more detail in Section 8.7.

The Refinery is also constrained with regard to the aromatics content of petrol. As previously noted, petrol blendstocks are already used to achieve the required octane rating while staying within aromatics limits. Further reductions in aromatics and in future olefins as well, will have implications for the production of petrol at the Refinery. BP and Mobil's high octane petrols are imported directly from Australia.

### Distribution of Refinery Product

There are three main avenues for distribution of product from the Marsden Point Refinery to regional centres:

- By pipeline to the Wiri storage terminal in South Auckland;
- By coastal tanker to storage terminals at New Zealand ports;
- By road tanker – the tanker loading facility adjacent to the Refinery is used for distribution to outlets throughout Northland and North Auckland.

About 800,000 tonnes of petrol and 470,000 tonnes of diesel are pumped through the Refinery to Auckland pipeline to the Wiri terminal each year. Fuel is distributed from Wiri by road tanker throughout the greater Auckland area and as far south as the Waikato. Last year, areas supplied from Wiri accounted for around 36% of New Zealand's total petrol and 25% of the total diesel usage. Together with jet fuel, the pipeline throughput made up around 45% of the Refinery's total production.

### Imported fuel

The balance of diesel and petrol requirements not met by the Refinery is imported directly, predominantly to the storage terminals at Wellington, Lyttelton and Mt. Maunganui. This fuel comes mainly from refineries in the Asia – Pacific region including Australia, Singapore and Korea, but sometimes also from further afield (the USA and the Middle East). All four major oil companies import petrol and diesel to supplement the production from Marsden Point. In the past, the two smaller operators, Challenge and Gull Petroleum, have imported all their fuel – Challenge, through the ports of New Plymouth and Timaru, and Gull, through Mt. Maunganui (refer "New Entrants" in section 3.1.3).

As already noted, around 35% of New Zealand's current petrol requirements and 10% of its diesel is imported directly. Australia's refineries are generally configured to process Australian crudes which are relatively low in sulphur. Most of them produce petrol through catalytic cracking.

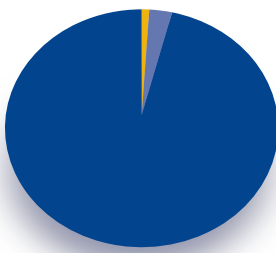
## 3.1.2 Where is New Zealand's fuel used?

Figures 3.4 and 3.5 show New Zealand's pattern of consumption of petrol and diesel respectively for the year 2000. Last year, 98% of petrol consumed was used for transport and 96% of this was sold through retail outlets (petrol stations). By comparison, 80% of diesel consumed was used for transport but only 65% of this was sold through retail outlets.

Non-road use of diesel is discussed in more detail in Section 3.4.

Figure 3.4 : Petrol Use in New Zealand, Year 2000

Petrol use in New Zealand, year 2000

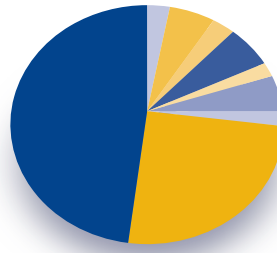


- Retail sale 96%
- Internal use 3%
- Agriculture Et hunting 1%

Source: Ministry of Economic Development

Figure 3.5 : Diesel Use in New Zealand, Year 2000

Diesel use in New Zealand, year 2000



- Retail sale 48%
- Internal use 25%
- Fishing 6%
- Agriculture Et hunting 6%
- Other Industry 5%
- Other primary Industry 3%
- Building Et construction 2%
- International transport 2%
- Other uses 3%

Source: Ministry of Economic Development

### 3.1.3 Fuel Suppliers

#### “Majors”

While the deregulation of the oil industry in 1988 opened the way for new players to enter the market, after more than ten years the four major oil companies (Caltex, Mobil, Shell and BP) still supply around 95% of the petrol and diesel sold in New Zealand. These four companies each have a shareholding in the Marsden Point Refinery, as well as having joint ownership of Wiri Oil Services Limited (which operates the Wiri Storage Terminal) and the Marsden Point Tanker Loading Facility.

The four “majors” also operate storage terminals and distribution facilities at 10 ports throughout New Zealand. Shell and BP own the New Zealand Oil Services Limited joint venture, which operates a number of these terminals on their behalf. Coastal Tankers Ltd, which operates the two coastal tankers Kakariki and Taiko, is also jointly owned by the four majors.

Competition in the fuels market has seen significant rationalisation of distribution infrastructure in the last few years. “Borrow and loan” and hosting arrangements enable all four companies to optimise shipping and use of terminal storage capacity and distribution infrastructure. There are also established arrangements for management and allocation of fuel stocks in each distribution centre if these fall below minimum levels (such as in the event of disruption to shipping or fuel quality problems).

#### “New Entrants”

Until recently, there were two smaller independent operators supplying petrol and diesel in New Zealand – Gull and Challenge, but with the recent sale of Challenge to Caltex, there is now effectively only one. Gull Petroleum has a storage terminal at Mt. Maunganui and retail outlets in the northern half of the North Island. It sources all of its product directly from overseas rather than through the Marsden Point Refinery and has around 2% of the market.

Challenge Petroleum, which was formerly owned by Fletcher Challenge Energy, has storage terminals in New Plymouth and Timaru and a national network of retail outlets and truckstops. Previously as an independent operator, it had around 4% of the market. It also sourced its fuel from outside New Zealand, but under the new ownership, this may change as its parent company has access to production from the Marsden Point Refinery.

### 3.1.4 Regulatory vs. Internal Specifications

All the suppliers of fuel are required to meet the mandatory quality requirements of the Regulations which apply (in most cases) at the point of sale or supply. Some minor changes in fuel properties will inevitably occur during storage and distribution and the costs of handling and reprocessing off-specification product, particularly if it has just arrived on a tanker from overseas, can be considerable. The fuel suppliers therefore have their own internal specifications for refined product which are significantly more comprehensive and in some cases more stringent than the regulatory requirements.

These reflect more specific marketing requirements (such as geographical variations) and allow some operating margin for quality changes between storage and sale.

As all four major oil companies are common users of the Marsden Point Refinery, and all receive imported product at their various terminals, a common “NZRC and User Company” specification is used for all product refined by the Refinery on their behalf, and all imported fuel which they purchase. The smaller operators have their own internal specifications. The net effect of the above arrangements is that while all fuel supplied in New Zealand must comply with the requirements of the Regulations, more than 95% of it also complies with a common internal specification. However, past experience indicates that variations within the specified range can still cause operating problems, as evidenced by the recent problems with blocking of diesel filters.

One of the key questions in this review is to determine the appropriate balance between government regulation and oil industry self-regulation – deciding those fuel quality parameters which it is necessary to specify by law and those which the oil industry can be left to control itself. Given the high level of integration of the distribution infrastructure and the dominance of the four major players, fuel quality problems, if they do occur, are unlikely to be limited to only one supplier. Again the recent diesel problems illustrate this very graphically.

As New Zealand is a small country, and with the current high level of public interest in fuel costs, all suppliers have a strong vested interest in ensuring that the fuel they sell is of consistent high quality and that there is a high level of consumer satisfaction. However, there is a role for the Regulations in ensuring a level playing field and protecting consumers and the environment, particularly in relation to fuel quality issues that may not immediately manifest themselves.

## 3.2 New Zealand's Vehicle Fleet

New Zealand's vehicle fleet covers a wide range of vehicle and emission technologies and is considered to be, on average, quite old. This is an important consideration when looking at current fuel quality specifications in other countries, which have generally been developed for fleets which are, on average, much newer, and highlights the need for any changes to the specifications to reflect the unique character of the New Zealand fleet.

However, all vehicles entering the fleet (both new and second-hand) are sourced from overseas and incorporate engine and emission technology available at the time of their manufacture (though this may vary according to the market the vehicle was manufactured for). Therefore over time, the “average” state of technology of the fleet will improve as vehicle development feeds through via fleet turnover. The extent to which this “average” technology level will continue to lag behind the “state-of-the-art” as reflected in new vehicles depends on policies and other influences which determine vehicle turnover in New Zealand.

### 3.2.1 Vehicle Fleet Emissions

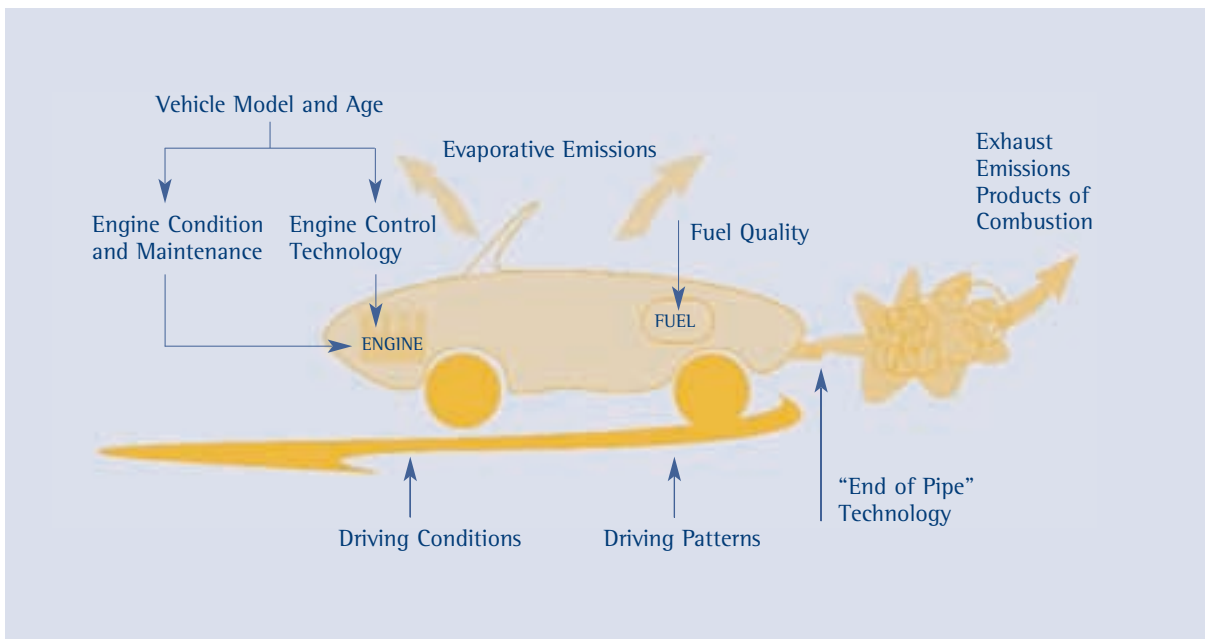
In 1996, the Ministry of Transport began work on its Vehicle Fleet Emissions Control Strategy (VF ECS). The purpose of this work was to characterise and quantify emissions from the New Zealand vehicle fleet, as a basis for evaluating policy options for emissions reduction. A summary of this work is given in Appendix D. More detail is given in the various VF ECS reports (MOT, 1997, 1998a-g, 1999).

The VF ECS work involved the development of a detailed vehicle fleet emissions model (VFEM) to characterise emission rates according to vehicle type, age, fuel and driving conditions and to predict the likely impact of fleet changes and driving patterns over time. In addition to the VFEM, an Environmental Capacity Analysis (ECA) model was also developed to predict emissions rates at a localised geographical level, based on vehicle routes and traffic patterns, for use as a tool in local air quality management.

There are a number of factors that influence emission rates from vehicles, as illustrated in Figure 3.6. One of the key findings from the VF ECS work was the significant impact that congestion and driving conditions have on vehicle emissions rates and the relatively smaller impact of vehicle and emissions control technology. VF ECS identified that a review of fuel quality should also be carried out and this has been one of the drivers for this present work.

The VFEM provides a means for predicting fleet and traffic growth and characterising the fleet by age, condition and level of engine and emissions technology and so has been a useful source of indicative data for the following sections.

Figure 3.6 : Influences on Vehicle Emissions



### 3.2.2 Fleet make-up

The following figures from the Land Transport Safety Authority (LTSA) vehicle registry data summarise the characteristics of the New Zealand vehicle fleet, as at the end of 2000 (LTSA, 2001).

#### Vehicle numbers and types

There were around 2,750,000 vehicles on the current register, an increase of 61,000 over the previous year. Of these, there were 427,000 trucks, 14,000 buses, 13,000 motor caravans and 79,000 motorcycles and mopeds. The balance, which makes up about 80% of the total, is cars.

#### Geographical distribution

Around 39% of all vehicles were registered in the Auckland or Hamilton areas.

#### New vs. used vehicles

During the year 2000, there were around 215,000 new registrations. Around 65% of these were used imports, the balance new vehicles. There were 174,000 cars of which 67% were used, and 23,000 commercial vehicles of which 30% were used.

#### Petrol vs. diesel

Nearly 93% of cars currently on the register are petrol driven, and around 7% (approximately 148,000) are diesel driven. There are around 278,000 other diesel vehicles including trucks, buses, motor caravans and tractors. LPG and CNG account for less than 1000 cars in total and less than 1700 other vehicles. However, the majority of CNG or LPG powered vehicles are dual-fuelled, and so appear on the register as petrol or diesel vehicles, according to their primary fuel.

#### Vehicle age

82% of cars on the register are now more than 5 years old, 49% are more than 10 years old and 20% are more than 15 years old. The figures for buses and trucks are similar.

#### Sports/Age and Classic Vehicles

The size of the classic and older vehicle fleet has been estimated from LTSA vehicle registry data, and represents vehicles currently registered, not necessarily on the road. This is summarised in Table 3.2.

Table 3.2: Sports/Age, Classic and Older Vehicle Profiles

Age of vehicle (date of first registration)	Cars	Trucks, buses and motor caravans	Total vehicles*	Motorcycles and mopeds	Percentage of total vehicle fleet*
Pre-1980	199,900	61,300	261,200	17,300	9.8%
Pre-1970	42,200	16,700	58,900	5,600	2.2%
Pre-1960	23,100	6,500	29,600	3,500	1.1%
Pre-1950	10,500	2,500	13,000	1,300	0.5%
<b>Total</b>	<b>275,700</b>	<b>87,000</b>	<b>362,700</b>	<b>27,700</b>	<b>13.6%</b>

\* Excludes motorcycles and mopeds Source: LTSA, 2001

Many pre-1980 vehicles will have been designed to run on leaded petrol and must now use after-market additives such as Valvemaster, or specialist fuels. Their numbers as a percentage of the overall fleet are small.

#### Other Vehicles

Other vehicle types on the register are shown in Table 3.3.

Table 3.3: Other Vehicles

Vehicle type	Petrol	Diesel	Total
Tractors	2,690	23,150	25,840
ATVs (All Terrain Vehicles)	1,765	15	1,780
Special purpose vehicles	520	1,630	2,150
Agricultural machines	135	1,015	1,150

Source: LTSA, 2001

It is expected that these figures significantly underestimate the actual fleet, particularly in the agricultural sector where many vehicles will not be registered for road use. Figures from Federated Farmers for instance, suggest that the number of ATVs in New Zealand is actually closer to 70,000.

### 3.2.3 Where do our vehicles come from?

In the year 2000, there were about 74,000 brand new vehicles added to the fleet, or less than 3% of the total number registered. 51% of the new cars imported were from Japan. Other key sources are Australia, Korea, the United Kingdom and Germany, contributing around 6 – 8% each. These vehicles were certified against the emission standards of their respective countries of origin.

With the relaxation of import duties on vehicles over the last 15 years there has been a major influx of vehicles imported second hand, mostly from Japan. Figures from the Motor Industry Association for the period 1991 to 1994 (referenced in the VFECs report) show that, on average, 50% of new registrations for that period were for new vehicles and the balance were used imports. By comparison in the year 2000, 65% of new registrations were used imports and nearly 93% of these were from Japan.

For the 1991 – 1994 period, around 40% of all brand new vehicles were CBU (completely built up) imports from Australia, Japan and Europe. The remaining 60% were locally assembled from CKD (completely knocked down) kits, almost all from Japan. Local assembly of CKD vehicles progressively reduced, and finally ceased, in 1998.

The dominant fuel grade in Japan is 90 RON/80 MON (refer octane number, Section 7.1) and so the majority of New Zealand's petrol vehicle fleet is able to run on our regular grade (91 RON/82 MON). This is reflected in the balance between regular and premium grade consumption.

The following data from VFECS shows the estimated source of the vehicle fleet as at 1998. As can be seen, Japanese vehicles, either imported (new or used) or New Zealand assembled, account for over 85% of our petrol driven fleet.

Table 3.4 : Petrol Vehicle Fleet Makeup, 1998

Petrol vehicles				
	Cars	LCVs	HCVs	Total
NZ Assembled (Japan)	47.4%	75.8%		1,054,000
Japan	36.0%	20.6%		703,000
Australia	4.7%	2.9%		92,000
Europe	11.9%	0.7%		215,000
Total no. of petrol vehicles	1,798,000	266,420		2,064,000

Table 3.5: Diesel Vehicle Fleet Makeup, 1998

Diesel vehicles				
	Cars	LCVs	HCVs	Total
NZ Assembled (Japan)	0.5%	37.4%	76.1%	99,800
Japan	63.6%	57.3%	22.6%	152,300
Australia	6.3%	5.0%	1.0%	13,300
Europe	29.7%	0.3%	0.3%	32,000
Total no. of diesel vehicles	104,000	122,900	70,000	297,000

Source: Table 4.2 (MOT, 1998a)

LCV = light commercial vehicle, HCV = heavy commercial vehicle.



### 3.2.4 Fleet Age and Turnover

Predicting the change in the vehicle fleet age and make-up over time as a basis for assessing its future environmental performance is difficult. The figures in Table 3.6 are projections based on the Ministry of Transport's VFEM (Vehicle Fleet Emissions Model). These projections are based on a number of assumptions about population growth and factors affecting fleet turnover, and therefore must be treated with caution. It is noted that they are not completely consistent with figures from the vehicle registry (refer Section 3.2.2) but this is partly related to the way vehicle ages are reported. However, the predictions provide a useful indication of the likely uptake of new vehicle technology in the short term at least and there are clear trends. The baseline assumptions are presented in more detail in VF ECS Stage 1 Report (MOT, 1997).

Table 3.6: Vehicle Fleet Age Profiles

Year	% of cars >10 years old (no. > 10 years old)	% of cars > 20 years old (no. > 20 years old)
1998	54% (1,025,000)	8.4% (162,000)
2001	62% (1,309,000)	10.7% (227,000)
2005	68% (1,521,000)	16.8% (377,000)

It must be noted when reading this table that a 10-year old car in 1998 will have been manufactured in 1988, whereas a 10-year old car in 2005 will have been manufactured in 1995 and therefore will have newer technology.

In 1998 there were around 121,000 cars first registered in 1988 (10 years before). By this year there are expected to be nearly 123,000 cars first registered in 1998, but by 2005 this will drop back to around 97,000.

The model also indicated that second hand imports made up 35% of the total car fleet in 1998 and predicts that this will rise to 47% by 2005. The corresponding figure for mid-1995, the base data originally used for the model, was 23%.

These predictions support anecdotal evidence that the vehicle fleet in New Zealand has started getting older, reversing the trends in previous years. The low exchange rate over the last year has forced importers to source cheaper vehicles. More countries are also opening up their borders to second hand cars so that the better quality cars are heading to more lucrative markets.

### 3.2.5 Fleet Utilisation

Vehicle kilometres travelled (VKT) is a measure of the fleet utilisation and, in the absence of significant changes in fuel economy or driving patterns, is an indication of the likely growth of the vehicle fuel market. Estimates and projections have again been drawn from the VFEM work.

In 1998 petrol vehicles travelled 31,500 million km and diesel vehicles 7,800 million km. Petrol vehicle VKT was expected to grow 4.5% by 2001 but only a further 0.7% by 2005. Diesel vehicle VKT on the other hand was expected to grow by 11% by 2001 and a further 24% by 2005, signalling a swing towards greater popularity of diesel vehicles. Again, these predictions are based on assumptions about changing driving patterns and vehicle fleet make-up.

## 3.3 Emission Standards

While mandatory vehicle emission standards have been in place in many countries for a number of years, New Zealand is currently the only OECD country with no such standards. The Motor Industry Association, which represents importers of new vehicles, has a voluntary code of practice in place for its members. This states that all new models brought into the New Zealand market since January 1997, must have complied with emission standards from either Europe, Japan, the United States or Australia at the time of their manufacture. The code currently only applies to petrol cars and has now been in place for over three years. The intention was that all new models (as opposed to new vehicles) from that time would be fitted with exhaust catalysts.

The Ministry of Transport is presently drafting proposals to make this requirement mandatory for all new vehicles. For second-hand vehicles imported to New Zealand, the rule would apply to vehicles manufactured from 1990 onwards. For example, in order to import a vehicle first registered in 1994, it would be necessary to demonstrate that this particular model complied with the emission standards of one of those countries at that time (ie. 1994). If for example, the vehicle in question was a Volkswagen manufactured in Brazil for the Brazilian market, and so was not certified for the emission

standards of one of the four named jurisdictions, it would not comply. The proposals are to be issued for consultation by the Land Transport Safety Authority (LTSA) later this year, with a likely date for implementation some time in 2002.

Other proposals by the LTSA, currently out for public consultation, will in future require all imported used vehicles to comply with frontal impact standards which have been in place in Japan since 1996 and Australia since 1997. This may have the effect, if adopted, of limiting the age of used vehicles able to be brought into the country and have a direct impact on the standards of emissions control technology fitted to those vehicles.

### 3.3.1 Emissions Control Capability of the New Zealand Fleet

New Zealand has never, apart from a few exceptions, manufactured its own vehicles. All vehicles entering the fleet have generally been designed for markets with established emissions regulations. However, the majority of Japanese vehicles that were assembled in New Zealand up until production ceased in 1998 were equipped to an “export specification” in terms of their emissions control equipment. The requirements of this specification were minimal, and would generally have been well below that required in their country of origin, or many other markets at the time. New Completely Built Up (CBU) vehicles brought into New Zealand up until 1997 will also have been manufactured to a range of emission standards, depending on their intended market.

The net effect is that the “potential” emissions control capability of the New Zealand fleet has lagged significantly behind many other countries, including Australia, which has had vehicle emission standards of some sort in place since the mid 1970s. This has partly been redressed by the large number of second hand cars imported in recent years.

The concept of “potential” capability is important; just because a vehicle is fitted with a catalytic converter on its exhaust, does not mean that it is actually working effectively. Emission standards set durability requirements (how long, in kilometres or years, the vehicle should continue to be capable of meeting those standards). Typically these may be 80,000 km or 5 years. Control equipment on the majority of imported second-hand vehicles is probably well past the durability requirements of the emission standards it was originally certified to. Maintenance of such equipment tends not to be a big priority when there is no monitoring of its performance or mandatory requirement for its effectiveness. However, even poorly functioning emissions control equipment is generally a lot more effective than none at all. On the other hand, anecdotal evidence also suggests that in many cases, this equipment has been removed from vehicles rather than maintained.

A more detailed discussion of vehicle emission standards is given in the Stage 1 VFECs report (MOT, 1997) and the Australian review of fuel quality (EA, 2000a), as well as in Section 5.

### 3.3.2 Engine and Emission Control Technology

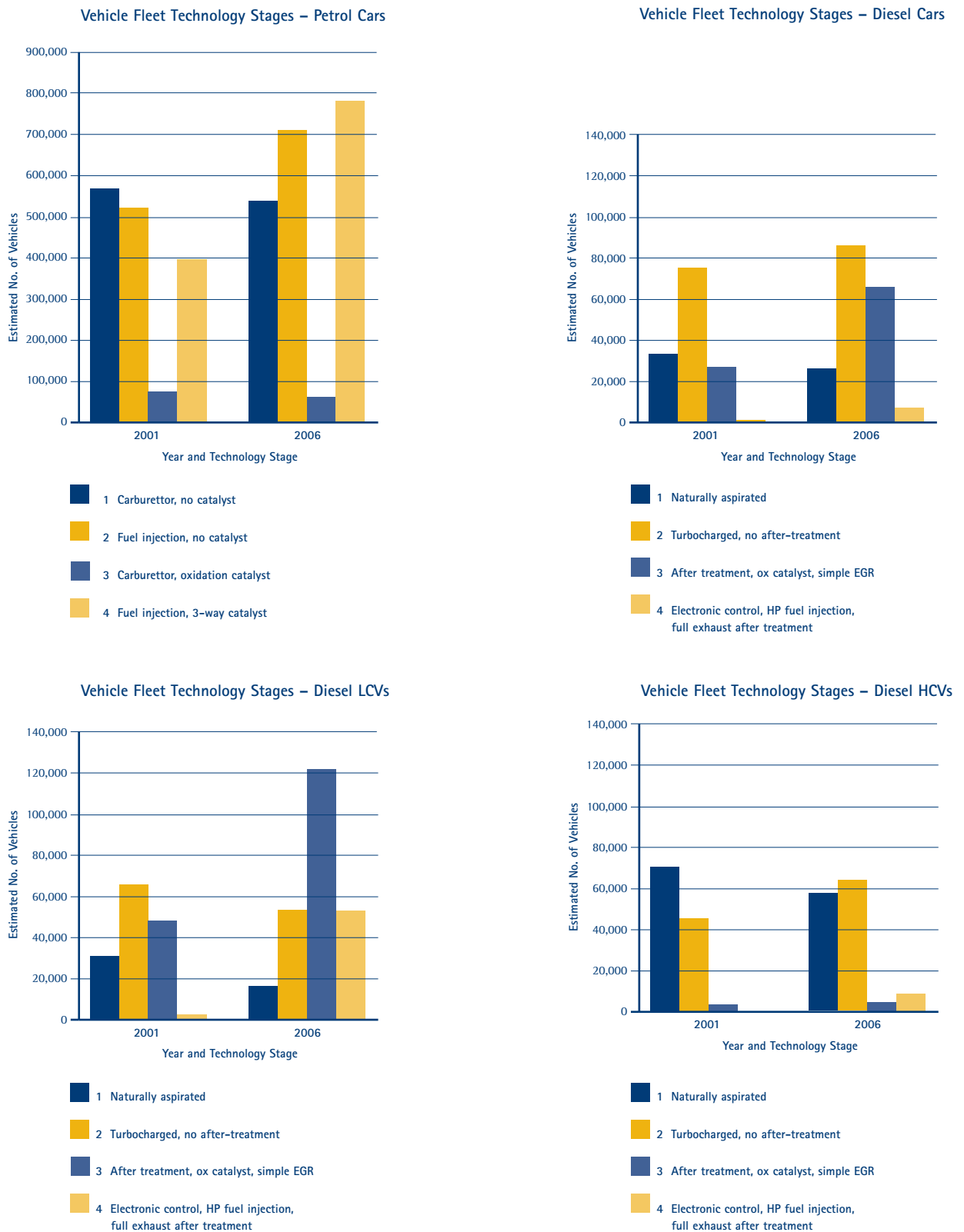
For the purpose of the development of the VFEM, the fleet was categorised according to the type of engine and emissions control technology fitted. Four main configurations were used for petrol and diesel vehicles. This was not a precise analysis, relying heavily on judgement, as this type of data is not collected. The following has been drawn from the VFEM and represents the best estimate of fleet capability for the current year and projections for 2006. The four vehicle technology stages are summarised in Table 3.7 for petrol and diesel vehicles respectively. The estimated numbers of vehicles in each category are presented in Figure 3.7.

Table 3.7: New Zealand Vehicle Fleet Technology Stages

Technology Stage	Petrol Vehicles	Diesel vehicles
1	Carburettor, no catalyst	Naturally aspirated, older technology
2	Fuel injection, no catalyst	Mechanical fuel injection control, turbocharging; no exhaust after-treatment
3	Carburettor, oxidation catalyst	After-treatment: oxidation catalyst, simple exhaust gas recirculation (EGR)
4	Fuel injection, 3-way catalyst	Advanced electronic control/high pressure fuel injection, full exhaust after-treatment

Source: MOT

Figure 3.7 : Vehicle technology Stages – Estimated Numbers by Vehicle Type for 2001 and 2006



Source: MOT

The data indicate that while emissions control technology in the New Zealand vehicle fleet will see an improvement over time, this change is relatively slow and depends very much on the influences that affect vehicle turnover in New Zealand. As a general rule, model cycles for cars (that is the number of years between new models being introduced) tend to be shorter than for heavy commercial vehicles so that new light vehicle technology will tend to become available more quickly.

While the VF ECS work has considered the environmental performance of the vehicle fleet over the longer term, any changes to the Regulations need to also consider the shorter term impact on vehicle driveability as well. For example, petrol engines with carburettors are much more sensitive to changes in fuel volatility than fuel injected engines. Future controls on volatility parameters need to take into account that even in 4 years time, a significant proportion of the petrol vehicle fleet will still have carburettors. This is discussed in more detail in Section 7.3.

## 3.4 Non-road Users of Petrol and Diesel

### 3.4.1 Marine

In the year ended December 2000, the fishing industry used around 115,000 tonnes of diesel and 600 tonnes of petrol. While in the past there has been a marine grade of diesel available in New Zealand, this was withdrawn in 1998 and now just one grade of diesel is currently available for both land and marine use. While some of the larger fishing vessels may use light fuel oil, figures from the Maritime Safety Authority (MSA) indicate that in 2000 there were approximately 1300 smaller fishing vessels (under 24m), most of which are likely to be diesel users. The recent problems with diesel filterability indicate just how critical fuel quality is to marine safety, particularly for smaller craft.

Commercial operators will generally bunker diesel via pipelines, road tankers or their own storage facilities. Petrol and diesel dispensers are available at many ports and marinas and this will be the refuelling point for most larger pleasure craft (launches, yachts etc). The estimated total diesel consumption for marine use in 1997 was around 240,000 tonnes (MSA, 1998).

Pleasure vessels are not usually registered so their numbers are not accurately known, but figures from the MSA indicate there may currently be around 260,000 such vessels. Many are small users, particularly where the primary mode of power is sail. Fuel for many petrol driven marine engines such as those in runabouts (which use portable tanks) and “jet skis” may be purchased through petrol stations so it is difficult to accurately estimate the quantities used.

MSA estimates of the size of the pleasure craft fleet in 2001 are as follows:

■ Trailer yachts and keelers	42,000
■ Motor launches	18,000
■ Trailer based motorboats	105,000
■ Personal water craft (commonly called jet skis)	13,000

### 3.4.2 Other Users – Commercial

The pie charts in Section 3.1 show the breakdown of petrol and diesel use in New Zealand. “Internal use” generally covers domestic transport. “Other uses” includes wholesaling and retailing operations, telecommunications, defence and local government.

Many commercial operators will have their own storage and dispensing facilities for refuelling vehicles. Diesel is used for stationary engines such as small boilers and generators as well as heavy machinery such as earthmoving equipment and mobile cranes.

### 3.4.3 Other Users – Retail

Fuel for garden maintenance equipment is generally bought through service stations. This equipment includes chainsaws, lawnmowers and weed eaters. No figures are readily available but in aggregate maintenance probably represents a very small percentage of the total volume of petrol sold, but a very large number of individual users (many homes have a motor-mower). Recent Canadian studies suggest that two-stroke motors used for lawnmowers, chainsaws and small marine outboards are significant sources of exhaust emissions.

### 3.4.4 Agricultural Use

Agricultural use accounted for around 120,000 tonnes of diesel and 26,000 tonnes of petrol in 2000. As shown in Figures 3.4 and 3.5, these levels equate to around 6% of New Zealand’s total diesel consumption and 1% of total petrol consumption. These figures are based on energy consumption data supplied to MED and do not include fuel purchased through retail outlets.

Figures presented in Table 3.3 show that in 1999 there were around 25,000 tractors, 1500 ATVs and 1100 other agricultural machines on the New Zealand vehicle registry. As previously noted, a large number of agricultural vehicles are not registered for road use.

This section discusses the key considerations relating to consumer protection, the environment, and health and safety that have been included in the review.

- Section 4.1 describes the existing consumer protection framework in New Zealand.
- Sections 4.2 and 4.3 describe the environmental impacts arising from the use of petrol and diesel, and the controls in place to minimise those impacts. Discharges of contaminants to air from the combustion of petrol and diesel are one of the greatest contributors to air pollution in New Zealand. The use of petrol and diesel also has an impact on water quality in New Zealand, although to a lesser (and less quantified) extent.
- Section 4.4 discusses the direct health impacts (both public and occupational exposure) arising from the use of petrol and diesel in New Zealand.
- Section 4.5 provides an overview of the present hazardous substances legislation and its linkages to the Petroleum Products Specifications Regulations.

## 4.1 Consumer Protection

The introduction of the Petroleum Sector Reform Act 1988 removed regulatory control of the motor spirits industry. To ensure that consumers would be able to buy petrol and diesel that was “fit for purpose” in the new deregulated market, the Ministry of Energy (Petroleum Products Specifications) Regulations were issued in 1988.

The Regulations sit within a wider consumer protection framework that includes the Fair Trading Act 1986 and the Consumer Guarantees Act 1993 as discussed below. There are also a number of “watch dog” organisations that perform a consumer protection role. Given this more general consumer protection legislation, consideration in the review was given to whether consumer protection should continue to be a feature of the regulations, or whether consumer rights are adequately protected via other mechanisms.

### 4.1.1 Consumer Protection Legislation

#### Fair Trading Act 1986

The Fair Trading Act applies to all aspects of the promotion and sale of goods and services, from advertising and pricing to sales techniques and finance agreements. This Act came into force on 1 March 1987. This Act essentially

- Prohibits people in trade from engaging in misleading or deceptive conduct generally (section 9); and
- Prohibits certain types of false or misleading representations about goods or services, including false claims that goods or services are of a particular price, standard, quality, origin or history or that they have particular uses or benefits or that they have any particular endorsement or approval (section 14).

Where this Act is deemed to have been breached, fines can be imposed and suppliers can face both criminal and civil actions. The Act does not require someone to suffer or to be directly affected by the trader’s behaviour for action to be taken, as the Act applies to conduct likely to mislead or deceive.

Contravention of this Act can result in fines up to \$30,000 for an individual and \$100,000 for a company. Frequently both a company and the individuals involved in a breach will be prosecuted by the Commerce Commission. Anyone can apply to the High Court for an injunction to stop the Act being breached and the Commerce Commission also has the right to apply to the High Court for corrective advertising orders.

#### Consumer Guarantees Act 1993

The Consumer Guarantees Act applies to products of a kind normally bought for personal, domestic or household use and purchased in trade. It:

- Sets minimum guarantees about quality and fitness of goods and standards of service;

- Sets remedies which can be used against sellers and service providers and in some cases, against manufacturers whose goods or service do not meet the guarantees; and
- Prevents sellers and service providers contracting out of the minimum guarantees, except in certain circumstances.

The Disputes Tribunal can hear claims under this Act.

#### How do these Acts protect consumers of petrol and diesel?

- Suppliers must not incorrectly label fuels (grade, quality and composition);
- The consumer has a right to request information about the product;
- Mandatory standards could be issued specifying product quality information that must be made available to consumers (this has not been done for petrol or diesel to date); and
- Any disputes about quality would be covered under the dispute provisions of this legislation. Civil proceedings under the Act can take place in the High Court, the District Court or the Disputes Tribunal. Criminal proceedings are taken in the District Court.

The Petroleum Products Specifications Regulations provide buyers of petrol and diesel with an additional layer of protection to ensure that fuel bought is “fit for purpose”, as consumers are not in a position to determine the quality of fuel at the point of purchase. Problems with poor quality fuel may not be experienced immediately and different brands of fuel may have been bought over a period of time before a problem is identified, making it difficult to link the consequences back to a specific source or retailer.

In the absence of Regulations, minimum quality would be a more flexible concept determined by consumers and suppliers. The main advantages and disadvantages offered by the Regulations are as follows:

Positives	Negatives
The definition of “acceptable quality ” is clear.	Consumers cannot buy lower quality products that might meet their requirements.
The Regulations provide certainty for consumers – petrol and diesel must meet a clear list of minimum quality requirements.	The Regulations may exclude some businesses from the market as they can not meet standards.
The Regulations provide a mechanism to monitor fuel quality.	The Regulations allow the supplier to be fined, however consumer recompense must come under other legislation.

### 4.1.2 Consumer Agencies

The **Ministry of Consumer Affairs** is an operating branch of the Ministry of Economic Development. It provides consumer and trader information, education and policy advice to the Government on consumer laws, investigates unsafe products, and ensures that market transactions based on weight and measurement are accurate, fair and consistent with international standards. The Energy Safety Service, which runs the Fuel Quality Monitoring programme (refer Section 4.1.4) is part of the Ministry of Consumer Affairs.

The **Commerce Commission** is an independent body that is constituted by the Commerce Act 1986. It is charged with enforcing the Commerce Act and the Fair Trading Act 1986, and making quasi-judicial decisions under the Commerce Act and the Electricity Industry Reform Act 1999.

Non-government organisations also play an important role in consumer advocacy and protection.

The **Automobile Association** has a key role as a representative of the motorist. The organisation examines measures that could have an impact on the motorist to determine if they are fair and appropriate, and lobbies government on behalf of vehicle users. It also gives advice to fleet operators, provides policy advice and carries out technical and scientific studies on behalf of its members. The Automobile Association has a specific interest in fuel quality and consistency, price and competition within the market.

The **Consumers’ Institute** is a non-governmental organisation that champions the rights of the consumer. It has a membership of approximately 100,000, but a self imposed responsibility for all consumers. The Institute carries out major car reliability tests every two years or so and has an interest in fuel specifications in respect of any impact on price (value for money), structure of the fuel supply industry, environmental outcomes and quality (especially variability).

### 4.1.3 Consumer Issues

#### Fit for Purpose

Fuel processing technology and additives used in petrol and diesel to control fuel quality change with time. Fuel problems in recent years have resulted from changes in fuel properties that the specifications did not adequately control or did not address, for example, the problems encountered with high aromatics in premium unleaded petrol in 1996. The inclusion of a “fit for purpose” statement in the Regulations would ensure that they cover these types of incidents.

#### Brand Products

Brand products that clearly meet the current specifications but offer additional features have become a recent addition to the petrol and diesel market. High performance European cars coming into New Zealand are creating a demand for higher octane fuels and in the last year, two suppliers have introduced products in response to this demand.

This raises the issue of whether there is a requirement for more extensive consumer protection as more of these products come onto the market (eg. low sulphur diesel, higher octane fuels). The current specifications set only a minimum fuel quality. Any statements made by retailers over and above these minimum qualities are not tested as part of the fuel monitoring programme (refer to section 4.1.4 below). Claims made in respect of brand products are, however, covered by the wider consumer protection legislation.

#### Variability within the Specifications

Consumer protection advocates in the past have noted that variations in fuel quality have caused problems for some consumers even where that variation has been within the current specifications. Occasionally fuel has been distributed with significant enough variations from the norm to be noticed by consumers and commented upon. Examples include variations in the octane levels and volatility for petrol, and issues in respect of the winter and summer mix for diesel. In all cases quoted it was noted that the fuel did meet the specifications set out in the Regulations.

#### Consumer Safety

It is noted that since 1989, there has been a marked increase in the use of self-service facilities at retail outlets. Issues of consumer safety are discussed in Section 4.4.

#### Labelling and Availability of Information

Provisions for labelling are not a requirement of the current Regulations. General controls on labelling are provided in the Fair Trading Act 1986. The Weights and Measures Regulations 1999 also require that all fixed fuel dispensers be labelled with the type of fuel dispensed, but this is only for inspection purposes. From time to time, consumers experience problems with misfuelling (filling the vehicle with the wrong fuel). This can lead to serious engine damage, as well as potentially being quite hazardous.

The need to provide additional information to consumers in respect of actual octane level, sulphur content (of both diesel and petrol), benzene levels, the use of additives and any other special properties of the fuel is also considered in this review. It is important that consumers are informed about the products they are purchasing and where relevant, that they are actually receiving the “boutique” qualities being advertised.

### 4.1.4 Fuel Quality Monitoring

Fuel quality monitoring is a key element of consumer protection currently provided under the Regulations. The Regulations set out the minimum requirements for each specified property as well as the test method that will be used to measure that property. They set out the procedures to be used for sampling and for interpreting test results (particularly if there is any disagreement about them). The Regulations also require that any person taking samples or doing testing on behalf of the regulator be accredited by a recognised accreditation agency.

#### The Fuel Quality Monitoring (FQM) Programme

A sampling and testing programme for fuel quality was initiated in March 1989. A statistically based sampling scheme was designed in 1991, based on factors including the known failure rate and fuel consumption from each regional onshore bulk storage location. Initially it was managed by the Office of the Chief Gas Engineer (OCGE) of the Ministry of Commerce. Since December 1999 it has been undertaken by the Energy Safety Service, a group in the Ministry of Consumer Affairs within the Ministry of Economic Development. The FQM Programme is funded by the Petroleum Fuels Monitoring Levy on all fuel sold. The current rate is 0.025 cents per litre.

The scheme specifies the required number of samples to be taken each month from each distribution region to give a 95% confidence level of detecting a 3% level of non-compliant samples. Each year a sampling plan, based on the sampling scheme, is produced. These plans provide for effective nation-wide coverage taking into account market share, regional use and other factors.



The annual sampling plan typically comprises around 100 service stations, with samples collected of each of the two grades of petrol and one of diesel (where available). The advantage of this system is that it monitors the quality of fuel that consumers receive including any contamination introduced during transport or distribution. However, a drawback is that in the event of any non-compliant samples, the fuel will generally have been sold before the results become available.

Samples are tested against the specifications set out in the Regulations using the defined test procedures. Therefore, while the properties of new fuel products (ie. brand products such as high octane or low sulphur fuels) may be tested if selected by the routine sampling plan, such testing would only be to confirm that they meet the minimum standards set out in the specifications for the relevant grade fuel. This monitoring would not test the retailers' specific claims in respect of that product.

#### What happens to test results?

A report summarising the results of the programme over the period 1992-1999 was published in July 2000 (MED, 2000). This period includes the introduction of premium unleaded petrol in 1996. A supplementary report for 1999-2000 has recently been published (MED, 2001b). The number of non-compliant samples has been very low and almost all non-compliance has been of a minor nature (within testing error). To date there have been no prosecutions. The results indicate that, for the most part, New Zealanders are provided with fuel that meets the specifications

#### How effective is the monitoring programme?

The fuel monitoring programme provides a level of protection to the consumer that is not available under other consumer protection legislation. However, concern has been raised by consumer groups that not enough product testing is carried out, that the information is not easily available to consumers, that there are delays in information release and that the form of release is not necessarily consumer friendly. The importance of retaining the FQM programme has been highlighted by consumer groups in particular as there is a perception that the oil companies are importing more and more refined product which could lead to greater variability in product supplied to the consumer.

The oil industry itself tests its batches of petrol and diesel prior to sale to ensure compliance with the specifications. The test methods set down by the Regulations for measuring compliance are in turn used by the industry to assure itself of compliance.

## 4.2 Environment – Air Quality

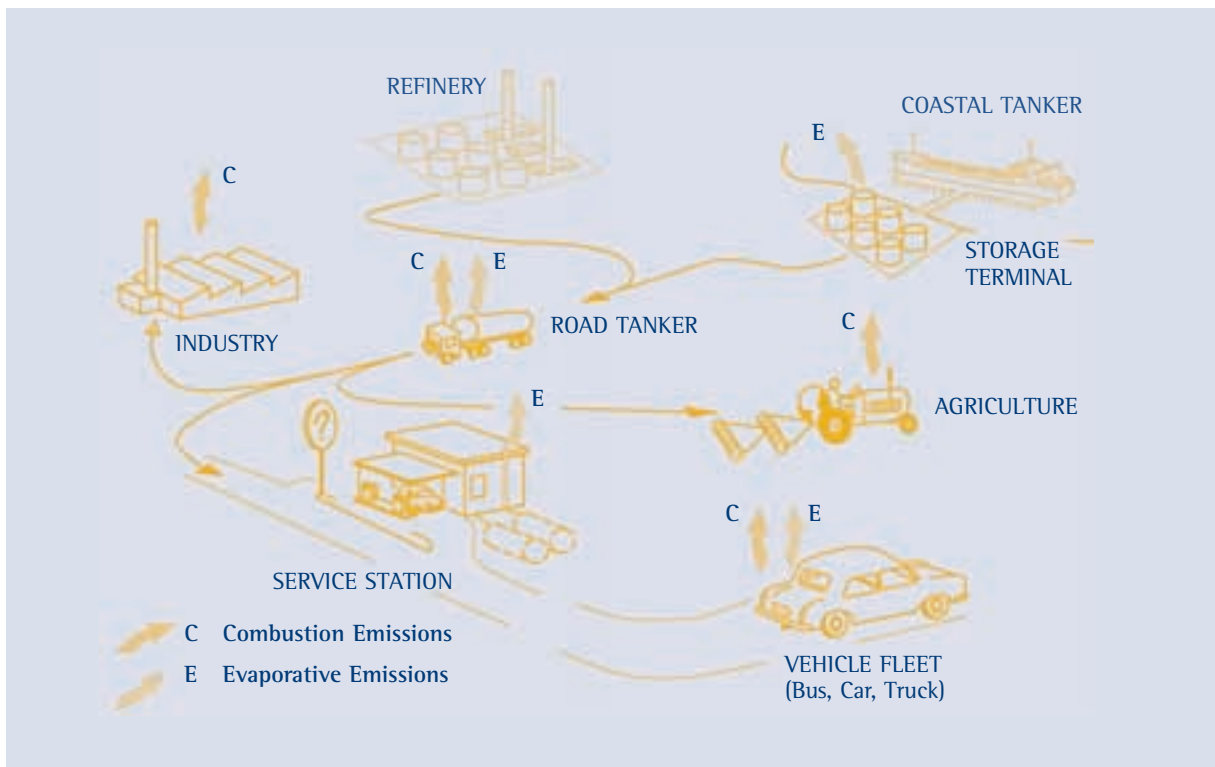
By world standards, air quality in New Zealand is comparatively very good. This is primarily due to our geographical location, the prevailing westerly winds, the coastal location of most of our large cities and the limited amount of heavy industry. However, in some urban areas, levels of air contaminants occasionally, and sometimes frequently, reach concentrations that are high enough to be a major health concern. The aim for New Zealand therefore is to ensure that air quality is maintained where it is currently healthy, and improved in areas that suffer periods of high pollution.

### 4.2.1 Sources of Air Emissions Arising from the Use of Petrol and Diesel in New Zealand

The majority of discharges to air arising from the use of petrol and diesel in New Zealand are the products of combustion emitted by vehicles in use. However, there are other sources that must be considered. Figure 4.1 provides a schematic illustration of the major sources of air emissions downstream of the refinery.



Figure 4.1 Air Emissions Arising from the use of Petrol and Diesel in New Zealand



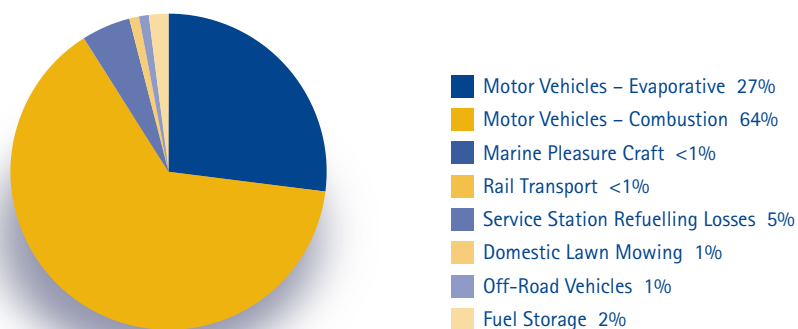
Emissions can be generally grouped as either products of combustion or evaporative emissions. The figure illustrates the following sources:

- Products of combustion.
- Evaporation during distribution (filling/loading operations and evaporation from thermal fluctuations).
- Evaporative losses from vehicles.

Evaporative losses can occur from both bulk storage sites and vehicles, however in practice, one mechanism predominates in each case: displacement losses predominate in bulk distribution, where the tank size reduces thermal fluctuations; evaporative losses predominate from vehicles.

Figures 4.2 and 4.3 present data from the Auckland Air Emissions Inventory (ARC, 1997), showing the relative contributions of various sources to air emissions in the region.

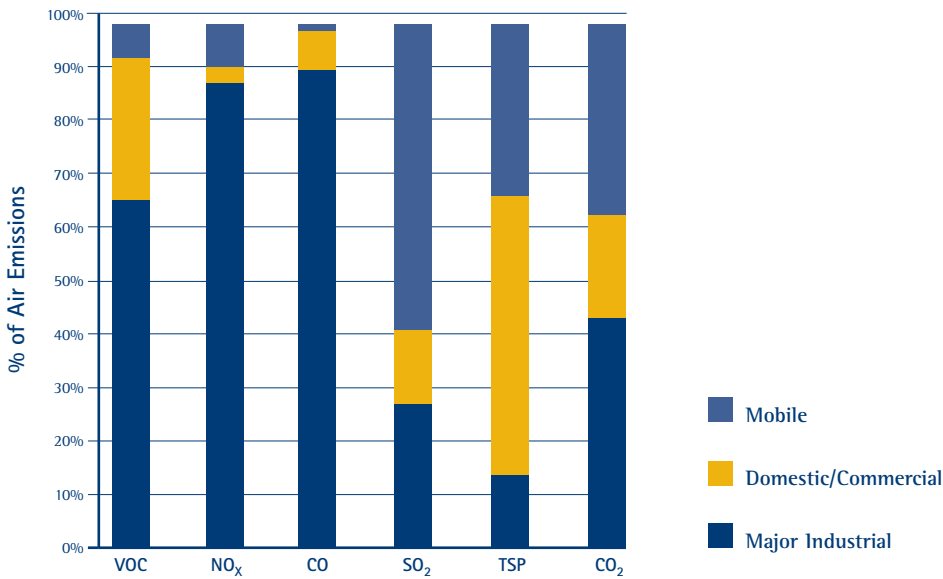
Figure 4.2  
VOC Emissions from Petrol Usage (Auckland, 1993)



Source: ARC, 1997

Figure 4.3 Relative Emissions from Mobile, Domestic/Commercial and Major Industrial Sources (Auckland, 1993)

Source: ARC, 1997



#### 4.2.2 Products of Combustion

As shown in Figure 4.2, products of combustion are the largest source of air emissions from fuels. These are sourced from petrol and diesel engines, and by far the majority of these sources are the vehicle fleet. The mechanics of the combustion engine and the emissions that result are well understood. Appendices C, D and E of this document provide an overview of “how engines work”, the vehicle fleet and key air contaminants emitted by combustion.

Other sources of combustion products are stationary industrial sources (diesel-fired boilers, stand-by generators, for example) and agriculture (farm machinery); these sources tend to use diesel fuel. There appear to be relatively few consented discharges for diesel combustion processes - the Auckland Regional Council has issued no consents for such processes (pers comm, ARC). Section 3.1 contains information on fuel usage, and it can be seen that the industrial and agriculture sectors use 10% and 6% of total diesel use respectively (Figure 3.5). However, there is no information on the proportions used in stationary plant, vehicles or other mobile machinery.

Serious health effects may occur as a result of exposure to air pollutants emitted as a product of combustion. In general, traffic-related air pollution contributes most to chronic cardiovascular and respiratory diseases, and there is increasing evidence of carcinogenic effects from both petrol and diesel exhaust exposure (WHO, 2000). The adverse health effects of the primary pollutants, such as CO, NO<sub>x</sub>, particulate matter and benzene (a known carcinogen) in particular are well documented, however, there is little information on the synergies that exist in a complex mixture of associated pollutants. The effects of individual pollutants are described in Appendix E.

#### 4.2.3 Displacement Losses from Distribution (Evaporative Losses)

When any storage vessel (large storage tank or vehicle fuel tank) is filled with petrol or diesel, air displaced from the vessel contains hydrocarbon vapour.

Vapour recovery is not widespread in bulk or retail storage facilities in New Zealand. Standard industry allowances for losses that occur between the bulk storage terminal and the fuel dispensed to vehicles are 0.4% and 0.2% for petrol and diesel respectively. In 1997, the Motor Trade Association (MTA) commissioned a study to review the mechanisms by which losses occur and the measurement methods by which they are identified. The study found that actual losses of petrol vapour in distribution in New Zealand were commensurate with the standard industry allowance of 0.4% (Woodward-Clyde, 1997b). Given the very low volatility of diesel, evaporative losses are likely to be less than 0.2%, however accurate quantification is constrained by the accuracy of the metering equipment (Woodward-Clyde, 1997b).

The Auckland emissions inventory estimated that 800 tonnes/year (1993) of volatile organic compounds (VOCs) may be emitted from (bulk) fuel storage and around 1750 tonnes/year emitted from refuelling operations at service stations (ARC, 1997). These figures equate to around 0.1% and 0.3% of total fuel throughput respectively, and accords well with the MTA data.

On a national basis, around 8,800 tonnes per year of VOCs are emitted through evaporative losses during distribution.

## 4.2.4 Evaporative Losses from Vehicles

Evaporation from thermal fluctuations are derived from a number of sources, however the most significant is generally considered to be diurnal breathing losses (DBL) which occur as fuel is heated by rising ambient temperatures. Other evaporative losses from vehicles include hot soak losses (loss of vapour after vehicle shutdown caused by residual engine heat) and running losses (Kar, 2000).

Evaporative emissions are in the order of 30% of total VOC emissions from vehicles (Kar, 2000 and ARC, 1997). Light hydrocarbons such as butane and pentane are the main species present in evaporative emissions; benzene typically comprises just over 1%, with toluene and xylene contributing around 3% (Kar, 2000 and ARC, 1997).

The Kar study estimated that up to 16 million litres (12,000 tonnes) of petrol may be lost annually from vehicles through evaporation mechanisms (Kar, 2000). This amounts to around 0.5% of total petrol consumed, based on 2000 data (MED, 2001a). While this study was based on a specific set of circumstances (an “average” Auckland driver who drives to work and parks the car (uncovered in summer) for the day before driving home), and a limited range of vehicles were taken as representative of the national fleet, this indicates the relative order of magnitude of this source.

Modern vehicles use a number of strategies to control evaporative emissions, including electronic engine management systems, purge-flow controls, sealed petrol caps and carbon canisters. The latter are a key component. The canister contains activated carbon which absorbs hydrocarbons evaporated from the fuel supply and engine, then “reclaims” them by drawing air through the canister into the engine while the engine is running. Up to 95% of evaporative losses can be captured by the use of carbon canisters, which will significantly reduce total emissions from evaporative losses (Kar, 2000).

## 4.2.5 Legal and Policy Framework

The legal and policy framework in New Zealand has an important bearing on how air quality is managed.

The Resource Management Act 1991 (RMA) sets out the legal framework for managing the environment in New Zealand. The overall purpose of the RMA is to promote the sustainable management of natural and physical resources. Responsibility for managing local air quality rests with regional councils (and unitary authorities). To assist them in managing the environment, councils must prepare a regional policy statement and can prepare regional plans, such as a regional air quality plan. Regional air quality plans specify rules to permit certain activities, specify those activities that require resource consents and prohibit activities that are known to have serious adverse effects on local air quality.

In summary, discharges arising from the consumption of petrol and diesel are either:

- stationary point sources (eg diesel-fired boilers), controlled by setting resource consents, rules in plans, or regulations;
- or the multitude of mobile point sources that are cars, motorbikes, trucks, buses, lawn mowers etc. Implementing controls on all these mobile sources is effected by a range of policy initiatives under the umbrella of the VFECS, with input from a number of government departments, notably MOT, MED and MfE. This Review is one of those policy initiatives.

Air quality guideline values fit into the regional planning process at an early stage and have been used to develop rules in plans, assess the effectiveness of methods and determine whether air quality improvements are required. The 1994 Ambient Air Quality Guidelines (MfE, 1994) provided a list of eight priority contaminants and their guideline values – the concentrations which were considered the minimum requirements for outdoor air quality, to protect human health and the environment. In 1998 MfE began a review of the guidelines, which has culminated in the publication of Proposals for Revised and New Ambient Air Quality Guidelines (MfE#16, 2000). Submissions on the proposals closed in March 2001 and revised proposals will be published by the end of the year.

MfE aims to update and review the air quality guidelines on a five-yearly basis, unless specific pollutants require otherwise. Incorporating revised guidelines into Regional Plans is the responsibility of regional councils, some of whom have adopted alternative, regional, criteria.

*Note: Distinction is made between local and global air quality issues. See Section 4.2.8 for a discussion of CO<sub>2</sub> emissions associated with the use of petrol and diesel in New Zealand.*

## 4.2.6 Air Quality Indicators for New Zealand

Five key or priority pollutants that provide a representative picture of air quality have been chosen as indicators for MfE's Environmental Performance Indicators (EPI) Programme: carbon monoxide (CO), nitrogen dioxide (NO<sub>2</sub>), sulphur dioxide (SO<sub>2</sub>), ozone (O<sub>3</sub>) and particulate matter smaller than 10 microns (PM<sub>10</sub>). The programme will be expanded to include benzene and PM<sub>2.5</sub> (particulate matter smaller than 2.5 microns) which are proposed in the new ambient air quality guidelines.

Ambient Air Quality Guidelines are also available for fluoride, hydrogen sulphide and lead, but these are not included in the EPI programme, and are not relevant to the current use of petrol and diesel. (Following the removal of lead additives from petrol in 1996, atmospheric lead levels in New Zealand are now well below guideline criteria, and are still decreasing (MfE#13, 2000)).

The EPI Programme has established a basis for defining "clean" or "degraded" air, by assigning five categories, based on a comparison of measured values with guideline values. This is shown in Figure 4.4. For example, concentrations above 66% of any guideline value fall within the "Alert" category, which provides a warning that the guideline value could be exceeded if upward trends are not curbed. Appendix E contains a discussion of the primary air contaminants, their sources and current ambient air concentrations

Figure 4.4: EPI Programme Air Quality Categories

Measured value as % of Guideline Value	Air Quality Category
>100%	Action
66-100%	Alert
33-66%	Acceptable
10-33%	Good
0-10%	Excellent

*Note: The EPI Programme also includes transport indicators for VKT and vehicle fleet composition, and propose future indicators for road congestion.*

## 4.2.7 How good is New Zealand's local air quality?

In general terms, the air quality monitoring to date confirms New Zealand's air quality is good for most of the time, but it also highlights problems in urban areas in meeting guideline values for CO and NO<sub>2</sub>, PM<sub>10</sub>, and, in the future, benzene (MfE#23, 2000). Pollution levels directly attributable to vehicles are generally at their highest at particular locations in high vehicle use traffic corridors. These pressures will only increase with predicted increases in traffic volumes.

- Petrol-fuelled motor transport is the major source of CO in urban airsheds. The highest CO pollution levels encountered are found in traffic corridors, under peak traffic loads. A reduction in emission rates of CO of at least 60% is needed to prevent exceedances of the CO air quality guideline at these locations (MOT, 1997). This is the target of the VFECs Programme.
- Motor vehicles contribute 80-95% of total nitrogen oxide (NOx) emissions. NOx levels in New Zealand are generally good, but can approach "alert" levels in traffic corridors, and given the trends for increasing urban traffic growth, such levels are likely to increase. NOx are a primary pollutant and contribute to the formation of secondary air pollutants such as ozone and secondary particles. Vehicle emission rates should therefore be managed downwards.
- Air quality in relation to SO<sub>2</sub> levels is "good". However, like NOx and VOCs, the role of SO<sub>2</sub> in secondary particle formation is important, and managing reductions in the emission rates of these pollutants will effect improvements in local PM values.
- Most air quality monitoring is for particles less than 10 microns in diameter (PM<sub>10</sub>) as these are the particles that can enter the lungs, although increasingly attention is turning to particles less than 2.5 microns in diameter (PM<sub>2.5</sub>). Breaches of the guideline value for PM<sub>10</sub> have occurred, especially in urban areas, where home-heating fires and adverse meteorological conditions combine. A new ambient air quality guideline for PM<sub>2.5</sub> is proposed, which is to be reviewed as newer research on the relationship between PM<sub>2.5</sub> and adverse health effects becomes available.

While vehicles contribute no more than 20% of the primary particle loading (MOT, 1998), secondary particle formation through the formation of SO<sub>2</sub>, NO<sub>x</sub> and VOC precursors is an important contributor from vehicles. Managing reductions in the emission rates of these pollutants will effect improvements in local PM values.

- The single largest source of VOCs in New Zealand's urban environment is the motor vehicle, and of the hazardous air pollutants, benzene is likely to be the primary pollutant requiring control (MfE#14, 2000). Some urban areas will not meet the proposed 2010 ambient air guideline criterion.

A Ministry of Health study has estimated that annual average benzene exposures for non-smokers in New Zealand cities and suburbs are in the range 1-40 µg/m<sup>3</sup> (Stevenson and Narsey, 1999). For a typical exposure scenario, for a person living and working in a typical suburb in a major city spending 5-10 hours driving in city and suburban traffic, annual average exposures are in the range 2.5-10 µg/m<sup>3</sup>. The top end of the exposure range (10-40 µg/m<sup>3</sup>) is experienced by people living in houses significantly affected by evaporative emissions from petrol-fuelled cars in internal garages, and/or those spending a high proportion of their time in vehicles in city and suburban areas eg. couriers and taxi drivers.

The proposed ambient air quality guideline for benzene is 10 µg/m<sup>3</sup>, however it is also proposed that this be reduced to 3.6 µg/m<sup>3</sup> in 2010. The population exposure data indicate that many New Zealanders living and working in urban and suburban areas are currently exposed to higher levels than this criterion. Exposure levels are likely to increase even more with increased VKT.

The study indicated that, because vehicles are essentially the only source of benzene emissions, as well as being the major exposure to benzene for most people, vehicle emissions make an even larger contribution to overall personal exposures than indicated by their estimated contributions to ambient air.

It would therefore be prudent to adopt a precautionary approach that manages benzene levels downwards.

## 4.2.8 Global Air Quality

Climate change is a global problem. One goal of New Zealand's Environment 2010 Strategy is to help stabilise atmospheric conditions of greenhouse gases. CO<sub>2</sub> is one of the major greenhouse gases, and is a normal by-product of the combustion of hydrocarbon fuels. Motor vehicles, electricity generation, the petrochemical, steel and dairy industries are the main sources of CO<sub>2</sub> in New Zealand. The generation of CO<sub>2</sub> is a direct function of fuel consumption. The transport sector currently generates 42% of total CO<sub>2</sub> emitted in New Zealand, with road transport alone contributing 39% of total CO<sub>2</sub> emitted, and projected to increase by 50% over the next 30 years (NZ Govt, 2001).

Government policies to reduce CO<sub>2</sub> target three areas, similar to the VF ECS, namely:

- Improving vehicle efficiency;
- Transport supply management; and
- Travel demand management.

This Review forms part of the policy to review vehicle efficiency. That is, if petrol and diesel quality is such that a vehicle is enabled to run as efficiently as possible, CO<sub>2</sub> (and all other air contaminant) discharges will be optimised. It is acknowledged, however, that no amount of initiatives related to fuel quality will offset the increase in CO<sub>2</sub> emitted purely as a result of the projected increase in fuel consumption and VKT.

Changes to fuel specifications to decrease CO<sub>2</sub> emissions must also be considered on a full life-cycle basis. The energy used by a refinery to process fuel generates significant quantities of CO<sub>2</sub> and the benefits of "cleaner fuels" may be offset by the higher energy requirements to produce them. This calls for a value judgment on the relative merits of a localised (refinery) discharge of a global pollutant versus the myriad of mobile emissions of both local and global pollutants. A full life-cycle analysis is outside the scope of this Review and has not been conducted.

## 4.3 Environment – Water Quality

### 4.3.1 Water Contamination Arising from the use of Petrol and Diesel in New Zealand

Figure 4.5 provides a schematic illustration of the discharges to water, downstream of the refinery.

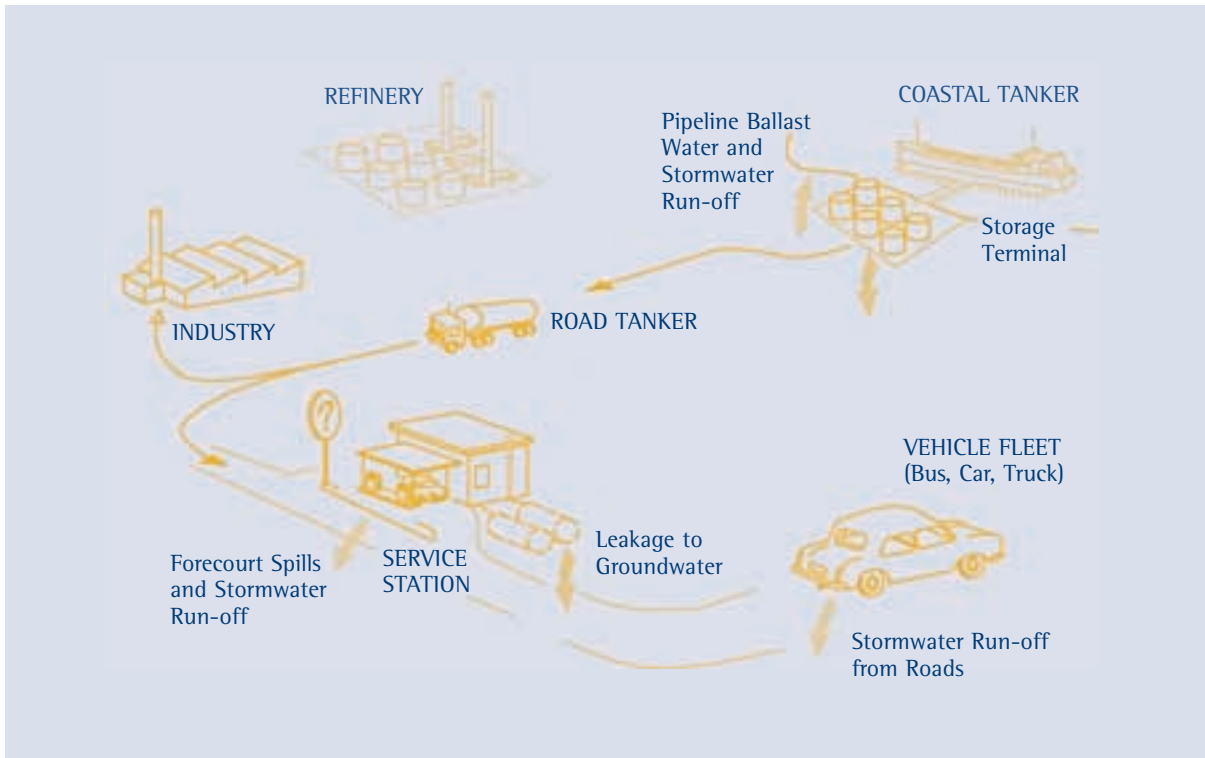


Figure 4.5 Discharges of Contaminants to Water Arising from the use of Petrol and Diesel in New Zealand

There are two primary routes:

- Discharges arising during distribution of petrol and diesel throughout New Zealand. These include (accidental) spills and leaks, and discharge of “ballast” water from pipelines during tankship unloading.
- Emissions from vehicles in use, either directly onto a road surface, or into the atmosphere, from where they may be deposited on the road or neighbouring environments. Once deposited, contaminants are subsequently mobilised during rainfall and enter aquatic environments entrained in stormwater runoff.

The discharge of pipeline ballast water is likely to be the single largest point source discharge arising from the use of petrol and diesel in New Zealand. Pipelines which carry fuel from tankships to terminals are typically “rested”, i.e. left sitting, with water in them. When a tankship is unloaded, this water must be flushed from the pipeline. The water, which contains dissolved hydrocarbons passes through oily water separators at the terminal, before being discharged to the local marine environment. Oil Industry guidelines indicate a level of 15 mg/litre as a typical industry standard for the concentration of total petroleum hydrocarbons (TPH) discharged in stormwater (MfE, 1998). This source of pollution is being eliminated as more and more terminals are changing to “water out” operation, that is, water is not used as ballast, and the pipeline remains full of diesel or petrol. This has environmental benefits, as well as reducing the level of water contamination of the fuel product.

(The issue of “water-free” or “water-out” operation also has implications for the use of oxygenates in petrol. Refer to the text box in Section 4.3.4).

Emissions from vehicles that may be deposited and subsequently entrained in stormwater runoff come from a range of sources including tyre wear, brake pad wear and oil use, as well as combustion and evaporative sources. The latter are the only emissions relevant to this review, that is, those emissions that arise directly from petrol and/or diesel use.

Evaporative emissions or products of combustion primarily enter the environment in the gaseous phase. For VOCs, atmospheric washout, which would result in contaminants being transported to the water phase is a possible, although minor, pathway. The more important contaminant in respect of potential stormwater contamination is particulates, which are deposited on road surfaces. Particulates, particularly from diesel engines, have been shown in international studies to contain polyaromatic hydrocarbons (PAHs), among other contaminants.



### 4.3.2 Legal and Policy Framework

Under the RMA, responsibility for managing water quality rests with regional councils (and unitary authorities). As with air discharges, a hierarchy of control is derived from regional policy statements and regional plans, such as regional coastal plans and/or freshwater plans. Such plans specify rules to permit certain activities, specify those that require resource consents and prohibit activities that are known to have serious adverse effects on local water quality.

As for air discharges, discharges to water arising from the consumption of petrol and diesel are either:

- Point source discharges to water bodies, controlled by setting resource consents, rules in plans, or regulations; or
- the multitude of diffuse point sources from roads and pavements that discharge, primarily via stormwater systems, to a range of receiving environments. Implementing controls on all these point sources is effected by a range of multi-party policy initiatives.

In New Zealand, there are no formal water quality criteria relevant to the contaminants present in discharges contaminated with petrol, diesel and their by-products. The Australia New Zealand Environment and Conservation Council (ANZECC) Guidelines for Fresh and Marine Water Quality (initially published 1992; re-issued in 2000) are the most commonly used of the international water quality guidelines.

The oil industry, in conjunction with MfE and local authorities, has developed voluntary guidelines for managing water discharges from petroleum industry sites, and these include guidance on “best management practices” (MfE, 1998). A similar document is in place to provide guidance on managing and controlling discharges to land and groundwater on assessing contaminated sites (MfE, 1999).

### 4.3.3 Water Quality Indicators for New Zealand

The only indicator formally adopted by the EPI Programme in relation to fresh or marine waters relates to the trophic state of lakes, a factor of the nutrient loading on fresh water lakes. Other indicators are currently under development.

### 4.3.4 How Good is New Zealand's Water Quality?

The State of the Environment Report (MfE, 1997) concluded that the main sources of pressure on water quality are non-point source pollutants, primarily from diffuse pasture run-off, but also from paved road runoff. There is documented evidence that a buildup of contaminants occurs adjacent to urban stormwater outfalls discharging to aquatic environments. However, few studies have assessed the effect of stormwater from roads in the absence of other sources, such as industrial sites, residential properties and roof run-off, and there is little data on the concentrations of VOCs or PAHs in stormwater. It is therefore difficult to quantify the effects of road transport from water discharges.

The MOT is currently extending the VFECs programme to assess the impacts of emissions to the aquatic environment. A study is due to be published shortly that characterises the sources of emissions and pathways by which they enter the aquatic environment, and quantifies the contaminant loading.

#### MTBE and its role as a water pollutant

The use in fuel of oxygenates (organic compounds containing carbon, hydrogen and oxygen) was made mandatory in the United States by federal law in 1990 on the grounds of their air quality benefits (reduced CO emissions). Methyl tertiary butyl ether (MTBE) is the most commonly used oxygenate and has been used in many parts of the world for a number of years as a petrol extender and octane booster.

MTBE and most other oxygenates, including ethanol, have an affinity for water, therefore if water is present in a fuel (or the storage vessel), oxygenates will preferentially partition into the water, and out of the petrol. In recent years MTBE has been found at low levels in groundwater in the USA. The primary route for contamination appears to be leakage from underground storage tanks.

At this stage the contamination levels are not perceived to be a health risk but MTBE is persistent and imparts an unpleasant odour and taste, even at very low concentrations. As a result, California has banned the use of MTBE and other ethers in petrol from the end of 2002 and other US states have followed. The issue is also under close scrutiny in the UK. Australia has recently announced that the MTBE content of petrol will be limited to 1% by volume from 2004 (EA, 2000c, 2001a).

Petrol sold in New Zealand does not generally contain MTBE at present, although the current specifications allow it. Low levels of MTBE may occur from time to time in imported fuel due to contamination from previous cargoes. With the exception of Gull Petroleum, the New Zealand distribution infrastructure is not set up to allow completely water-free operation, which is necessary for petrol containing MTBE.

## 4.4 Health Effects

For the majority of the population, the primary route of exposure to petrol and diesel occurs via exposure to vapours, whether they be products of combustion or evaporation. Protection of human health is the primary basis for derivation of the ambient air quality guidelines, and air quality and health effects are intrinsically linked. However, some sectors of the population do have regular, direct interaction with petrol and diesel, as a result of their occupation.

### 4.4.1 Fuel Distribution Occupations

Tanker drivers and service station workers are occupationally exposed to petrol and diesel. In 1996, following the introduction of PULP and concerns over potential health effects of increased concentrations of aromatics, the retail oil companies (then BP, Caltex, Mobil and Shell) commissioned a study to assess worker exposure to the VOCs present in petrol (Woodward-Clyde, 1996). (Diesel has a much lower volatility than petrol; exposure to vapour from diesel is therefore considerably lower than that from petrol).

The study found that, in most cases, short term exposures for tanker drivers were well below the appropriate workplace exposure standard (WES); exposures above the WES did occur when the driver was required to attend to a spill during a delivery. For service station forecourt attendants, the study found exposures to be very low, significantly below the WES. The monitoring indicated that, of the VOCs analysed, benzene was the most significant compound relative to the WES values.

Regular personnel monitoring has been undertaken by most oil companies, to fulfil their obligations under the Health Safety and Employment (HSE) Act 1992.

The results of the study carried out on service station forecourt attendants provide a guide to the level of exposure to petrol vapours experienced by members of the public who “self-serve” petrol. Based on those results, members of the public, who are exposed less frequently and for shorter durations than occupational exposure, are unlikely to be exposed to significant health risks during such activities. (Estimates of total population exposure to VOCs, primarily benzene, are discussed in Section 4.2 and Appendix E).

### 4.4.2 Motor Trade Occupations

A similar study to that carried out for the fuel distribution occupations was commissioned by the Motor Trade Association (Woodward-Clyde, 1997a). Occupational exposure monitoring was carried out at selected garages to assess individual exposure to hydrocarbon vapours from petrol and other solvents. The results indicated that full-shift routine exposures to hydrocarbons were significantly lower than the WES and did not present a risk to the health of workers (Woodward-Clyde, 1997a). Short-term monitoring during specific tasks was also undertaken. These results indicated that exposure was elevated, but exposure during tasks involving petrol did not exceed the WES; the highest exposure occurred during interior car grooming using a hydrocarbon-based cleaner (Woodward-Clyde, 1997a).

As a result of the study, the MTA produced a practice guide for members on minimising occupational exposure.

## 4.5 Hazardous Substances Legislation

On 2 July 2001, the hazardous substances provisions of the Hazardous Substances and New Organisms Act 1996 (HSNO) came into effect. The HSNO Act repealed the previous Dangerous Goods Act 1974 and the Toxic Substances Act 1979. The previous Dangerous Goods and Toxic Substances Regulations have been carried over into the HSNO Act under its transitional provisions. These Regulations will remain in force until the substances which they respectively regulate are transferred to the new HSNO regime. This transfer process will take place progressively over the next 3 – 5 years. The provisions of those Regulations as they currently stand and the implications of the new HSNO Regulations for petrol and diesel are discussed below.

Approvals for new hazardous substances (those not presently approved for use in New Zealand) and the assessment and classification of existing substances as part of the transfer will be the responsibility of the Environmental Risk Management Authority (ERMA).



### 4.5.1 Dangerous Goods Regulations

Petrol and diesel are regulated under the Dangerous Goods Regulations for their flammable properties. Petrol is classified as a Class 3(a) flammable liquid. Diesel, having a flash point exceeding 61°C, is classified as a Class 3(c) flammable liquid, along with other fuel oils. The Regulations cover storage, carriage, labelling and handling of flammable liquids. Until such time as the transfer of flammable liquids to the HSNO regime is fully completed and new HSNO controls set, the provisions of the Dangerous Goods Regulations will remain in force.

### 4.5.2 Toxic Substances Regulations

Motor fuels are not currently regulated as toxic substances under the Toxic Substances Regulations (they are listed as Exempted Substances under the Fifth Schedule). Part VII B of the Regulations (amended in 1999) defines a **restricted petrol additive** as a substance intended to be added to hydrocarbon fuels which contains more than 0.013g per litre of lead (ie. not petrol itself). Regulation 49L prohibits the distribution, handling, importation, keeping, storage transport and use of such a substance, subject to certain exemptions.

### 4.5.3 Hazardous Substances and New Organisms Act 1996 and Regulations

HSNO will manage the effects of hazardous substances by imposing performance requirements in respect of their hazardous properties. These hazardous properties are:

Explosiveness	Corrosivity
Flammability	Toxicity
Oxidising capacity	Eco-toxicity

The primary (most immediate) hazard associated with petrol and diesel is their flammability and this is generally independent of their general composition (in as far as their volatility characteristics will be regulated by the Regulations) or any additives they may contain. Likewise these substances are not considered to be corrosive, or oxidisers, or in the context of the HSNO Regulations, explosive. However they are toxic and also eco-toxic primarily due to their main constituents. Additives used in these fuels will generally be in very low concentrations and should not contribute significantly to their intrinsic hazardous properties, except perhaps in the case of their chronic and cumulative toxicity and ecotoxicity.

Under HSNO, each substance will be classified according to its hazardous properties against a set of threshold criteria. Controls will then be applied as necessary to manage the potential effects of these hazardous properties throughout the life cycle of the substance. Anyone wishing to import or manufacture a hazardous substance not previously approved for use in New Zealand will need to apply to the Environmental Risk Management Authority (ERMA) for the necessary approvals.

The transitional provisions carry over the previous provisions of the Dangerous Goods and Toxic Substances Regulations, with substances being progressively re-classified under HSNO and new controls imposed as necessary. Petrol and diesel are currently approved for use in New Zealand under existing legislation, but they will be subject to the transfer process described above.

Petrol is normally classified for transport as UN Class 3, Packing Group II, which equates to Flammable Liquid 3.1B under HSNO, though it could fall into Class 3.1A, depending on its initial boiling point (whether greater or less than 35°C). Diesel will be classed as a Flammable Liquid 3.1D. It is not known yet what classifications will be applied in respect of the other hazardous properties.

Similarly it is unclear whether HSNO will make any distinctions between fuels on the basis of any toxic or eco-toxic constituents or additives that they may contain. It is likely that there will be “blanket” approvals for “petrol” or “diesel” covering their hydrocarbon composition in a generic manner, and possibly some of the generic classes of common additives, such as detergents and dispersants. However, the use of any new additives that may impart new hazardous properties to the fuel may be considered as constituting a significant change (requiring approval and/or classification as a new substance) in terms of those minor constituents.

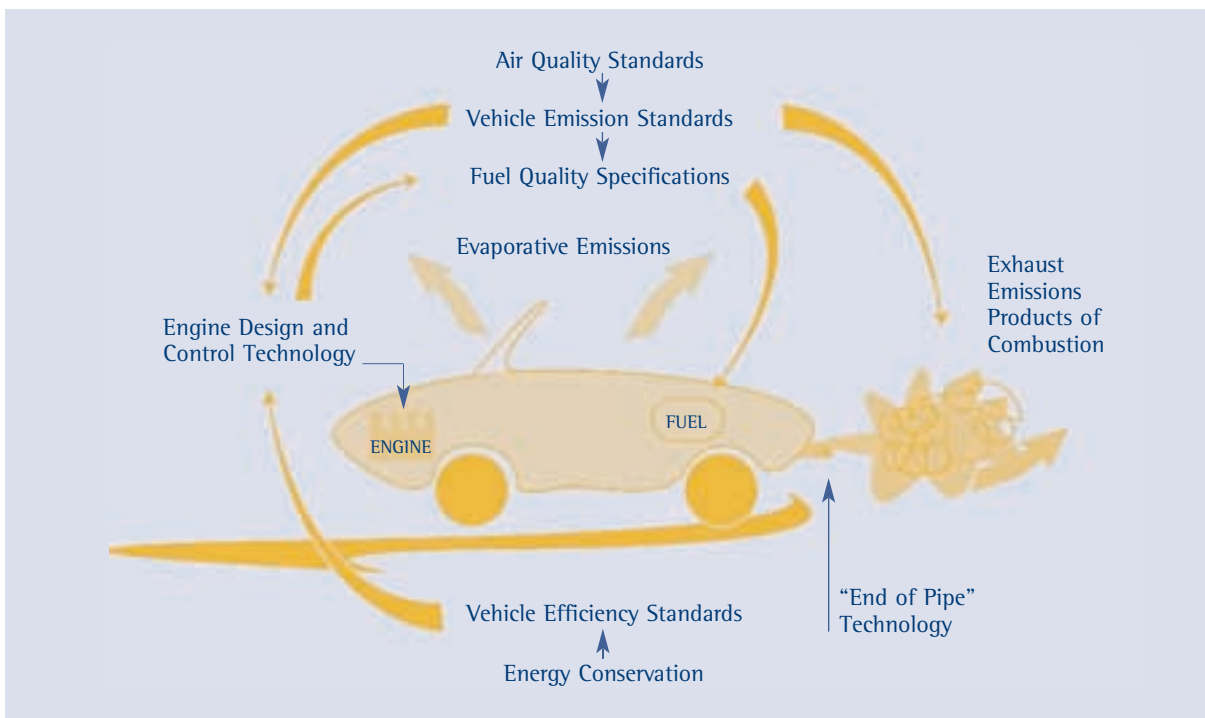
The application of HSNO will be limited to the manufacture, storage, handling, use and disposal of the hazardous substance. However, ERMA is also able to consider risks arising from the whole lifecycle when assessing any new substance for approval, which could include airborne emissions, if relevant.

# international scene

This section discusses vehicle emission standards and the relationships between fuel quality and vehicle emissions. It then reviews the current fuel quality specifications used internationally and discusses their relevance to New Zealand. Specifications for individual properties of petrol and diesel are compared and discussed in more detail in Sections 7 and 8 respectively.

In recent years, changes to fuel quality specifications in the USA, Europe, Japan, Australia and elsewhere have been largely driven by air quality targets which in turn have led to regulated vehicle emission limits and, more recently, fuel efficiency requirements. Vehicle technology and fuel specifications have been developing in response to these requirements. The relationship between these key drivers is illustrated in Figure 5.1.

Figure 5.1: Drivers for Fuel Quality



## 5.1 Vehicle Emission Standards

The first controls on vehicle exhaust emissions were introduced in the USA and Japan in the 1960s, in response to concerns about the impact of increased vehicle use on urban air quality. Since then, legislators in all the world's main vehicle markets have developed tailpipe and evaporative emission standards and set progressively more stringent limits on regulated emissions, such as CO, NO<sub>x</sub>, hydrocarbons, visible smoke and particulates.

Emission standards prescribe limits for the regulated exhaust components as well as the test conditions and test procedures under which these limits apply. These standards define test cycles to be used for engine and vehicle certification that are intended to simulate a range of, and reflect the transient nature of, actual vehicle operating conditions. Performance requirements relating to durability are now also stipulated. As noted, these standards have driven the development of engine and emissions control technology and also fuel quality specifications.

In practice, these test cycles can be quite different to actual driving cycles, so that even for the most sophisticated test cycle, actual on-road emissions may differ significantly from those derived from test cycles. In addition, the different vehicle manufacturing countries have developed their own standards and associated test cycles, in response to the nature

of their own particular air quality problems and through dialogue with their own manufacturers, so that direct comparisons between countries cannot easily be made.

New Zealand currently has no mandatory vehicle emission standards and is somewhat unusual in this regard. However, new vehicles coming into New Zealand have generally been designed and equipped to meet the requirements of their main markets. Therefore the current New Zealand vehicle fleet incorporates a wide range of engine and emission control technology spanning the whole history of vehicle emission limits. Until now, fuel quality has not been a limiting factor in the performance of this technology but this is now changing.

## 5.2 Fuel Quality and Emissions

A number of overseas studies have been undertaken on fuel specifications in recent years. The US Auto/Oil Quality Improvement Research Programme (AQIRP) was initiated in 1989 and completed in 1997. The programme, established by 14 oil companies and three domestic car manufacturers, identified clear relationships between fuel specifications and emissions for petrol vehicles. A similar study in Europe, the European Auto/Oil Programme (EPEFE), initiated by the European Commission in 1994, looked at the effect of specific fuel characteristics on emissions from both diesel and petrol vehicles. The objective of both programmes was to provide data to assist legislators and policy makers in developing and assessing measures to reduce emissions and improve air quality. The key findings from these studies in relation to both petrol and diesel, are summarised below. More detailed descriptions of the programmes are given in the Environment Australia review of fuel quality (EA, 2000a).

### 5.2.1 Effects of petrol composition and properties on vehicle emissions

- Sulphur content affects the performance and durability of catalysts. Advanced catalyst formulations being developed for Euro 4 compliance are particularly sensitive and can only be used with very low sulphur fuel (50 ppm or lower).
- Fuel parameters such as volatility and aromatics content affect engine emissions as follows, but do not directly affect emissions control technology.
- Reducing the volatility of petrol through reduced Reid Vapour Pressure (RVP) and/or lower distillation temperatures, has a significant impact on VOC emissions.
- Addition of oxygenates reduces CO emissions.
- Reduction of aromatics content reduces emissions of air toxics, hydrocarbons and CO.
- Reduction of olefins significantly reduces butadiene emissions.

There is a down side however; some of these changes may affect the energy content of the fuel and so increase fuel consumption.

### 5.2.2 Correlations between petrol quality and emissions

Various correlations have been developed for predicting toxic and other emissions as a function of fuel quality, based on the results of the AQIRP, EPEFE and other studies. These are generally expressed as mass emission rates of individual components per kilometre, and presented as functions of fuel composition or other properties. It is important to note that the data on which these correlations are based is generated from vehicle emissions testing and standard drive cycles and may not be particularly representative of actual driving conditions. The Ministry of Transport's VF ECS work has identified that driving patterns and congestion have a major impact on actual emission rates.

While the emission rates for vehicles fitted with catalytic converters have generally been expressed as functions of multiple fuel quality variables, the data for older vehicles without catalytic converters have been presented as percentage changes to individual parameters in isolation and, it is noted, the results were not always clear cut.

The computer models developed using the correlations are designed to predict vehicle emissions (tailpipe and evaporative) and do not predict the resultant air quality. However, they do provide a good basis for comparing the likely effects of changes to certain fuel parameters.

The goal of the United States' Environmental Protection Agency's (USEPA) reformulated gasoline (RFG) programme has been to achieve vehicle emissions reductions relative to 1990 levels (refer Section 5.3.5). The USEPA has developed a complex model based on fuel quality/emissions relationships to provide a means of measuring these reductions through fuel quality changes, while allowing some flexibility for refiners as to how they achieve this through control of fuel properties. Fuel characteristics modelled include sulphur, benzene, olefin, total aromatics and oxygenate content, as well as distillation parameters and RVP. The USEPA model considers both evaporative and exhaust emissions and generates an Air Toxics Index (ATI) as well as emission rates for benzene, aldehydes, butadienes and polyaromatic matter.

The South Australia EPA has recently (March 2001) incorporated the USEPA model into its environmental protection legislation (SAGG, 2001).

The air toxics model approach has been used in the past as a basis for setting specifications using pool averages and caps rather than fixed limits for certain petrol parameters. The use of this approach in New Zealand is discussed in Section 9.6.1 but is not proposed as part of this review, for the reasons outlined therein.

### 5.2.3 Effects of diesel composition and properties on vehicle emissions

There is a clear correlation between some diesel properties and regulated emissions, but drawing general conclusions is somewhat difficult due to such factors as inter-correlation of different fuel properties, different engine technologies or engine test cycles.

- Sulphur increases particulate emissions in both light duty and heavy duty diesels. It also degrades the performance of nearly all emissions control equipment. In particular, de-NO<sub>x</sub> catalysts and continuously regenerating particulate traps require very low sulphur levels.
- In heavy duty diesels engines, increasing cetane number reduces HC, CO and NO<sub>x</sub> emissions. Reducing fuel density reduces NO<sub>x</sub> and PM but increases HC and CO emissions.
- Light duty diesels show different fuel sensitivity to heavy duty diesels.

The characteristics of light and heavy duty diesel engines are discussed in Appendix C.

## 5.3 International Fuel Specifications

This section looks at a number of fuel quality specifications currently in existence and their relevance in setting new standards for New Zealand. These are as follows:

Japan	Source of the majority of our vehicle fleet.
Australia	Source of a significant proportion of our imported fuel. Australia has just completed its own review of fuel quality, which has proved a valuable resource for this review.
Europe	Euro 2, 3 and 4 fuel specifications are de-facto international standards and a benchmark for fuel quality worldwide.
The World-Wide Fuel Charter	The international automotive industries preferred fuel standards.
United States	There are a range of specifications in place across the United States, however, California is acknowledged to have the most stringent vehicle emission fuel quality standards in the world.

These specifications have not developed in isolation but result from ambient air quality and vehicle emission standards in the respective jurisdictions in which they apply, which in turn have developed in response to particular air quality problems. The Review has not considered those air quality standards or emission standards in any detail.

Comparisons of these international specifications for petrol and diesel with the current New Zealand specifications is made on a property-by-property basis in Sections 7 and 8 respectively.

### 5.3.1 Japan

#### Petrol

The current Japanese standard for motor gasoline (petrol), JIS K2202:1999, includes mandatory limits on sulphur (100 ppm max.), benzene (1% max. by volume) and MTBE (7% max. by volume). Prior to January 2000, the benzene limit was 5% max. by volume. There are currently no limits on aromatics or olefins. Two grades of petrol are specified in the standard, No.1 (96 RON min.) and No.2 (89 RON min.). Petrol must not contain methanol, lead or kerosene.

#### Diesel

The Japanese standard for diesel fuel for diesel engines (primarily for automotive use) is JIS K2204:1997. Prior to 1992, the allowable sulphur content of diesel was 2000 ppm. This was reduced to 500 ppm in 1997. A recent high profile court case over health impacts from vehicle emissions has prompted the Japanese Environment Agency to push ahead with plans to reduce allowable sulphur levels to a maximum of 50 ppm by the end of 2004. Five cold weather classes are specified, according to pour point.

#### Relevance to New Zealand

- Japanese vehicles dominate the new vehicle market.
- Used vehicles imported from Japan (both petrol and diesel driven) make up a significant proportion of the New Zealand vehicle fleet. These vehicles were designed to run on fuels domestically available in Japan and to meet

Japanese emission levels.

- Tighter controls proposed on diesel vehicle emissions within the next 3- 4 years may increase the availability of second-hand older technology vehicles for export.

### 5.3.2 Australia

In the past, Australia has had no national mandatory controls governing fuel quality. Fuel properties affecting performance, health and environmental impacts have variously been regulated at state and national level. However, Australia has had vehicle emission standards for a number of years. Exhaust and evaporative emission standards for new petrol driven cars and light commercial vehicles are currently set by ADR 37/01, revised in 1997/1998. ADR 70/00, implemented in 1995/1996, sets emission limits for heavy-duty diesel vehicles.

The Australian Government has recently finalised national environmental standards for petrol and diesel quality. These standards will be implemented as regulations under the National Fuel Quality Standards with the initial changes coming into effect from 1 January 2002. The process and outcomes of the Australian review are summarised in various references (EA, 2000a, b, c; EA 2001a, b)

The standards focus primarily on air quality ie. those fuel parameters with health and environmental implications. In summary, they harmonise:

- Petrol standards with Euro 2 in 2002 and Euro 3 in 2005;
- Diesel standards with Euro 2 in 2002 and Euro 3 in 2006 (except for sulphur in diesel which harmonises with Euro 4 in 2006).

Where standards are already better than these, they have been locked in and some flexibility has been allowed in the transitional period (2002 – 2006). A number of Australian states already regulate environmental parameters such as vapour pressure in petrol and diesel in sulphur, with more stringent requirements and/or a tighter timetable for implementation than the new national regulations. As previously noted, South Australia has recently regulated some aspects of petrol quality using an air toxics model.

The national proposals also allow for development of operability standards for petrol and diesel which focus more on fuel performance requirements and these are currently under development for intended implementation alongside the environmental standards in 2002. Proposals had not been published at the time of writing.

#### Relevance to New Zealand

- Australia is a significant source of imported fuels and petrol blendstocks for New Zealand, and also a significant source of vehicles.
- Australia has opted to harmonise substantially with European standards but on its own timetable.
- The Environment Australia review was guided by a number of principles to assist in determining the extent of harmonisation with European standards and the timeframe that was most appropriate for Australia, and many of these have been taken into consideration in the New Zealand Review.
- Australia is our nearest neighbour and competitive issues in terms of transport costs may be relevant.

### 5.3.3 European Fuel Specifications

The current European fuel specifications have developed out of European Union directives on vehicle emissions, starting with passenger cars in 1992, and subsequently extending to heavy duty vehicles and light commercial vehicles by 1997. These emission standards became known as Euro 1 and Euro 2. The drive for further emissions reduction has since led to the Euro 3 emission standard (implemented in January 2000), a tighter Euro 4 standard (from 2005, applicable to all vehicles) and a Euro 5 standard for heavy duty vehicles from 2008.

In developing these standards, the relationship between emissions and fuel quality was recognised and has resulted in the development of European-wide specifications for diesel and unleaded petrol. The current European standards for fuel are EN 228:2000 and EN 590:2000 respectively, which reflect the parameters required to achieve the Euro 3 emission targets. They cover environmental, health and driveability requirements. While these apply equally to all member countries of the European Union, they also allow for volatility specifications (for petrol) and cold flow properties (for diesel) to be set on a national basis. These fuel specifications are referred to as Euro 3 elsewhere in this document.

In order to meet Euro 4 emissions standards in 2005, the corresponding Euro 4 fuel specifications include further reductions in sulphur and aromatics content of petrol, and lower sulphur limits for diesel. Some European countries, notably the United Kingdom and Sweden, have brought forward the availability of lower sulphur fuels by means of tax incentives. All diesel now sold in the United Kingdom is ULSD (ultra-low sulphur diesel, maximum 50 ppm) and ULSP (ultra-low sulphur petrol) is now also widely available.

Following completion of the second stage of the Auto/Oil programme (Auto/Oil II), the European Commission is currently proposing a progressive phase-in of sulphur-free (<10 ppm) petrol and diesel from 2005 to 2011.

**Relevance to New Zealand**

- European standards are effectively a true international standard with respect to international harmonisation of fuel quality, as unlike national standards, they apply across national borders.
- They incorporate environmental, health and operability parameters, and are therefore a good model for what could be included in our specifications.
- Australia is working towards alignment with Euro 3 and eventually Euro 4, and is a significant source of imported fuels and blendstocks, hence alignment with European standards by New Zealand over time would complement regional alignment.
- New Zealand imports vehicles from Europe which has some of the leading technology in light duty diesels (France in particular) and is a significant manufacturer of heavy duty diesels used here.
- European fuel standards have been developed to achieve emissions standards which address urban air quality issues particular to Europe – these issues are not all necessarily relevant to the New Zealand situation.

**5.3.4 World-Wide Fuel Charter**

The World-Wide Fuel Charter (WWFC, 2000) is a set of recommendations for unleaded petrol and diesel specifications, produced by a group of four international automotive manufacturing associations. The purpose was to promote a greater understanding of the fuel quality needs of motor vehicle technologies and to harmonise fuel quality world-wide in accordance with vehicle needs. The original charter was published in 1998 and revised in 2000.

The four associations that were involved in the development of the charter are:

- AMMA            American Automobile Manufacturers Association
- ACEA            European Automobile Manufacturers Association
- EMA             Engine Manufacturers Association
- JAMA            Japan Automobile Manufacturers Association.

Four categories of specification were developed for diesel and petrol, reflecting different levels of engine and emissions technology required by international vehicle markets.

Table 5.1: World-Wide Fuel Charter Fuel Categories

Category	General Description
1	Fuel quality based largely on engine performance considerations – minimal or no emissions control requirements
2	Stringent requirements for emissions control – equivalent to Euro 1 and 2, US Tier 1 and 2
3	Advanced requirements for emissions control – equivalent to Euro 3 and 4, US California LEV and ULEV
4	Sulphur-free fuel to meet the needs of future vehicle technologies

Although the charter did have some oil company input, it clearly represents the international automotive industry’s perspective.

**Relevance to New Zealand**

- Current New Zealand fuel quality is roughly equivalent to Category 1 or slightly better. Categories 2 and 3 represent possible short and medium term targets respectively, whereas Category 4 is looking beyond vehicle technology currently available.
- The specifications have a slant towards engine and emissions control technology and specify a number of parameters that are probably not necessary in a regulatory specification.
- The specifications largely reflect current and developing technology which forms only a small part of the current New Zealand fleet.

### 5.3.5 United States of America

Fuel quality in the United States is regulated at both state and federal level. The State of California has the most stringent requirements in the world with respect to vehicle emissions, and as a consequence, fuel quality. Since 1990, the USEPA has been working to implement the use of cleaner fuels on a national basis through the Clean Air Act.

#### Petrol

In 1995, Phase 1 of the reformulated gasoline (RFG) programme was introduced (RFG1), requiring the use of RFG in key metropolitan areas with major air quality problems, particularly related to ozone. In reformulated gasoline, the components are regulated to achieve cleaner burning and lower vehicle emissions, by imposing limits on, for example, volatility parameters, aromatics and oxygen content. Phase 2 of the programme (RFG2), requiring more stringent limits, was brought in from January 2000. California has had its own specifications for reformulated gasoline (CaRFG2) and a third phase (CaRFG3) was introduced in September 2000.

The focus of the RFG programme has been on reducing emissions of VOCs, air toxics and NO<sub>x</sub> in order to achieve emissions targets relative to a 1990 baseline. All RFG produced by refiners is required to be certified, with the emissions performance of the fuel being determined using a complex air toxics model developed by the USEPA. The use of pool averaging allows some flexibility in meeting targets for individual components and properties.

The specification of a minimum oxygen content in petrol as a means of reducing CO emissions, was first introduced under the Clean Air Act in 1990, much earlier than the RFG programme. This legislation effectively made the use of oxygenates mandatory in a limited number of cities with high levels of carbon monoxide.

As a result of this move, MTBE, the most popular oxygenate, has been widely used in the United States for a number of years. However, in response to recent concerns about groundwater contamination, the use of MTBE and other oxygenates (except ethanol) will be banned in California from December 2002. Other states have followed suit.

#### Diesel

USEPA standards for diesel fuel for on-road use came into effect in 1993. These included a limit of 500 ppm sulphur, a minimum Cetane Number of 46 and total aromatics limit of 35% maximum by volume. Exemptions to the sulphur limit apply in certain states, and there is currently no sulphur limit on diesel for non-road use. In California, more stringent standards were adopted around the same time, with a similar sulphur limit and a 10% maximum by volume limit on total aromatics. The Californian standard applies to both on-road and off-road use, but excludes marine and locomotive use and allows some flexibility for alternative specifications.

In 1999, the USEPA gave notice of its intention to set a more stringent standard for diesel fuel in line with efforts to implement Tier 2 vehicle emission standards. Earlier this year, the Bush administration confirmed its intention to proceed with a further reduction in diesel sulphur levels to 15 ppm from 2006, in conjunction with more stringent controls on emissions control equipment for heavy diesel vehicles.

#### Relevance to New Zealand

- Californian requirements, being the most stringent in the world, effectively fix the “green” boundary of the fuel quality spectrum, thereby providing a benchmark as to what can actually be achieved given the resources.
- The USA is consequently a leader in vehicle emissions control and fuel efficiency technology.
- New Zealand imports few vehicles from the USA.
- The USA’s significant lead over New Zealand in implementation of vehicle emissions control policies provides an opportunity for us to learn from their experiences (viz. MTBE).
- The USEPA air toxics model has recently been adopted in South Australia which is a source of imported petrol for New Zealand.



# key issues

The Petroleum Products Specifications Regulations have been in place since 1989. Sections 3, 4 and 5 of this Resource Document have described the technological and legislative context, and the commercial and political climate in which petrol and diesel are supplied and used in New Zealand. This information, together with the outcomes set out in the Discussion Document (see What we do and don't want from petrol and What we do and don't want from diesel – in the Discussion Document) and the guidance of the underlying principles for the Review (listed in Appendix A), provide the basis for assessing the specifications and Regulations in detail and making any recommendations for changes.

It is apparent that there are competing tensions in some of the underlying principles, and that trade-offs may have to be made in some cases. These have been outlined in developing the recommendations presented in Sections 7, 8 and 9 of this Resource Document, and this section summarises those key issues.

## 6.1 Key Issues for the Fuel Supply Market

- Any changes to the specifications and/or regulations must promote competition in the fuel supply market, both domestically and internationally, in both the retail and refining sectors.
- The continuing role of Marsden Point Refinery as the major source of supply in New Zealand must be recognised. The strategic value and economic benefits of a New Zealand refinery must be balanced against its ability to compete in the Asia Pacific refining market.
- There should be movement towards international harmonisation in specifications as far as possible. New Zealand is too small to support specifications that are significantly different from elsewhere.
- Fuel specifications need to be internally consistent, reflecting the interdependence within products and between products. We should avoid a hybrid specification that is difficult or expensive to produce.
- Given New Zealand's market size, geography, and fuel distribution infrastructure, the scope for regional or sectoral variations in fuel specifications is limited.

## 6.2 Key Issues for Fuel Use

### Vehicle fleet

- New Zealand's fleet is unique. Our fuel needs to match both current and future needs.
- Introduction of new vehicle technology should be encouraged and customer demand for cleaner/more efficient vehicles met by ensuring the ready availability of the fuels they require. Until now, fuel quality has not been a limiting factor in the performance of vehicle technology, but this is now changing. The timing of the recommended changes must therefore reflect expected development and uptake times for the relevant technologies (see Section 6.4).

### Consumer protection

- Fuels must provide reliable and consistent performance. Controlling variability can ensure this, but this must be balanced against over-regulation, which creates an unnecessary compliance burden on suppliers.
- The specifications must ensure that New Zealand does not become a dumping ground for poor quality fuel.
- Customer safety and product satisfaction must be assured, through identification and labelling.

## 6.3 Key Issues for Environment and Health

- While the effects of fuel quality changes alone on emissions from vehicles are relatively small, real benefits accrue when the fuel enables new technologies to be introduced. This is intrinsically linked with the timing considerations in aligning the required fuel quality with the vehicle fleet.
- New Zealand's air monitoring data confirms that reductions of some priority pollutants are needed now, to protect



public health in some areas of the country, primarily urban road corridors. Some changes in fuel quality will provide direct public health benefits. (eg. reducing sulphur in diesel to minimise secondary pollutant levels, reducing benzene levels in petrol).

- The potential environmental impacts associated with certain fuel constituents (for example, MTBE) must also be recognised. Where the risk is still unknown, or significant uncertainty remains, a precautionary approach has been taken.
- The potential for regional specifications to address local air quality problems must be recognised although, as noted earlier, this may be limited by the distribution infrastructure.

## 6.4 Timing

The proposed changes outlined in the following sections are timed to occur over the next five to six years. Some changes are proposed to have immediate effect. In most cases, this is to regulate for good practice already occurring. Other changes are proposed to coincide with technological advances in the fuel processing and vehicle manufacturing industries. Unless there are demonstrable benefits, it has not been recommended that any changes are made in advance of Australian and European requirements, as this may unnecessarily create barriers for suppliers. For some parameters (eg. sulphur in diesel, benzene and distillation end point in petrol) a staged programme has been proposed that will allow suppliers to introduce changes over a period of time.

These stages recognise the timetables for changing specifications elsewhere in the region, estimated lead times for refinery upgrading and the availability of new vehicle technology. The proposed changes also recognise the strong interdependence of many of the specified fuel properties.

The amended Regulations will contain firm dates when the changes must be in place.

Immediate changes will be implemented as soon as the new Regulations can be issued. This is anticipated to be around mid-2002.

Stage 1 changes will be implemented in 2-3 years' time (2003 - 2004)

Stage 2 changes will be implemented 5-6 years' time (2006 - 2007)

# properties of petrol

This section examines the main properties that specify petrol quality. These include:

- Properties specified in the current regulations;
- Other properties currently not specified.

These properties are presented generally in the order in which they appear in Schedules 1 and 2 of the Regulations. Each is examined under the following headings (as applicable):

## Property

What is it?

Why is it important (its effect on engine performance)?

How is it controlled?

## Comparison of current New Zealand and international specifications

## Why regulate?

Why does this property need to be regulated?

Should the current specifications be changed?

## Proposed changes

Proposed changes and timing

Implications of changes, potential costs and benefits

It is noted that for some properties of petrol, there is a high degree of interdependence – for example, volatility and distillation parameters, composition and density are all inter-related so it is not possible to change one in isolation and not affect the others. In refinery operations, where each crude oil produces a range of fuels, changing the properties of one product will also have flow on effects for other products – for example, changes required to meet new specifications for petrol may have an impact on production of diesel or other products. Therefore a broader view needs to be taken when considering the implications of any changes to specified quality properties.

Appendix C contains a description of how spark-ignition engines work, and the fuel characteristics that are relevant to petrol engine performance.

## Properties Currently Specified

### 7.1 Octane Number

What is it?

Octane Number is a measure of a petrol's resistance to auto-ignition. Auto-ignition in petrol engines can be classified into two types:

- **Knock**, caused by spontaneous combustion of a portion of unburnt air-fuel mixture ahead of the advancing flame front; and
- **Surface ignition (pre-ignition or post ignition)**, where ignition is initiated by any hot surface in the combustion chamber rather than spark discharge at the spark plug.

Both processes result in uncontrolled combustion which, if severe, can cause major engine damage. Knock is generally the more common form of abnormal combustion. A significant defining feature of knock is that it is able to be controlled by ignition timing.

The higher the octane number of a petrol, the greater its resistance to knock. Iso-octane (octane number 100) and n-heptane (0) are used as the reference points for octane number. An octane number of 91 means that the fuel, when tested in a specified engine and procedure, has the same anti-knock quality as a mixture of 91% iso-octane and 9% n-heptane by volume.

There are two common measures of octane:

- **Research Octane Number (RON)** is an indicator of the fuel's anti-knock performance at lower engine speed and typical acceleration conditions.
- **Motor Octane Number (MON)** reflects the anti-knock performance of a fuel under high engine speed and higher load conditions.
- The difference between them (ie. RON – MON) is called the **sensitivity** and reflects the effect of changing operating conditions on the fuel's anti-knock performance.

In common usage, the term “octane”, as in the 91 and 96 grades of petrol available in New Zealand, refers to RON, which for petrol, is always the higher value.

The specified test methods are ASTM D 2699 for RON and ASTM D 2700 for MON.

#### Why is it important?

Spark ignition engines are designed for a certain octane rating, corresponding to the compression ratio. Using a fuel of a lower rating may result in knocking, due to compression ignition occurring before spark ignition. In many modern engines, the spark occurs before the end of the compression stroke, to maximise the length of the power stroke, which requires the fuel to be resistant to compression ignition.

Many modern vehicles are designed with knock sensors which can retard the spark timing to accommodate conditions that would cause knocking. However, compensating for a low octane fuel by this mechanism results in loss of performance and efficiency. Using a petrol with a higher octane rating than specified will generally not improve engine performance.

As engine technology develops to achieve greater fuel economy, higher compression ratios may become more common in engine designs, necessitating higher octane fuel. A 95 RON/85 MON grade is seen as being the optimum octane rating, providing a balance between reducing fuel consumption and increasing the energy required to produce the fuel. Most Japanese cars are designed to run on 90 RON which is the regular grade standard in Japan, and these vehicles dominate the current New Zealand fleet. However, over the long term the demand for premium grade petrol worldwide is projected to increase.

Low speed knock during acceleration is generally audible and the driver can ease back on the accelerator if it is severe. This form of knock is influenced more by the RON than the MON. The MON will have more impact on high speed, high load conditions when knock may not be audible to the driver and is potentially more damaging. A greater sensitivity will mean a lower MON for a given RON and greater potential for the more damaging and less detectable high speed knock. Sensitivity should not generally exceed a value of 10 – 11, though for high octane petrols (97 – 98 RON) it may be higher.

#### How is it controlled?

Branched chain hydrocarbons, olefins and aromatics are high octane components of petrol and their presence tends to improve its anti-knock performance. These compounds have differing sensitivities and so their use will affect the balance between RON and MON. Octane enhancing additives (organo-metallic compounds such as lead alkyls and MMT) can be used to improve the octane number of petrol. High octane blending components (oxygenates such as MTBE and ethanol) can also be used.

All of these means of meeting octane rating specifications are constrained in New Zealand:

- The formation of branched chain hydrocarbons is achieved through alkylation and isomerisation during refining of the gasoline fraction of crude oil. While all the Australian refineries have some level of capacity for either one or both of these processes, the Marsden Point Refinery does not. Therefore improving octane rating via addition of branched chain hydrocarbons can only be achieved at Marsden Point by the use of imported blending stock containing high levels of these compounds.
- There is a trend worldwide to reduce the amount of aromatics and olefins in petrol because of the effects of some of their products of combustion on air quality. These are discussed in more detail in Sections 7.9 and 7.12 respectively.
- The use of lead alkyls has now been phased out in New Zealand because of the adverse environmental effects of lead discharged from vehicle exhausts. Lead in petrol is discussed in Section 7.8.
- Similarly, other organo-metallic compounds (such as MMT) are not favoured by the automotive industry as octane enhancers because of their effects on engine components and catalysts. Manganese is covered in Section 7.13.
- Oxygenates such as MTBE and ethanol have a strong affinity for water and can rapidly migrate from fuel spills into ground water. Also the majority of the New Zealand petrol distribution infrastructure is not completely water-free and is therefore not suited to the use of MTBE or ethanol. Oxygenates are discussed in more detail in Section 7.11.

Because of these constraints, the Marsden Point Refinery, which produces about two thirds of the gasoline used in New Zealand, has limited capacity for reducing the benzene and total aromatics content of petrol, with its current configuration and balance of feedstocks. Even production of premium grade currently requires the use of significant volumes of imported gasoline blendstocks to achieve octane targets. This has implications for other properties considered in the review.

### Current New Zealand and International Specifications

Most petrol specifications in other countries state a minimum limit only for both RON and MON. International specifications for octane number are already closely aligned as shown below.

In the United States, an Anti-knock Index (AKI) is commonly used, which is the average of RON and MON ie.  $(RON + MON)/2$ . USEPA regulations require a minimum anti-knock index of 87. The value of AKI for New Zealand's 91 grade is 86.5, and for premium grade is 90.0.

Grade Specification	Regular		Premium		98 RON	
	RON	MON	RON	MON	RON	MON
New Zealand	91	82	95	85		
Euro 3 (2000)	90 <sup>1</sup>	80 <sup>1</sup>	95	85		
World-Wide Fuel Charter	91	82.5 <sup>2</sup>	95	85	98	88
Australia (from 1 Jan 2002)	91	-	95	-		
Japan	89 (No. 1)	-	96 (No. 2)	-		

1. Regular grades specified at a national level for EN228 – these are the requirements in the United Kingdom.

2. Category 2, 3 and 4 only; Category 1 is 82.0.

In 1998/1999, regular grade petrol sampled in New Zealand had an average RON of 91.7 and an average MON of 83.0. Premium grade had an average RON of 96.5 and an average MON of 86.2.

While the current statutory requirements for premium grade petrol are 95 RON/85 MON minimum, the supply specification used by the refinery and the four main oil companies (the NZRC and User Company specification) is actually 96 RON/86 MON minimum. Some companies (but not all) market premium grade specifically as 96 octane. This level is understood to have been adopted following “octane satisfaction surveys” carried out prior to the introduction of premium unleaded petrol (PULP) to establish the appropriate octane range for the premium grade to suit the vehicle fleet.

BP and Mobil are now both marketing high octane grades in New Zealand (nominally 98 RON).

### Why regulate?

The primary reason for continued regulation is to ensure that the consumer is able to buy petrol of known and consistent octane number.

Newer engine designs are less prone to higher speed knock. Given this, the recent Australian review of fuel quality (see Section 5.3) concluded that MON is an outdated parameter and it has not been included in the environmental specifications which come into effect next year. This effectively removes any direct control on sensitivity. However, it is important to maintain sensitivity control for older technology cars. In view of the make-up of the New Zealand fleet, it is considered that the maximum sensitivity still needs to be controlled through specifying minimum limits for both RON and MON.

The “boutique” high octane grades now available are of relatively small volume and because of this, it is not considered that their octane number specifically needs to be regulated, other than that they should meet the octane number being advertised. This is discussed in more detail in Section 10.

## Changes proposed to the Regulations

Current Regulations	Proposed changes
Octane number for regular grade petrol: 91 minimum RON; 82 minimum MON	no change
Octane number for premium grade petrol: 95 minimum RON; 85 minimum MON	no change

## 7.2 Colour

### What is it?

Petrol is normally colourless and a dye is added (usually at the refinery) to provide any required colour. Generally, colours are used to differentiate between grades during distribution, in particular between leaded and unleaded petrols. This dye does not affect vehicle performance.

### Current New Zealand and International Specifications

International specifications do not stipulate any colour requirements for petrol. The New Zealand specifications currently only require that the colour of petrol ensures that it “not be mistaken for a harmless substance”. The change from specifying particular colours was made in 1998 following concerns about the cost of compliance.

There is also no requirement for the two grades to be of different colours, and in fact the colour may vary depending on whether it comes from the Marsden Point Refinery or is imported. Currently regular grade from the refinery is red. Regular grade in Australia is purple (leaded is red). Premium grade and the new higher octane grades now available are yellow.

It is understood that Australia proposes to continue with its standard colours.

### Why regulate?

Normally the consumer will not see the fuel that is being put into a vehicle, but the colour does allow the grade of petrol to be easily determined when it is sampled and for it to be readily distinguishable from diesel, which has no added colour.

The requirement for petrol “not to be mistaken for a harmless substance” is primarily for consumer protection and child safety. However, the interpretation of a “harmless” colour is very subjective. Regulating the colour of petrol does not seem to achieve the original intention and the present requirement is considered to be unenforceable.

## Changes proposed to the Regulations

Current Regulations	Proposed Change
Colour: not to be mistaken for a harmless substance	Immediate removal of requirement

## 7.3 Volatility and Distillation Parameters

### What are they?

These properties characterise the volatility of the petrol, that is, its tendency to vaporise. This is critical to both engine performance, particularly starting, as well as vapour emissions from the fuel distribution system. As petrol is a mixture of a large number of different hydrocarbons, the boiling point is a temperature range rather than a single value, and so four main measures of volatility are commonly used.

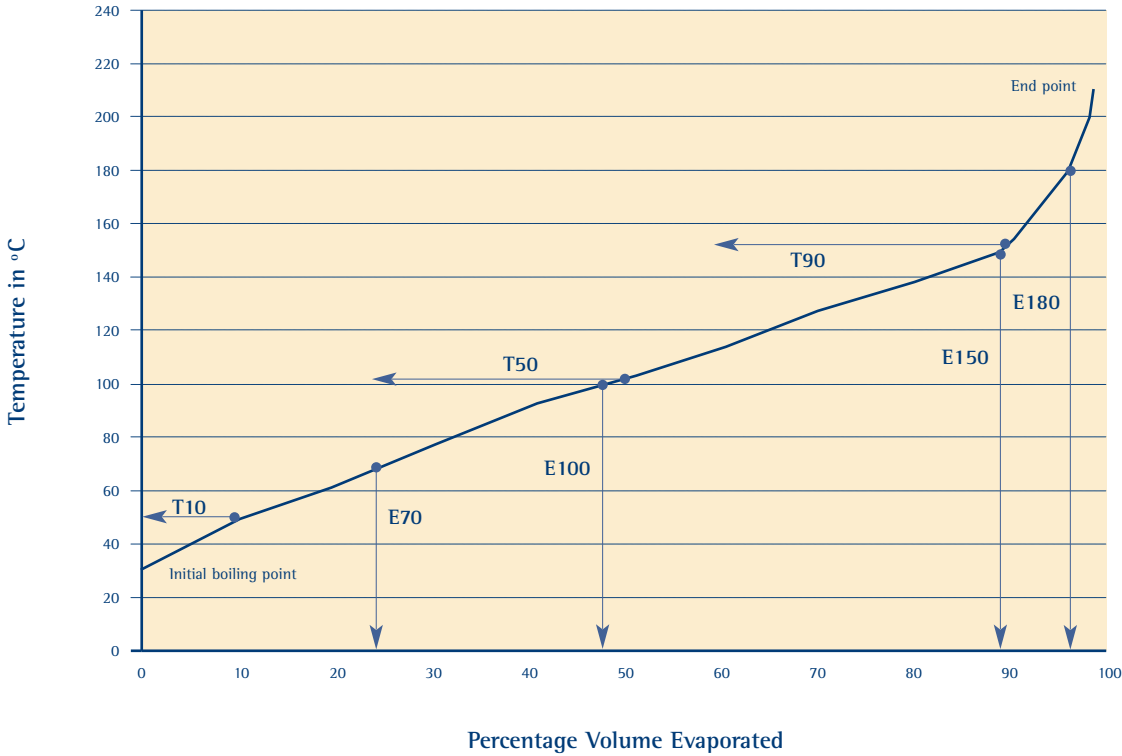
#### ■ E70, E100, E150 and E180

These are the percentages by volume of petrol that evaporate when it is heated to 70°C, 100°C and 180°C respectively. E70 is a measure of cold running performance. The distillation properties can alternatively be expressed as temperatures corresponding to different volumes, for example T10, T50 and T90. These are the temperatures at which 10%, 50% and 90% by volume of the petrol has evaporated.

■ **Distillation End Point**

This is the temperature beyond which all the volatile components have boiled off, leaving only a residue (see Section 7.4). These properties are illustrated in Figure 7.1 which shows a typical distillation curve for petrol.

Figure 7.1: Typical Distillation Curve for Petrol



■ **Reid Vapour Pressure (RVP)**

The vapour pressure is another measure of the volatility of the fuel and relates principally to the lighter components in the fuel such as butane. To measure the true vapour pressure is quite involved, so a simpler parameter, **Reid Vapour Pressure**, is used and is referenced to a standard temperature (37.8°C or 100°F).

■ **Flexible Volatility Index (FVI)**

This is a parameter calculated from the RVP and the measured value of E70, and is an indicator of the hot running performance (the tendency for vapour lock).

$$FVI = RVP + (0.7 \times E70)$$

**Vapour Lock Index (VLI)** is used in European specifications and is essentially the same as FVI, though it differs by a factor of 10.

Another indicator of volatility is the **Driveability Index or Distillation Index (DI)** which is calculated from T10, T50 and T90 and also allows for the effects of oxygenates. The formula is:

$$DI = (1.5 \times T10) + (3 \times T50) + T90 + (11 \times \%O_2 \text{ w/w})$$

DI is a measure of cold driveability. 'T' numbers have traditionally been used in the USA, Japan and Australia although the USEPA is moving away from these in favour of % evaporation properties (E70 etc.) which behave linearly when blending different batches.

**Why are they important?**

Fuel must contain enough volatile components (light ends) to enable easy starting and acceptable driveability when an engine is cold, but not so much that it begins to vaporise in the fuel lines when the engine is hot (this is known as vapour lock and impedes fuel flow). The fuel must also not be so volatile that evaporation from the fuel tank is excessive – both for environmental and health reasons. Therefore, volatility must reflect not only the general performance requirements of spark-ignition engines but also the range of climatic conditions in which they must operate, so direct comparisons with other countries are not necessarily valid.

The high end of the distillation curve, that is the least volatile (heaviest) components, are important in contributing to deposit formation and exhaust emissions. These compounds may not fully vaporise before entering the combustion chamber, particularly under cold running operation. This can cause oil dilution and increased cylinder wear, and may lead to combustion chamber and inlet system deposits and spark plug fouling. Exhaust hydrocarbon emissions are also influenced to a small extent by the heavy compounds; reducing the fuel's T90 value leads to small reductions in hydrocarbon emissions, particularly under cold running conditions. The evaporative emission of VOCs is also reduced with decreased T90. These effects are generally fairly small.

The heavier compounds in petrol are generally those with the highest energy content and density, so their reduction will tend to reduce the energy content per litre of fuel slightly, thereby increasing fuel consumption.

#### How are these properties controlled?

RVP is usually controlled during refining by adjusting the proportion of butane, the most volatile component, in the final blend. Reducing RVP reduces evaporative losses and the international trend is towards lower maximum RVP limits.

End Point is reduced by altering the cut point between the petrol fractions and heavier products during refining.

The other distillation properties are not usually controlled directly but reflect the composition of the petrol.

#### Current New Zealand and International Specifications

The following table compares the current New Zealand requirements with a range of volatility specifications used internationally. It is important to note that the values of these volatility properties must be set to suit the climatic conditions in which the fuel is used. The European specifications define volatility classes, based on climate which each EU country is able to assign on a seasonal basis. The World-Wide Fuels Charter volatility classes are based on minimum expected ambient temperatures.

Parameter Specification	E70		E100		E180	End Point	RVP	FVI
	Vol % min	Vol % max	Vol % min	Vol % max	Vol % min	°C max	kPa max	
New Zealand	25	45	45	67	90	220	-	77.5-115
Euro 3 (2000) <sup>1</sup>	20-22	48-50	46	71	75 (E150)	210	45-70	1250 max <sup>2</sup>
World-Wide Fuel Charter <sup>3</sup>	20-25	45-47	50-55	65-70	90	195	55-70 <sup>4</sup> 65-80	
Australia	See Note 5					210 (from 1 Jan 2005)	Controlled at state level	See Note 5
Japan	T10, T50 and T90 specified					220	44-78	
USA							Note 6	

1. Dependent on volatility class – figures for UK shown

2. A VLI of 1250 is equivalent to an FVI of 125. For the UK, VLI only specified for transition periods between summer and winter.

3. Volatility parameters in WWFC as specified for Categories 2, 3 and 4. Ranges reflect minimum expected ambient temperature – dependent on country and season.

4. First figure is for minimum ambient temperature range of 5 – 15°C, the second for –5 to +5°C

5. To be included in future operability standards (under development)

6. Subject to control under RFG (reformulated gasoline) specifications.

#### Why regulate?

##### ■ Performance

After cold starting problems were encountered with a shipment of imported fuel in 1994, the specified minimum values for E70 and E100 in New Zealand were increased from 15% and 40% respectively to the current values of 25% and 45%. Some suppliers believe that a minimum E70 value of 22% would be less constraining on refineries while not unduly affecting performance and similarly that E70 maximum could be increased to 50%. While changing the minimum E70 should not have any significant impact on engine performance, increasing the maximum will increase the evaporative losses.

The current specifications for FVI (77.5 min and 115.0 max) reflect the allowable seasonal variation but do not specify summer and winter requirements per se. If RVP limits were introduced, FVI might be considered superfluous. However, engines with carburettors are more susceptible to vapour lock than those with fuel injection systems. As carburetted engines currently make up a significant proportion of New Zealand’s petrol vehicle fleet, it is considered that the maximum limit on FVI needs to be retained, as has been done for the “shoulder seasons” in the United Kingdom. The minimum requirement is not seen as necessary to control engine performance and minimum FVI is not regulated elsewhere.

Reducing the end point will reduce smoke emissions due to reduced high molecular weight aromatics. Changing the distillation end point to 210°C will align with the Euro 3 standard and the current Australian proposals (to be implemented in 2005).

■ **Evaporative Emissions**

In order to reduce evaporative losses and resulting hydrocarbon emissions from vehicles and during bulk storage and distribution, there have been moves in many other countries to reduce the allowable vapour pressure. Many countries set maximum RVP limits in summer. In New Zealand, there are no direct limits on vapour pressure, though it is controlled indirectly through limits on FVI. Based on the current E70 limits, the FVI specifications allow RVP to range between 46 and 97.5 kPa, although other properties may be constraining. However, the NZRC and User Company specification does set seasonal limits for RVP (albeit at a high level).

RVP reduction is achieved by reducing the lighter ends such as butanes which in turn affect cold starting. Lower volatility fuels are less of a problem in fuel-injected engines common in many new vehicles but can cause difficulties with carburetted engines in older vehicles, which make up a significant proportion of the New Zealand fleet. Therefore RVP limits should not be set too low.

■ **Harmonisation with other specifications**

Volatility requirements set in international standards reflect a range of climatic conditions and care needs to be taken when identifying suitable values for use in New Zealand. It has been suggested that E100 limits be changed to 46% (minimum) and 71% (maximum) to align with Northern European volatility classes. However the benefits of this would be limited.

E150 is considered to provide better control of volatility and 75% (minimum) is an appropriate level to set. Specifying an E150 value instead of E180 will align with the Euro standard

It is considered that there is no benefit from adopting DI in favour of the current property/properties.

**Changes proposed to the Regulations**

Current Regulations	Proposed changes
E70: 25% minimum; 45% maximum	Immediate reduction of minimum E70 to 22%
E100: 45% minimum; 67% maximum	No change
E180: 90% maximum	Stage 1 replacement of E180 specification with E150, set at 75% maximum
Distillation end point: 220°C maximum	Stage 1 reduction of distillation end point to 215°C Stage 2 further reduction of distillation end point to 210°C
Reid Vapour Pressure: not currently specified	Immediate introduction of maximum RVP limits by season (see table below) (test method ASTM D 323)  Stage 1 reduction of RVP limits  Stage 2 further reduction of RVP limits
Flexible Volatility Index: 77.5 minimum; 115 maximum	Immediate removal of minimum limit on FVI



Proposed RVP limits by season

Season	Dates	Immediate	Stage 1	Stage 2
Summer:	1 December – 30 April	85 kPa max.	75 kPa max.	65 kPa max.
Autumn:	1 May – 31 May	90 kPa max.	85 kPa max.	80 kPa max.
Winter:	1 June – 30 September	95 kPa max.	No further change	No further change
Spring:	1 October – 30 November	90 kPa max.	85 kPa max.	80 kPa max.

The test method for RVP is ASTM D 323 and is already specified in relation to FVI.

Implications of proposed changes

- Reducing the E70 minimum limit to 22°C will provide more flexibility for suppliers without compromising cold start performance.
- Lowering the end point to 210°C will have a minimal effect on petrol production at the Marsden Point Refinery. While this change is expected to deliver environmental outcomes in respect of reduced smoke emissions, the availability of sources outside New Zealand could constrain imports (Australia is not reducing until 2005). It is proposed that New Zealand follows a similar timetable to Australia in achieving this final step.
- The effect of reducing RVP on the operation of a refinery is to reduce the volume of petrol produced and create a surplus of butane. As the Marsden Point Refinery has no market for this butane it would be used as fuel with an associated impact on operating costs. Limiting the maximum summer RVP to 75 kPa and a subsequent further reduction to 65 kPa will therefore have economic penalties for the Refinery. There would also be some impact on blending as butane content has an impact on octane.
- The immediate RVP limits proposed reflect the current NZRC and Refinery Users specification limits. These limits will apply at the point of supply. For imported fuels, RVP limits already exist in most source countries.

## 7.4 Residue and Existent Gum

What are they?

The residue is the percentage volume remaining after the distillation end point is reached and represents the proportion of non-volatile components in the fuel. This material, which is primarily waxes and gums, may form deposits in engine fuel inlet systems. The residue is determined as part of the standard distillation test using ASTM D 86.

The residue is then washed in a solvent before drying and weighing to determine the amount of gum present – the “Existent Gum.” The test method is ASTM D 381.

These properties are a function of the petrol composition and distillation characteristics.

Current New Zealand and International Specifications

The current specification requires a maximum of 2% by volume residue after distillation which is almost universal in international petrol specifications. The specification for gum is 5 mg per 100 mls, which is in line with the European and Japanese standards as well as the World-Wide Fuel Charter.

No changes to either specification are considered necessary.

Changes proposed to the Regulations

Current Regulations	Proposed changes
Residue: 2% maximum by volume of petrol	No change
Existent gum (solvent washed): 5mg/100ml maximum	No change

## 7.5 Copper Strip Corrosion

### What is it?

Corrosiveness in petrol is usually due to free sulphur or sulphur compounds which combine with water from combustion to form acids. The test procedure uses a strip of polished copper which is immersed in a sample of the fuel and heated to a specified temperature for a specified time. The degree of corrosion is measured by comparing the staining with a reference sample. The test method is ASTM D 130.

### Current New Zealand and International Specifications

While the New Zealand specification calls for 2 hours at 100°C, this is now out of step with practice elsewhere (for example, in Europe and Australia ) where a longer duration and lower temperature test (three hours at 50°C) is becoming more common. It is understood that the New Zealand test conditions may have originally been adopted to offer adequate corrosion protection for a particular type of dispenser pump.

The current test is considered more severe than that used elsewhere due to the higher temperature. While a test at 50°C for three hours would take longer, it would also be less hazardous to the technician carrying it out. On balance it is considered that a revised test will be safer, while offering adequate corrosion protection and aligning with international practice. For imported fuel, the standard test could be used, rather than having to perform a unique New Zealand one, thereby reducing compliance costs. No change to the test method or required corrosion test standard is proposed.

### Why regulate?

Some measure of the corrosivity of petrol needs to be retained to provide protection for fuel tanks, dispenser pumps and vehicle engine and fuel system components.

### Changes proposed to the Regulations

Current Regulations	Proposed changes
Copper strip corrosion test: 100°C for 2 hours, then compare with a reference sample	Immediate: Copper strip corrosion test: 50°C for 3 hours, then compare with a reference sample

## 7.6 Sulphur

### What is it?

Sulphur occurs naturally in crude oils and must be removed to an acceptable level during the refining process as it promotes corrosion and affects the performance of vehicle emissions control equipment.

### Why is it important?

Sulphur does not affect engine performance directly but it reduces the efficiency of catalytic converters. Developing petrol engine technologies such as gasoline direct injection (GDI) and lean burn will require advanced catalyst technology in order to meet Euro 4 emission levels (in 2005) for CO, hydrocarbons and NOx. These technologies are very sensitive to sulphur and require levels at or below 50 ppm. Euro 5 (2008) emission standards are likely to require further reductions.

While there is no direct environmental benefit in reducing sulphur in petrol from the current levels, by enabling new engine and emissions control technology, it will have an indirect effect on emissions of CO, hydrocarbons and NOx.

## Current New Zealand and International Specifications

Specification	Maximum sulphur content
New Zealand	500 ppm
Euro 3 (2000) Euro 4 (2005)	150 ppm 50 ppm 10 ppm to be available from 2005 onwards, and required for all petrol by 2011 (proposed)
World-Wide Fuel Charter	1000 ppm (Cat.1 ), 200 ppm (Cat.2), 30 ppm (Cat.3), none (Cat. 4)
Australia	500 ppm in ULP & 150 ppm in PULP from 1 Jan 2002 150 ppm in all grades from 1 Jan 2005 50 ppm (proposed in future, (EA, 2000b))
Japan	100 ppm
USA (CaRFG only) <sup>1</sup>	CaRFG2: 80 ppm (cap) - current CaRFG3: 60 ppm (cap) from Dec 2002, 40 ppm (cap) from Dec 2004 Both flat limits and pool averages/cap specified

1. CaRFG2/3: California Reformulated Gasoline specification Phase 2 or 3

The catalytic reforming process (platformer) used at the Marsden Point Refinery to upgrade naphtha to high octane gasoline blendstocks require; the sulphur in the feed to be removed before processing. As a consequence, the sulphur levels in petrol produced in New Zealand are very much lower than the current 500 ppm limit. The test method presently used can detect levels down to 100 ppm, but only 5% of samples collected in 1998 – 1999 contained detectable levels of sulphur.

Any sulphur in the petrol produced at the Marsden Point comes from the imported blendstocks required to boost the octane. A lot of these blendstocks come from Australia, and are produced by a catalytic cracking process which does not require the feedstock to be desulphurised. Last year blendstocks made up about 11% of the total volume of petrol produced at Marsden Point.

Similarly, imported petrol produced primarily from catalytically cracked spirit will also contain higher levels of sulphur than the Refinery's product.

### Why regulate?

- As noted, current sulphur levels in New Zealand petrol are already well below the 500 ppm maximum limit and in many cases below Euro 3 levels (150 ppm) and often Euro 4 levels (50ppm).
- Sulphur at this level in petrol does not currently present any environmental or health concerns and should not prove a barrier to engine or emissions control technology before at least 2005. However, it is evident that vehicle and emission control technology will ultimately require levels below 50 ppm and that New Zealand will have to cater for this (probably from 2007 onwards).
- When making decisions to introduce new technology, vehicle manufacturers will generally rely on regulated sulphur levels rather than actual sulphur levels. This is particularly so where this will affect equipment performance and warranties and therefore clear signals are needed regarding future sulphur levels in New Zealand petrol for the vehicle industry.
- Australian refineries currently cannot produce finished petrol or blendstocks with the same levels of sulphur that the Marsden Point Refinery can achieve, and will not be able to for some years. Australia is a major source of supply for imported regular and premium petrol, as well as blendstocks, and may become more so if benzene and aromatics limits are to be reduced. Early imposition of Euro 3 or even Euro 4 levels for sulphur on New Zealand petrol could constrain future supplies from Australia, however, other low sulphur supplies are available from Pacific Rim refineries.
- If New Zealand aligns its timetable for reducing petrol sulphur limits with Australia, there is a potential for actual levels to increase in the interim.
- On balance, there are benefits to going at least some way to locking in the current low levels of sulphur in New Zealand's petrol as soon as practicable and providing a clear signal on future direction.

As the current test method is not particularly suited to detection of low sulphur levels, adoption of a new method, ASTM D 5453, which is suitable for both petrol and diesel is proposed. This is currently used by refineries in California and is available at the Marsden Point Refinery as well.

### Changes proposed to the Regulations

Current Regulations	Proposed changes
Sulphur: 500 ppm maximum (mg/kg)	Immediate reduction of maximum to 150 ppm (test method ASTM D 5453) Stage 2 further reduction to 50 ppm maximum Ultimate requirement for sulphur free petrol (less than 10 ppm).

## 7.7 Oxidation Stability Induction Period

### What is it?

This test is a measure of the stability of the petrol during long term storage. Oxidation results in the formation of gums, deposits and sludges.

The test method is ASTM D 525. The sample is heated in a sealed vessel with oxygen and the time measured before it starts to absorb the oxygen (ie. oxidise) and form gum. The induction period measured does not equate to the safe storage time. A figure of 240 minutes minimum usually ensures a satisfactory level of stability for normal storage and distribution and this is the current New Zealand specification.

Petrol containing sufficient straight-run naphtha contains naturally occurring anti-oxidants. However, some petrols require dosing with antioxidants to control oxidation.

### Current New Zealand and International Specifications

The current level specified in New Zealand is 240 minutes, which is the same as in Japan. The European standard requires a 360 minute induction period and the World-Wide Fuel Charter 480 minutes (for Category 2+ fuels).

The present requirement is considered to be somewhat outdated and is exceeded by a significant margin. A change to 360 minutes minimum would align with international practice. The test would, however, take longer (six hours vs. four hours).

No change to the test procedure is required.

### Changes proposed to the Regulations

Current Regulations	Proposed changes.
Oxidation stability induction period: 240 minutes.	Immediate: Oxidation stability induction period of 360 minutes.

## 7.8 Lead

### What is it and why is it important?

Previously lead was added to petrol in the form of compounds such as tetra-ethyl lead (TEL) to improve the octane rating. It does not affect engine performance as such but lead contamination accumulates in catalytic converters and poisons the catalyst. This effect is cumulative and irreversible. No reference has been found to the minimum level of lead required to avoid damage to catalysts but a standard of 5 mg/litre has become a common international standard for unleaded petrol.

Concerns over effects on human health have resulted in the phasing out of petrol additives containing lead in many countries over the last 10 – 20 years. As lead affects the performance of catalysts in vehicle emission control systems its withdrawal has been necessary to enable the introduction of catalyst technology in petrol vehicles. New Zealand petrol has been lead-free since 1996 and we are ahead of many other countries, including Australia, where leaded petrol is still available.

The current test method specified is IP 224.

### Current New Zealand and International Specifications

The current New Zealand specifications set a maximum level of 13 mg/litre to allow for some level of minor contamination, though the test procedure used can detect down to 0.3 mg/litre. However measured lead levels are very low and often it is not detectable. Maximum levels measured do not typically exceed 3 mg per litre which is the level set

by the NZRC and User Company specifications. Any lead detected will generally be due to contamination during transport in ships tanks which have previously been used for leaded fuels.

The European standard for unleaded petrol sets a maximum level of 5 mg/litre. Australia proposes to align with this by January 2002. The World-Wide Fuels Charter requires lead to be below detectable limits (though it does not define the test procedure to be used). The Japanese petrol specification requires 1 mg/litre. The basis for the current New Zealand figure is in line with the Toxic Substances Regulations, which also restrict the use of lead in petrol. Prior to 1994, the maximum limit for unleaded petrol was 50 mg/litre.

#### Changes proposed to the Regulations

Current Regulations	Proposed changes
Lead: 13 mg per litre maximum	Immediate reduction to 5 mg per litre maximum

With progressive removal of lead from petrol in the main sources of imported supplies in the future (such as Australia), this should be readily achievable.

## 7.9 Total Aromatics

### What are they?

Aromatics are hydrocarbons with a molecular structure based on cyclic carbon (benzene) rings. Benzene itself is the simplest aromatic compound (discussed separately below) but others common in petrol include toluene and xylene. Some, particularly benzene, are known to be carcinogenic. Aromatics containing multiple benzene rings are known as polycyclic aromatic hydrocarbons or PAHs (also referred to as PCAs). Many PAHs detected in exhaust emissions display some mutagenic and carcinogenic activity.

Aromatics occur naturally in crude oil. They are also produced as part of the catalytic cracking and reforming processes used in refining and are used to increase the octane rating of petrol.

The aromatic content is determined by gas chromatography, using test method ASTM D 5580.

### Why are they important?

Aromatics are high octane constituents of petrol, and therefore any reductions in levels need to be made up with some other high octane constituents or octane improving additives. With the move to the wider use of unleaded petrol, refiners have tended to increase the level of aromatics to meet octane requirements, particularly for premium grades.

As they are solvents, at high concentrations aromatics can affect some of the elastomers used in seals and gaskets in pumps and fuel lines, particularly on older vehicles. The problems encountered following the introduction of PULP in 1996 were attributed in part to a particular shipment of imported fuel that contained a high level of toluene. At that time there were no limits on total aromatics; this led to the current limit of 48% by volume of total aromatics being imposed.

However, sudden large reductions in aromatic levels or low levels can also cause loss of elasticity or shrinkage in some elastomers “acclimatised” to higher levels. This can also be a problem in diesel fuels.

The heavy compounds, particularly PAHs, can be more difficult to combust; this may lead to combustion chamber and inlet system deposits and spark plug fouling. Exhaust hydrocarbon (HC) emissions are also influenced to a small extent by these heavy compounds; reducing the fuels aromatics content (manifesting as a reduced T90) leads to small reductions in the HC emissions, particularly under cold running conditions.

### Current New Zealand and International Specifications

Total aromatics levels in New Zealand petrol currently average around 44% by volume for premium grade and 35% for regular grade. The NZRC and User Company specification also has a limit on toluene + xylenes, which was established following the introduction of premium unleaded petrol in 1996. However this is not regulated.

The current maximum allowable level of aromatics in Europe is 42%, with a move to a 35% limit proposed for 2005 (Euro 4).

The USEPA and South Australia (since March 2001) have adopted air toxics models for regulation of emissions which allow some flexibility in setting limits on benzene and total aromatics. Australia is not targeting 42% aromatics until 2005 and even then this will be a pool average, with a cap set at 45%. There are no plans at present to move to the Euro 4 target of 35%.

Specification	Total aromatics
New Zealand	48% max by volume
Euro 3 (2000) Euro 4 (2005)	42% max by volume 35% max by volume
World-Wide Fuel Charter	40% max by volume reducing to 35% for Category 3+
Australia	45% pool average over 6 months with a cap of 48% (from 1st Jan 2002) 42% pool average over 6 months with a cap of 45% (from 1st Jan 2005)
Japan	Not specified
USA <sup>1</sup>	CaRFG2: 22% average by volume, cap 30%, flat 25% CaRFG3: 22% average by volume, cap 35%, flat 25%

1. Indicative limits only – actual limits are determined by complex formulae relating to overall VOC emissions and vary according to state.

### Why regulate?

The control of aromatics levels in petrol is the most direct way of limiting evaporative losses and exhaust emissions of these compounds, thereby reducing human exposure to them. Hence in recent years international standards have focused on progressively reducing allowable aromatics levels. Attention originally focused on benzene because of its carcinogenic properties and higher volatility.

As previously noted, sudden changes in aromatics levels can affect elastomers in engines and too low a level may also cause shrinkage in seals in older vehicles in the New Zealand fleet which have always operated on higher levels. It is noted that Japan, the major source of our vehicles, has no aromatics limit.

A lower limit for aromatics could be imposed immediately for regular grade petrol which would reflect actual levels and lock them in, without significantly affecting production. Regular grade accounts for around 75% of New Zealand's petrol consumption at present. However, it is not international practice to impose different limits for regular and premium grades.

The benefits of an early reduction in aromatics levels are less obvious than reductions in benzene. Unless the use of oxygenates such as MTBE are permitted, it will be extremely difficult to meet the octane requirements for petrol produced at Marsden Point if aromatics levels are restricted to less than 42%. At this stage it proposed to restrict the use of MTBE until the environmental case is established (see Section 7.11) so a less aggressive timetable for reduction of aromatics is proposed.

### Changes proposed to the Regulations

Current Regulations	Proposed changes
<b>Total Aromatic Compounds:</b> 48% maximum by volume (including benzene).	For regular grade: Immediate reduction to 40% maximum by volume  For premium grade: Stage 2 reduction to 42% maximum by volume

### Implications of proposed changes

The impact of any reduction in total aromatics cannot be assessed in isolation as it is very dependent on what changes are made to other specifications, including benzene, sulphur, oxygenates and olefins. These last two are alternative sources of octane.

A 42% limit on aromatics with the current configuration of the Marsden Point Refinery would impose restrictions on the feedstocks and blendstocks that can be used. A reduction to 35% is at the limit of what could be accommodated without major investment. Plant modifications to achieve reductions by 2006 would require major investment and would still be quite limiting in terms of requiring suitable blendstocks (ie. an additional operating cost).

## 7.10 Benzene

### What is it and why is it important?

Benzene is the simplest aromatic compound and the one that has received most attention due to its known carcinogenic properties. The benzene content is determined by the same test method used for total aromatics.

Vehicles emit benzene through evaporation from their fuel systems and through exhaust emissions. International practice in recent years has been to set lower limits on benzene in petrol in response to health and air quality concerns.

The benzene content does not directly affect engine performance, but like other aromatics, it is a good source of octane.

### Current New Zealand and International Specifications

Specification	Benzene
New Zealand	5% max by <b>weight</b> (approximately 4.2% by volume)
Euro 3 (2000)	1% max by volume
World-Wide Fuel Charter	2.5% max by volume reducing to 1% for Category 4.
Australia	1% max by volume in all grades from 1 Jan 2006  No earlier mandatory reduction is proposed as industry averages are already low as required by state regulations
Japan	1% max by volume since January 2000
USA <sup>1</sup>	Ca RFG2: 1% by volume (flat) Ca RFG3: 0.8% (flat)

1. Indicative limits only – actual limits are determined by complex formulae relating to overall VOC emissions and vary according to state.

Benzene levels in New Zealand petrol have risen slightly in the last 3 – 4 years and currently average (1998-1999) around 4% (by weight) for premium grade and 3.3 % for regular, still below the specified maximum of 5%. This value was set in the original specifications in 1988 and has remained unchanged since then.

The maximum allowable benzene concentration in the regulations is currently expressed as a percentage by weight rather than a percentage by volume which is out of step with most international specifications. The limit of 5% by mass is roughly equivalent to 4.2 % by volume.

As noted previously, some jurisdictions use air toxics models for setting limits on benzene in petrol.

### Why regulate?

Benzene levels have historically been regulated to control both evaporative emissions and exhaust emissions. Population exposure assessments indicate that current benzene levels in New Zealand's air would result in an annual exposure level which is commensurate with current, risk-based, guidelines (see Section 4.2). However, it is proposed to reduce the ambient air quality guidelines for benzene in 2010, hence reducing the additional lifetime cancer risk. The population exposure data indicate that most New Zealanders living and working in urban and suburban areas are currently exposed to higher levels than this criterion. Exposure levels are likely to increase even more with increased vehicle movements and congestion.

While for many other air contaminants, such as particulates, exposure comes from a number of different sources, for most people, motor vehicles are the primary route of exposure to benzene.

#### ■ Controlling evaporative losses

The evaporation of volatile components from petrol can be reduced by minimising the concentration of those components in the fuel and by minimising the exposure of the fuel to air. Reduction of benzene levels achieves the first objective; modern vehicle fuel systems design (including absorption traps on fuel tank breathers and fuel injection systems instead of carburettors) achieves the second.

■ **Vehicle exhaust emissions**

Benzene emissions in vehicle exhausts arise from benzene in unburned fuel, and from pyrolysis and partial combustion of heavier aromatics and possibly some other hydrocarbons, therefore reducing total aromatics also reduces benzene levels in exhaust from vehicles. 3-way catalytic converters are therefore the most effective way to reduce benzene in exhaust emissions. Other newer measures to further reduce hydrocarbon emissions, such as better control of the air-fuel ratio, improved catalysts and reducing the light-off time (how quickly the catalyst heats up and starts to operate effectively) will also reduce benzene concentrations in exhausts.

However, with the current fleet turnover and replacement trends it will be a number of years before this technology becomes dominant in the New Zealand fleet. The same applies to control technology for evaporative emissions from petrol. There are no plans at present to introduce vapour recovery for bulk transfer and distribution in New Zealand.

It is therefore proposed that benzene levels in petrol be managed downwards, and that New Zealand moves to align with the limits already adopted in Europe, Japan and the USA. Australia proposes a 1% limit by 2005 which would mean that from that time, imported product could be sourced and would not restrict supply.

**Changes proposed to the Regulations**

Current Regulations	Proposed changes
Benzene: 5% maximum by mass (equivalent to around 4.2% maximum by volume)	<p>Immediate change to specifying benzene content as % by volume; set at 4% maximum</p> <p>Stage 1 reduction to 3% maximum by volume</p> <p>Stage 2 reduction to 1% maximum by volume</p>

**Implications of proposed changes**

As for total aromatics, any reduction of benzene limits will require the octane to be made up from other sources. If the use of oxygenates or octane-enhancing additives is precluded, then the octane has to be made up with olefins, alkylates or isomerates. For the Marsden Point Refinery operation, some reduction in benzene levels can be achieved by appropriate selection of crudes and blendstocks. The alternative is adding further processing capability to convert benzene and other aromatics to other octane-boosting compounds.

As noted previously, significant quantities of imported blendstocks are already required to produce the current grades, and much of this is sourced from Australia. The high octane petrol currently being marketed by BP is sourced directly from Australia and contains 2% max by volume benzene.

A 3% limit could be achieved for New Zealand produced petrol by appropriate selection of feedstocks and blendstocks but this would impose significant costs on the Refinery as well as well as the users. Other constraints on the petrol specifications would make these costs higher. Fuel could be imported to meet the 3% limit, but it would depend on availability (such as timing of changes in Australia) and any change to the level of imports would also affect the Refinery operation.

A 1% limit for New Zealand produced petrol would require major capital investment with a significant lead time, so that implementation earlier than 2006 would be unlikely. Under current proposals, 1% benzene petrol should be available from all Australian producers by 2005.

The approach of using pool averages (as proposed for Australia) or an air toxics formula (USA, South Australia) can provide more flexibility for the refiners in achieving the targets. While such an approach focuses on controlling effects rather than absolute limits it is potentially difficult to administer in a small market like New Zealand and may lead to significant variations in petrol properties. A further discussion of pool averaging is given in Section 9.6.1. This type of model is not proposed at this stage.



## 7.11 Oxygenates

What are they?

Oxygenates are organic compounds containing carbon, oxygen and hydrogen. They can be added to petrol as a blending component and to increase octane. Their use in petrol effectively increases the available oxygen for combustion which has the effect of reducing CO formation and hydrocarbon emissions. The two main groups are alcohols (such as ethanol and methanol) and ethers (such as methyl tertiary-butyl ether (MTBE)). Blends containing up to 11% MTBE are common and for ethanol, 10% or higher.

Why are they important?

- **Driveability**

The use of oxygenates can induce a “lean shift” in the fuel/air stoichiometry thereby reducing CO in vehicle exhaust emissions (CO occurs when there is insufficient oxygen for complete combustion to CO<sub>2</sub>). This tends to benefit mostly older carburetted engines as modern electronic engine management systems monitor the oxygen content of the exhaust gases and adjust the air/fuel ratio accordingly.

Oxygenates in petrol can cause over-leaning depending on how the engine management system is calibrated, leading to drivability problems and increasing emissions of NO<sub>x</sub>. For MTBE, the effect is quite small – 15% MTBE results in a change in the stoichiometric air/fuel ratio of only 2%. Ethanol requires more heat to vaporise than ethers and this can also affect the drivability of petrol/ethanol mixtures.

- **Volatility**

Blending oxygenates into petrol can increase the vapour pressure of the fuel and significantly modify the volatility and distillation characteristics, resulting in increases in evaporative emissions. Methanol has the most dramatic impact – small amounts (in the order of 2%) can cause 35% increases in vapour pressure. Ethanol can also have significant effects on vapour pressure, whereas for MTBE, the effect is much smaller (around 5% max at 4–5% concentrations) and can drop to zero at higher concentrations.

- **Exhaust emissions**

PM emissions from petrol engines, while already low compared with diesel engines, can be reduced by up to 50% with the addition of oxygenates to petrol.

- **Octane enhancement**

Oxygenates are good sources of octane but also have high sensitivities (see Section 7.1) which can limit their application for octane enhancement. MTBE does not appear to deteriorate high speed octane performance, while methanol may do. Generally, the effects will vary with the base fuel and specific vehicles, however MTBE appears to be more effective in providing octane enhancement.

### Current New Zealand and International Specifications

Many new specifications allow oxygenates to be added but place a limit on the overall oxygen content of the final blend. A limit of 2.7% max by mass is common, which is equivalent to around 7.5% by volume ethanol and 15% by volume MTBE. A number of countries allow exemptions and/or place limits on specific types of alcohols and ethers.

The use of oxygenates was made mandatory by Federal law in the United States in 1990 on the grounds of its air quality benefits (primarily reduced CO emissions). Because of its lower volatility and cost, MTBE has generally been more attractive as an oxygenate than alcohols or other ethers, and its use increased significantly in the United States with the subsequent introduction of the reformulated gasoline (RFG) programme (see Section 5.3). It is also used widely in Europe and parts of Asia. However MTBE has a strong affinity for water and has been found at low levels in groundwater both in the USA and the United Kingdom. As a result, California has now banned the use of MTBE and other ethers in petrol from the end of 2002 and other states have followed. The issue is under close scrutiny in the United Kingdom as well.

Specification	Oxygenates	Oxygen
New Zealand	0.1% max by weight for any oxygenates but up to 11% by volume MTBE may be added. (This is equivalent to around 0.1% by volume ethanol).	Not specified
Euro 3 (2000)	Max allowable content determined by type (3% v/v methanol, 5% ethanol). Oxygenate boiling point must not exceed specified FBP of overall fuel. Ethers must contain 5 or more carbon atoms, up to 15% MTBE allowed.	2.7% max by mass.
World-Wide Fuel Charter		2.7% max by mass. Up to 10% ethanol subject to quality requirements. No methanol permitted.
Australia	All specified ethers - max. 1% (MTBE from 1 Jan 2004, others from 1 Jan 2002). Limit still to be set for ethanol.	2.7% max by mass from 1 Jan 2002 (ethanol exempt).
Japan	7% max by volume MTBE	Not specified
USA (California)	Certain exemptions – MTBE to be progressively phased out in response to environmental concerns.	2.7% max by mass.

Petrol sold in New Zealand does not generally contain MTBE at present, although the current specification allows it, by means of an exemption. The maximum oxygenate limit in New Zealand effectively precludes the use of alcohol blends or other ethers.

Low levels of MTBE may occur from time to time in imported fuel due to contamination from previous cargoes. MTBE and other oxygenates have an affinity for water and the New Zealand distribution infrastructure is generally not set up to allow water-free operation. Hence, the use of MTBE is avoided. Some of the major oil companies have also taken a position against the use of MTBE until the environmental case for its use is conclusively proven.

#### Why regulate?

Both environmental and consumer concerns suggest that the use of oxygenates needs to continue to be regulated. The particular issues relating to MTBE and ethanol are discussed separately below.

#### MTBE

##### ■ Environmental issues

The main route for environmental impact of MTBE is via leakage of petrol from storage tanks.

MTBE has a strong affinity for water (MTBE solubility in water is 4.3%, water in MTBE 1.4%). While levels found in groundwater in the United Kingdom and United States do not appear to pose a significant health risk as such, MTBE has a distinctive taste and smell and will taint water groundwater supplies, even at very low concentrations. Groundwater is an important resource in New Zealand and contamination of the resource from leaking storage tanks does occur. The main benefits of MTBE are the reduction of CO emissions and its use as a source of octane, thus allowing for reduction of the level of benzene and aromatics in petrol. A more detailed discussion of water quality issues is given in Section 4.3.

##### ■ Consumer issues

Like all oxygenates, the addition of MTBE can reduce the volumetric energy content of petrol, as the oxygen portion does not combust. This can have the effect increasing fuel consumption (litres per 100 km) slightly. As noted, the effect of MTBE on volatility of petrol blends is generally not significant.

## Ethanol

With the use of MTBE now being phased out in some parts of the United States because of concerns over groundwater contamination, the use of ethanol as an oxygenate is expected to increase.

Ethanol-blended petrol is sold in parts of Australia and its use has been reviewed as part of the preparation of the new environmental standards (EA, 2000c). At this stage, no standard for ethanol content in petrol has been agreed, but it is likely that at least 10% ethanol blends will be allowed (EA, 2001a,b). The Australian Government, in response to submissions from the domestic ethanol industry, is in the process of determining whether a higher volume of ethanol would be appropriate for their climate conditions and vehicle fleet.

### ■ Environmental issues

Ethanol is completely soluble in water and is not considered toxic. However, it can increase the solubility of other hydrocarbons in water and increase the mobility of hydrocarbon plumes from subsurface spills in the soil, so there are some environmental concerns.

Vehicles in the United States and Europe, where oxygenated fuels are widely used, are mandated to have advanced emissions control systems. New Zealand does not have a similar requirement, and many of our vehicles lack even basic emissions control devices. Due to these differences in vehicle technologies, it is difficult to predict with certainty the changes in tailpipe emissions that would result from using ethanol-blended petrol. There is general agreement that oxygenated fuels reduce CO emissions. However, results of studies examining the effects of ethanol-blended petrol on exhaust emissions of hydrocarbons, volatile organic compounds, and oxides of nitrogen have been mixed.

In terms of other air emissions, combustion of ethanol produces acetaldehyde, a toxic air contaminant, and peroxyacetyl nitrate, an eye irritant and cause of plant damage. Acetaldehyde is included on the Ministry for the Environment's proposed list of air contaminants. The amount of these pollutants that will be emitted from a vehicle burning ethanol-blended petrol will depend on the emissions control technologies incorporated into the vehicle.

A further area of concern in terms of air quality is evaporative emissions from the carburettor, fuel tank, or other part of the fuel system. Ethanol-blended petrol may lead to increases in evaporative emissions because rubber, plastics, and other materials in the fuel system are permeable to ethanol.

The mixing of ethanol-containing and ethanol-free petrol in vehicle fuel tanks may also increase evaporative emissions. The relationship between vapour pressure and ethanol content of a blend can be non-linear so that the mixture may have a higher vapour pressure than either product alone. Any use of ethanol should be subject to the fuel meeting all the volatility properties (distillation, RVP, FVI) for unoxxygenated fuel.

If ethanol is produced from biomass or as a by-product of the dairy industry (as it is in New Zealand) then there are clear benefits from the perspective of greenhouse gases.

### ■ Consumer issues

10% ethanol blends have been shown to perform well without any detrimental effects on vehicle performance. However it should be noted that much of the operating experience supporting this contention comes from the USA where all vehicles have been designed to run on oxygenated fuels since they were first mandated in 1990. The implications on driveability and materials performance need to be carefully considered if its use is to be permitted in New Zealand.

#### Driveability

Generally, in order to meet regulated vapour pressure limits, petrol blended with ethanol will contain less butane, which is itself volatile and has a high energy content. Like any oxygenated fuel, ethanol-blended petrol, because of its oxygen content, contains less total energy than unblended petrol. This means that the air-fuel mixture coming from the carburettor is "leaner" with ethanol-blended petrol than with petrol alone. For this reason, cold starting and cold weather driveability may be problematic for some cars in the New Zealand fleet.

Cold starting depends on vaporisation of the petrol, and more heat is required to vaporise blends containing ethanol. In addition, when ethanol-blended petrol is used, the vapour contains a greater concentration of alcohol than its concentration in the petrol. As a result of these factors, cold starting may be difficult.

The mixture of air and ethanol-blended petrol from the carburettor may be so lean that it causes "lean misfire"; that is, the mixture may be too lean to combust. Lean misfire causes one or more cylinders to pass unburned fuel into the exhaust system. Symptoms include a rough idle and hesitation or stumble on acceleration.

Mixing ethanol-blended petrol with regular petrol in a vehicle's fuel tank may also cause driveability problems. Older cars are more likely to have water in their fuel tanks, and this water may cause the alcohol in the blended fuel to

separate from the fuel and mix with the water. If this happens, layering may occur in the fuel tank; the petrol-rich upper layer may no longer have a sufficiently high octane number to operate the engine properly and the alcohol rich aqueous layer may cause rough running or complete stoppage of the vehicle.

#### Effects on Fuel System Materials

Ethanol in petrol can cause the elastomers in vehicle fuel systems, to swell and lose strength, leading to failures of critical components such as fuel pumps and hoses and the risk of fire. The result could be similar to the situation encountered with the introduction of unleaded petrol, when fuel system leaks were attributed to high aromatics levels in petrol.

There may also be problems for motorists switching between ethanol-blended petrol and regular petrol, as elastomers that swell with ethanol use would subsequently shrink with petrol, potentially causing fuel system leaks. This effect could be especially pronounced in vehicles that are more than 10 years old.

There may be other proprietary components in fuel systems that are also susceptible to damage from exposure to ethanol, particularly in non-automotive engines such as lawnmowers.

#### ■ Manufacture and Distribution of Ethanol-Blended Petrol

Because of the effect that ethanol has on petrol properties, particularly on vapour pressure, the preparation of blends must be carefully managed. Ideally, blending would take place at a facility that is capable of performing product quality tests and correcting any deficiencies in the fuel. Blending at ports or in tankers would be difficult logistically, as it would require special petrol blendstocks that are then mixed with ethanol to produce a blend that complies with all the regulated properties. The quality of ethanol used for blending is also critical and properties such as water content and acidity need to be specified.

As ethanol can separate out on contact with water, ethanol blends must be transported through a completely water-free system. Although international practice is moving away from the use of “wet” distribution systems, some of New Zealand’s fuel distribution infrastructure is not water-free. Ethanol blends would therefore not be able to be made at the Refinery and shipped throughout the country in tankers, as is the case for unoxxygenated petrol. In addition, older storage tanks at service stations may contain some water and would need testing and upgrading before they could be used with ethanol-blended petrol. However, Gull Petroleum’s distribution system, which is all relatively new, is dry and therefore suitable for ethanol blends.

While some smaller operators may be keen to pursue the use of ethanol-petrol blends in New Zealand if permitted in the future, operational requirements and cost implications suggest that their widespread adoption will not occur in the short term.

### Changes proposed to the Regulations

Given environmental concerns about contamination of groundwater in other jurisdictions, it is proposed that the use of MTBE and other ethers in petrol be banned until the environmental case is proven. This would be achieved by removing the exemption for MTBE from the oxygenates limit. This decision should be subject to review as more information becomes available, and may have an impact on the timetable and ultimate reduction of aromatics levels.

Given that MTBE is still in widespread use in some countries which are sources of imported petrol for New Zealand, maximum limits of 1.0% vol. for MTBE and 0.1% vol. for all other oxygenates would be included to allow for contamination from previous cargoes.

A significant amount of research into the use of ethanol blends was done in New Zealand back in the 1980s, but this was not progressed for various reasons, including difficulties in sourcing long-term supplies of ethanol. Interest has been expressed recently in the possibility of supplying ethanol-blended petrol to the New Zealand market. Given that the use of ethanol-blended petrol could assist New Zealand to meet climate change responsibilities to reduce greenhouse gas emissions, there is merit in providing for the possibility of petrol blended with up to 10% ethanol. However, there are significant risks associated with the use of ethanol-petrol blends as highlighted above, and these risks would need to be carefully managed.

One approach would be to allow the sale of ethanol-blended petrol for a limited amount of time on a test basis. A decision on the sale of ethanol-blended petrol on a permanent basis could then be based on the outcome of a New Zealand-based trial. There would need to be a clear framework for this testing and approvals process. A test period of 6 to 12 months would probably be needed. The test would need to demonstrate clearly that it had involved a large number and range of vehicles and that no adverse effects on engine performance had occurred. Consumers taking part in the test would need to be fully informed and to agree to their participation. It should be noted that such an approach may require an amendment to the legislation under which the Regulations are made.

These considerations form the basis for the proposed changes.

Current Regulations	Proposed changes
Oxygenates: 0.1% maximum by mass on total oxygenates, excluding MTBE.	<b>Immediate:</b> 0.1% maximum by mass applies to all petrol. Changes to ethanol and MTBE as below.
MTBE: Up to 11% by volume	<b>Immediate limit of 1% maximum by volume, applying to all petrol</b>
Ethanol: limited as per total oxygenates	<b>Immediate:</b> Allow addition of ethanol to petrol up to 10% by volume, subject to a testing and approval process.

The Regulations currently require only petrol sold by retail sale to meet the specified limit. It is proposed the restrictions on MTBE and other oxygenates (other than ethanol) apply to all petrol.

#### Implications of proposed changes

Limitations on oxygenates severely restricts the options and increases the costs for reducing benzene and aromatics levels in petrol. While the costs of ethanol are an issue for the market, not for this review, it is generally accepted that with the current tax regime, it is too expensive to use for blending in New Zealand. However, recent moves in Australia suggest that there may be more widespread adoption of ethanol blends there in the next few years.

Making provision for ethanol blends in New Zealand will allow these fuels to be tested on a commercial scale and enable consumers to make an informed choice regarding its use. Controls on the use of ethanol blends will need to include requirements that:

- All fuels containing ethanol be labelled at the pump;
- Blends meet all other specified properties of petrol, including limits on volatility;
- The quality of ethanol used for blending be subject to suitable controls; and
- Consumer information on ethanol blends be provided.

## Properties Currently Not Specified

The following properties for petrol are not currently included in the New Zealand specifications but have appeared in specifications elsewhere or are under discussion. Therefore their significance is discussed here.

### 7.12 Olefins

#### What are they?

Alkenes and cycloalkenes are referred to as olefins in the oil industry. They have double bonds (ie. are unsaturated) and are not normally present in crude oil, but are created during cracking and other refinery processing.

The olefin content of petrol will depend on source refinery configurations and feedstocks. Catalytically cracked petrols (such as produced in Australian refineries) tend to be higher in olefins.

#### Why are they important?

Olefins are often good octane components. However they are thermally unstable and this can lead to gum formation or deposits in engine intake systems. Very high levels of olefins could create problems similar to toluene – this could occur if maximum limits on benzene and total aromatics are reduced without regulating olefins at the same time.

Olefins are also formed during combustion of fuel. Their evaporation into the atmosphere has been established as contributing to ozone formation and their combustion products form toxic dienes such as 1,3-butadiene. Environmental concerns are the main basis for limiting their content in petrol, although some recent studies indicated that olefins may not be the only contributor to these emissions.

#### Current New Zealand and International Specifications

Environmental concerns have increased the focus on olefin content of petrol, and limits have been imposed or suggested in several jurisdictions as shown below. The current levels in New Zealand petrol are believed to be below 25%.

Specification	Max % by volume
Euro 3 (2000)	21%
World-Wide Fuel Charter	20% (Cat. 2), 10% (Cats. 3 & 4)
Australia (proposed)	18% pool average over 6 months with a cap of 20% (from 1 Jan 2004) 18% max. (from 1 Jan 2005)
Japan	Not regulated
USA	CaRFG2 & 3: 6% flat, or 4% average, 10% cap.

### Why regulate?

Ambient butadiene levels in New Zealand are low and are not considered to be a significant environmental concern at present. Therefore there is no clear justification for reducing levels from this perspective. The greater imperative is likely to be engine performance, particularly the need to control against petrol with a very high olefins content.

A maximum limit of 25% by volume is proposed immediately to limit olefins at current levels and control against excessively high olefin cargoes. Australia proposes to adopt an 18% max limit by 2005, though this has not yet been agreed. New Zealand could follow a similar timetable with a two-stage reduction to 21% initially (aligned with Euro 3) and ultimately to 18% allowing for alignment with Euro 4 and Australia. A proposed test method has been specified.

### New regulations proposed

Current Regulations	Proposed changes
Olefins: Not currently regulated	<p>Immediate limit of 25% maximum by volume, to apply to all petrol (Test method ASTM D 1319)</p> <p>Stage 1 reduction to 21% maximum by volume</p> <p>Stage 2 reduction to 18% maximum by volume</p>

As olefins have relatively high octane ratings, any reduction will necessitate replacement with some other more acceptable octane components so the implications of imposing limits on olefins content will be similar to those from aromatics limits.

The above timetable should not be constraining for the Marsden Point Refinery but it does remove one source of octane. A phased reduction as above would align with Australia so should not constrain imported fuel from there.

## 7.13 Manganese

### What is it?

The use of the organometallic compound methylcyclopentadienyl manganese tricarbonyl (MMT) as an octane booster in petrol is somewhat controversial. It has been used in Canadian petrol for a number of years but was later banned for a time (the ban has subsequently been lifted). The current New Zealand specification does not exclude its use.

### Why is it important?

MMT is added in low concentrations (typically 18 mg Mn/litre) to boost octane. Engine manufacturers are strongly against the use of metal-based fuel additives from the perspective of potential ash formation, and there is significant uncertainty and disagreement about its environmental and health impacts. Higher concentrations (>165 mg Mn/litre) can cause problems with fuel instability, deposit build up and can adversely affect catalyst performance, particularly for hydrocarbon oxidation.

### Current New Zealand and International Specifications

The use of MMT or compounds containing manganese in petrol is not currently regulated in New Zealand. It is understood that New Zealand petrol does not contain MMT at present.

The World-Wide Fuel Charter specifically bans the use of MMT. In the USA, although MMT is permitted for use in petrol, the EPA is requiring further study to determine whether or not manganese can have any cumulative effect on human health by building up in the bloodstream, and whether there is any need for future regulatory action. In Australia, it has been decided not to regulate at this stage pending the outcome of the USEPA process and assessment of the chemical hazards. MMT has also been the subject of much litigation in Canada. The European and Japanese specifications do not include any controls on manganese addition.

#### Why regulate?

The case against MMT from an environmental and health perspective is unclear. However there is a perception in some quarters that its use as an octane enhancer in place of lead or benzene would be merely substituting one hazardous substance for another. The Toxic Substances Board (now dissolved) previously reviewed its use under the Toxic Substances Act 1979 (see Section 4.5), and raised some concerns. However as it was not a scheduled poison, there was no requirement to obtain formal approval.

The major fuel suppliers in New Zealand do not currently use MMT in petrol because of the objections of the automotive industry. In the light of these objections and concerns from environmental regulators elsewhere, a precautionary approach is proposed with a limit on manganese content and a test method being included in the regulations immediately. If other sources of octane are to be further constrained (benzene, aromatics, olefins and oxygenates) suppliers may see MMT as one means of meeting octane requirements, and if the Regulations do not specifically address it, there will be no means of controlling its use.

#### New regulations proposed

Current Regulations	Proposed changes
Manganese: Not currently regulated	Immediate limit of 0.25 mg per litre maximum, to apply to all petrol (test method ASTM D 3831)

## 7.14 Phosphorous

### What is it and why is it important?

Phosphorous was used in the past as an additive in petrol to prevent pre-ignition and spark plug fouling when fuel contained high levels of lead. It is understood to be a component of Valvemaster, an after-market additive (one that is added after the fuel is sold) used for older vehicles which were designed to run on leaded petrol.

Phosphorous can degrade the performance of catalysts in catalytic converters.

### Current New Zealand and International Specifications

The European specifications and the World-Wide Fuel Charter prohibit the use of phosphorus containing compounds in petrol. The Australian review proposes a limit of 1.3 mg/litre from 1 Jan 2002. It is currently not covered by the New Zealand specifications.

#### Why regulate?

Given the concerns about effects on engines, some level of consumer protection is considered necessary. This should take the form of a maximum limit on phosphorous content and a suitable test method, in line with that agreed in Australia.

#### New regulations proposed

Current Regulations	Proposed changes
Phosphorus: Not currently regulated	Immediate limit of 0.20 mg per litre maximum, to apply to all petrol (test method ASTM D 3231)

## 7.15 Density

### What is it?

Density is a measure of a fuel's mass per unit volume. Density is a function of fuel composition, which is constrained by volatility parameters and aromatics content. Aromatics typically have densities of 880 kg/m<sup>3</sup>, C6+ naphthenes 780 kg/m<sup>3</sup> and paraffins 700 kg/m<sup>3</sup> or lower.

### Why is it important?

The requirement to narrow the density range of petrol is driven largely by the desire of the engine manufacturers to improve fuel economy and improve combustion through improved fuel management systems.

As fuel is sold by volume not mass, fuel injection systems meter fuel volumes and consumption is measured on a volumetric basis, so any significant reduction in density could effectively increase fuel consumption. Narrowing the limits will allow better control of fuel/air ratio in new engine designs.

### Current New Zealand and International Specifications

The World-Wide Fuel Charter and the European standard have both set density limits (minimum and maximum) on petrol. Japan has a maximum limit. There are no such proposals in Australia as yet.

The density range of petrol in New Zealand is typically 729 – 750 kg/m<sup>3</sup> for regular grade and 740 – 760 kg/m<sup>3</sup> for premium grade. The WWFC limits for Category 4 (the most stringent) are 715 – 770 kg/m<sup>3</sup>.

### Does it need to be regulated?

The benefits for the New Zealand fleet are not clear – the lack of density limits on petrol is not believed to be a barrier to new engine technology in the foreseeable future, nor does it directly affect emissions. Density is already constrained to some degree by other properties. It is generally considered that direct limits on petrol density would be an unnecessary constraint for refiners and not provide any significant benefit to users.

No change is proposed at this stage.



This section examines the main properties that specify quality for diesel. It follows the same format as the previous section for petrol.

Like petrol, there is a high degree of interdependence between certain properties and again, within a particular refinery, diesel specifications have flow-on effects for the production of other products.

Appendix C contains a description of how compression-ignition engines work and the diesel characteristics that are relevant to diesel engine performance.

## Properties Currently Specified

### 8.1 Density

What is it?

Density is a measure of a fuel's mass per unit volume. It is temperature dependent and for diesel fuel is normally referenced to 15°C. Diesel is made up of a mixture of many different hydrocarbon compounds of various densities and molecular weights, and thus the overall density is a function of the composition of the fuel. For this reason, density is strongly correlated with other fuel parameters, particularly cetane number, aromatics content, viscosity and the distillation characteristics (boiling range or volatility). Reducing the high end distillation temperatures (T85, refer Section 8.11) will reduce the maximum density by excluding the heaviest components.

Why is it important?

In diesel engines, fuel is injected directly into the combustion chamber using a volume based metering system (in most cases). The energy content of fuel is approximately proportional to the mass of fuel injected. Thus, for a constant volume injection system, variations in fuel density can result in variations in the energy content of the fuel injected. Consequently engine power, emissions and fuel consumption may be affected. In order to optimise the engine performance and exhaust emissions, fuel density must be controlled within a fairly narrow range.

Black smoke emissions from diesel engines occur primarily at full load operation. They normally arise when the mixture is over-rich or there is incomplete mixing of fuel and air. Limits on smoke emissions therefore limit the maximum power output of engines. Although there is some relationship between visible smoke and particulates, the optical and size characteristics, and number density of particles vary greatly, and hence the relationship between them is not well understood.

If the fuel being used is denser than the fuel for which the engine is calibrated, this may lead to generation of smoke through overfuelling. Conversely, lower density fuel should reduce the level of smoke, but will reduce power as well if the fuel injection system is not set up for that lower density. For a constant maximum power output (constant mass of fuel injected) volumetric fuel consumption will increase with lowering density and decrease with increasing density.

The volumetric quantity of fuel injected can also be used as a parameter in some advanced emission control systems such as exhaust gas re-circulation (EGR) so variations in fuel density may affect their efficiency.

## Current New Zealand and International Specifications

Specification	Density in kg/m <sup>3</sup> at 15°C	
	Min.	Max.
New Zealand	810	860
Euro 3 (2000)	820	845
World-Wide Fuel Charter	820	860 (Cat.1 ), 850 (Cat. 2), 840 (Cat. 3&4)
Australia	820	860 from 1 Jan 2002 850 from 1 Jan 2006
Japan	Not specified	

The density range for fuel from the Marsden Point Refinery over the year 2000 was 826 – 859 kg/m<sup>3</sup>. Data from Australia indicates a wider range (812 – 870 kg/m<sup>3</sup>) has been typical in the past.

### Why regulate?

Reductions in the upper limit have generally been for the purposes of limiting heavier aromatic components, thereby reducing emissions, principally particulates. However, this effect is also achieved to some extent by control of the high end of the distillation curve (see T85, Section 8.11).

A narrower density range gives reduced emissions due to better control of air/fuel ratio.

Alignment with other specifications is desirable, as far as is practicable. As 90% of New Zealand's diesel is produced at the Marsden Point Refinery, the Australian timetable for density changes is less directly relevant to New Zealand. However, reducing the upper density limit will have major cost and so some trade-off may be needed in terms of both level and timing.

The opportunity should be taken to adopt the standards units for density – kg/m<sup>3</sup> instead of the current kg/litre.

### Changes proposed to the Regulations

Current Regulations	Proposed changes
Density at 15°C: 810 kg/m <sup>3</sup> minimum; 860 kg/m <sup>3</sup> maximum	Immediate increase to 820 kg/m <sup>3</sup> minimum  Stage 1 reduction to 850 kg/m <sup>3</sup> maximum  Stage 2 reduction to 845 kg/m <sup>3</sup> maximum

### Implications of proposed changes

- Changing the density specifications will alter the composition of the fuel and thus will generally affect most other fuel properties important to diesel engine performance and emissions, such as cetane number, aromatics content, volatility, viscosity and others.
- Narrowing the allowable density range will limit the range of crudes which the Marsden Point Refinery is able to process. A lower maximum density will result in more fuel oil being produced as heavier components are excluded from the diesel. Current fuel oil production already exceeds the market, requiring surpluses to be exported.
- These changes will reduce diesel production and flexibility and therefore impose some cost.

## 8.2 Appearance and Colour

What are they?

Water and sediment in diesel fuel usually result from poor fuel handling and storage. The general appearance, colour and clarity are useful indicators of contamination. However, the small amount of water or solids required to give diesel a hazy appearance is usually insufficient to affect its performance.

The specifications currently include two visual tests:

- A check on appearance at a standard temperature of 15°C using test method ASTM D 4176(B);
- A comparison of colour against a standard chart using test method ASTM D 1500.

Why are they important?

Contamination with water and sediment can result in corrosion, blocking of filters, injection system wear and deposits in engines.

### Current New Zealand and International Specifications

Many international specifications include specific limits on water and sediment, rather than only specifying appearance and colour as per the New Zealand specification. Water and sediment limits are also currently included in the NZRC and Refinery Users specifications (0.05% max. water by volume, 0.01% max. sediment by weight).

Specification	Parameter	Test procedure	Specification
New Zealand	Appearance at 15°C Colour	ASTM D4176(B) ASTM D1500N	Clear and bright
Euro 3 (2000)	Water content Total contamination	prEN ISO 12937:1996 EN 12662	200 ppm max. 24 ppm max.
World-Wide Fuel Charter	Water content Particulates	prEN ISO 12937:1996 EN 12662	200 ppm max. 24 ppm max.
Australia (proposed) <sup>1</sup>	Water and sediment		0.05% max. (by weight) ~ 500 ppm
Japan	General requirement that fuel should not contain water or precipitates		

1. Likely to be included in future operability specifications

Why regulate?

If appearance is to be used as a quality standard, a reference temperature is necessary and a fixed reference (as opposed to ambient temperature) provides a consistent basis for quality checks. The current value of 15°C appears to be a good choice, reflecting an average ambient temperature for New Zealand. The current NZRC and Refinery User specifications already call for a lower test temperature (10°C).

The requirement to carry out the test at 15°C can cause difficulties with diesel from some Australian refineries where the fuel may appear hazy at this temperature but otherwise meets internal water and sediment specifications. Hence this reference temperature can be constraining on sources of imported supplies.

Appearance and colour are useful quick tests for fuel quality, so it is proposed to retain them. However it is also proposed that specific limits on water content and total contamination be added, in line with international specifications. These are discussed in more detail in Section 8.14.

### Changes proposed to the Regulations

Current Regulations	Proposed changes
Appearance at 15°C: Clear and bright	No change
Colour: (ASTM colour) 3.0 maximum	No change

## 8.3 Cetane Number and Cetane Index

What are they?

### Cetane Number

The Cetane Number (CN) of a fuel is a measure of its propensity for autoignition. In practical terms the CN has a strong influence on the length of time from the start of fuel injection to the start of combustion in a diesel engine. The higher the CN, the shorter this ignition delay period. The CN affects the ease of starting, the combustion generated noise and the exhaust emissions of diesel engines.

Cetane (n-hexadecane), which ignites very easily, has a CN of 100, and heptamethyl nonane has a CN of 15. The CN of a fuel is the proportion of cetane in a mix of the two that has equivalent ignition characteristics when tested in a specified test engine. The test method is standardised in ASTM D 613. There is no test engine in New Zealand and the test itself has poor reliability and repeatability.

The CN is related to the aromatic content of the fuel and in turn to the fuel density. As the aromatic content decreases, and thereby the density, the CN will generally increase.

### Cetane Index

Cetane Index (CI) is an estimation of the Cetane Number calculated from distillation data and density. As there are very few test engines in existence, CI is the more commonly used. The current specification requires this to be calculated using the method outlined in ASTM D 976, as follows:

$$CI = 454.74 - (1641.416 \times \rho) + (774.74 \times \rho^2) - 0.554 \times T50 + 97.803 \times (\log T50)^2$$

$\rho$  is the density in g/litre at 15°C

T50 is the mid-boiling point temperature in °C (the temperature at which 50% of the sample (by volume) has evaporated).

The relationship between CI and CN varies depending on the refining techniques and consequent composition of the fuel. Generally the difference between the two measures will be in the range  $\pm 2$ .

Cetane improving additives can be used to increase the CN by aiding the self-ignition of the fuel. They do not change the parameters on which the CI is based, so cetane improvers do not change the calculated CI.

### Why are they important?

A higher CN reduces ignition delay and results in smoother combustion and lower combustion noise. It also improves the cold starting of diesel engines. An increase in CN produces a decrease in NO<sub>x</sub> emissions due to lower gas temperatures and pressures in the combustion chamber. Reductions in CO and hydrocarbon emissions have also been reported. These benefits are less marked in new engine designs. However benefits are not generally achieved above a CN of about 50.

If anything, fuel consumption will tend to increase slightly with an increase in CN. Lower CN fuels will contain more higher aromatics and heavier hydrocarbons and have a higher density, giving a lower volume of fuel for the same amount of energy.

Although there are uncertainties in the correlation between CN and CI, an increase in CN will cause a increase in CI.

### Current New Zealand and International Specifications

Specification	Cetane Number (min.)	Cetane Index (min.)
New Zealand	45	47
Euro 3 (2000)	51	46
World-Wide Fuel Charter	48 (Cat. 1) – 55 (Cat. 3 & 4)	45 (Cat.1) – 52 (Cat. 3 & 4)
Australia	Not specified	46 from 1 Jan 2002
Japan	Not specified	Special No. 1 and No.1 – 50, No.2 – 45
USA	40	

Currently the CI for diesel from the Marsden Point Refinery averages 52 – 53 and as cetane improvers are not generally used, this is equivalent to a CN of 50 – 51. This is comparatively high by world standards.

The general trend in international specifications is for small increases in CN to improve engine performance and emissions, however the future specifications in Europe and the USA are not significantly higher than current New Zealand values.

#### Why regulate?

##### ■ Why specify Cetane Number?

At present there is no CN test engine in New Zealand and only one in Australia so CN cannot easily be measured directly, but only inferred from the calculated CI. The ASTM D 613 test for CN is quite involved and relies heavily on the skill of the operator to obtain consistent results. Repeatability is poor. For these reasons, the current Australian proposal is to have no specification for CN at all and rely only on CI.

However, as CN is the parameter that directly reflects performance of diesel fuel in an engine, rather than CI, it seems logical that this should continue to be the main parameter specified, though the difficulty of measuring it necessitates the continued use of CI as a proxy. Development work is currently underway overseas to provide an easier and more reliable test for CN but it may take some years before such a method is available and accepted as an oil industry standard.

A progressive increase from the specified minimum CN of 45 to a minimum of 51 to align with European specifications would ensure that performance and environmental benefits of the present high CN diesel available in New Zealand are locked in.

##### ■ Cetane Number vs. Cetane Index

The relationship between CI and CN depends on refining methods and feedstocks. Generally most New Zealand diesel is a mixture of straight run and hydrocracked distillates. It is noted that whereas in most other specifications CN is generally a few points higher than CI, the current New Zealand requirement is the reverse.

The relative values of CN and CI in the current specifications were originally set in 1988 based on the relativity observed at that time. Work carried out by the Ministry of Commerce in 1998 (MOC, 1999) measured the CN of over 80 samples collected throughout New Zealand and looked at the relationship between CN and CI. Typical New Zealand diesel sampled had a value of CI typically 1.5 to 2 points higher than CN, but the difference was quite variable; the average CI was around 53.2.

The study calculated CI using both the 2-parameter correlation (ASTM D 976) and a newer 4-parameter correlation (ASTM D4737). It was concluded that for diesel available in New Zealand, ASTM D 976 provided a better correlation with CN and so should be retained.

The specifications currently require a minimum CN of 45 or a minimum CI of 47, so the diesel only has to meet whichever condition is less onerous. As noted above, the actual CN and CI levels for New Zealand diesel are already much higher.

Setting an appropriate CI for diesel from the Refinery to meet the suggested targets for CN may be unobtainable for imported diesel where the CI could be lower than the CN. If the appropriate level and means of determining the CI required is left to fuel suppliers, there still needs to be a level set in the specifications for the purpose of fuel quality monitoring. The specified CI also needs to reflect whether CN improver additives are used.

It is proposed that diesel be required to meet both a minimum CN and a minimum CI value and that the present CI remain unchanged. Having both specifications will ensure that both the CN target is met and will limit the amount of cetane improver that can be used. The change is a balance between preserving the high CN diesel currently available in New Zealand and allowing flexibility in sourcing imported diesel.

#### Changes proposed to the Regulations

Current Regulations	Proposed changes
Cetane Number: 45 minimum or Cetane Index: 47 minimum	Immediate requirement to meet both cetane number and cetane index minima; increase cetane number to 49 minimum  Stage 1 increase cetane number to 51 minimum.

### Implications of proposed changes

The Marsden Point Refinery has a large hydrocracker so meeting higher Cetane Number targets is not expected to be a significant constraint.

Cetane improvers may be required to be added to imported diesel to achieve the proposed CN targets. Some allowance may be required in the carbon residue specification to cater for this (see Section 8.10).

## 8.4 Cold Flow Properties

### What are they?

Diesel fuel can have a high content of paraffins which will start to form wax crystals as the fuel is cooled. This can lead to blockages of fuel filters and interruption to fuel supply under cold conditions. Cold flow performance is a key requirement for diesel fuels.

### Cloud Point

Cloud Point is the temperature at which wax crystals start to precipitate out and the fuel becomes cloudy. Cloud point is determined according to the test method specified in ASTM D 2500.

### Cold Filter Plugging Point

Cold Filter Plugging Point (CFPP) is the lowest temperature at which the fuel can pass through a standard test filter under standard conditions. CFPP is more precise and is a better indication of fuel performance in an engine. The test method is specified in IP 309.

Cold flow properties depend on the proportion of waxy components in the diesel (controlled by the selection of crude oils and the refining and blending processes). Cold flow improving additives lower the cold filter plugging point by changing the size and shape of the wax crystals that form at cold temperatures. However, these additives generally do not change the cloud point.

### Why are they important?

Inadequate cold flow performance will result in high viscosity at low temperatures, leading to difficulties with starting and blockage of fuel filters.

### Current New Zealand and International Specifications

As cold flow properties are related to climatic conditions, a direct comparison with specifications in other countries is not particularly useful. Most international specifications include a range of grades corresponding to different ambient temperature ranges and or geographical regions. Current New Zealand specifications are:

Property	Summer (1 Sept to end-Feb)	Winter (1 March to 31 August)
Cloud point °C	4 max.	-6 max.
Cloud point or CFPP °C		-6 max.

The current specifications apply at the **time of manufacture** in New Zealand or, for imported fuel, at the **time of discharge** into port storage. Diesel for marine use may be summer grade at any time of the year.

The NZRC and Refinery User Company specifications in New Zealand are much more specific and have been developed over years of experience to suit the local conditions. There are four geographical areas as well as seasonal groupings within each. Both CFPP and Cloud Point are specified and the assigned values in some cases are lower than the regulatory specifications (3°C to -15°C). Generally this is believed to provide a satisfactory level of cold weather performance to New Zealand consumers.

For fuels without cold flow improvers, CFPP is normally 1 or 2°C below the Cloud Point. For New Zealand diesel the difference can be much more variable, with CFPP up to 10-15° lower than Cloud Point.

### Why regulate?

- The Cloud Point test is quite adequate for the fairly mild New Zealand climate. It is a relatively simple test and typically underestimates the low temperature performance of the fuel, particularly when low temperature performance additives are used. The CFPP test is a more realistic laboratory test procedure which closely correlates with vehicle operability tests. It is relevant for fuels both with and without cold performance additives.

- Both parameters are useful complementary measures and should be retained. However the current specification levels do not adequately cover the range of conditions encountered in New Zealand; a  $-6^{\circ}\text{C}$  cloud point or CFPP which meets the specifications would provide inadequate protection for Southland winter conditions.
- Ensuring adequate cold flow properties for a given season and location is primarily the suppliers responsibility and there needs to be sufficient flexibility to allow for variations from year to year, both in temperature and timing of specification changes. This specification is currently regulated at the time of manufacture or, for imported diesel, the date of discharge at New Zealand ports. This is due to the difficulty of ensuring product specifications at the pump during change over dates.
- Given the annual seasonal variations, it may be difficult to actually regulate for all circumstances without being too constraining. The consumer is already protected to some degree by the requirement to provide a fuel that is fit for purpose at the point of delivery, and this provision is being strengthened in the regulations (refer Section 9.2). Industry seasonal and geographical self-regulation appears to have generally worked well in the past.
- However, the current specifications need to be updated to reflect reality, and on balance, it is considered that a degree of regulation needs to be maintained. It is therefore proposed that changes to the regulations incorporate aspects of the industry standards. In particular, the maximum CFPP for the lower North Island and all of the South Island will be changed from  $-6^{\circ}\text{C}$  to  $-9^{\circ}\text{C}$ , providing a higher degree of cold weather protection for residents of those areas.
- It is also proposed that Cloud Point and CFPP should apply at the point of retail sale, as do all the other specifications. These properties are essential for consumer protection, and the regulations should ensure that consumers are supplied with appropriate fuel at all times during the year. To help facilitate the change between summer and winter seasons, spring and autumn periods are proposed, as outlined in the table.
- The current test method for Cloud Point is ASTM D 2500. An alternative test method, ASTM D 5773 uses an automated instrument with a constant cooling rate and so is more accurate, reliable and reproducible.
- The recent problems with plugging of diesel filters may be related to the effect of a particular additive on the ability of the fuel to be filtered at low temperatures. This problem was not detected by the normal cold flow tests (neither the regulatory requirements nor the stricter industry ones). It is therefore proposed that to ensure adequate filterability, a filter blocking test be added to the specifications (see Filter Blocking Tendency, Section 8.16).

#### Changes proposed to the Regulations

Current Regulations	Proposed changes
Summer: Cloud Point: $4^{\circ}\text{C}$ maximum	<b>Immediate:</b> Change to seasonal and geographical limits (see table)
Winter: Cloud Point: $-6^{\circ}\text{C}$ maximum	Change Cloud Point test to ASTM D 5773
or Cold Filter Plugging Point: $-6^{\circ}\text{C}$ maximum	Introduce a new filterability test (IP387).

#### Proposed Seasonal and Geographical Limits

Upper North Island		
Summer	1 October – 31 March	Cloud Point maximum $4^{\circ}\text{C}$
Rest of Year	1 April – 30 September	Cloud Point maximum $-1^{\circ}\text{C}$ Cold Filter Plugging Point maximum $-6^{\circ}\text{C}$
Lower North Island and all of South Island		
Summer	1 October – 31 March	Cloud Point maximum $4^{\circ}\text{C}$
Autumn	1 April – 30 May	Cloud Point maximum $-1^{\circ}\text{C}$ Cold Filter Plugging Point maximum $-6^{\circ}\text{C}$
Winter	1 June – 31 August	Cloud Point maximum $-1^{\circ}\text{C}$ Cold Filter Plugging Point maximum $-9^{\circ}\text{C}$
Spring	1 September – 30 September	Cloud Point maximum $-1^{\circ}\text{C}$ Cold Filter Plugging Point maximum $-6^{\circ}\text{C}$

## 8.5 Viscosity

### What is it?

Viscosity is a measure of a fuel's resistance to flow. It affects the performance of diesel fuel pumps and injection systems. Viscosity is dependent on fuel composition and so is reflected in the distillation parameters, density and cold flow properties.

The current test method, ASTM D 445, measures the kinematic viscosity at 40°C in centistokes (cSt – equivalent to mm<sup>2</sup>/s).

### Why is it important?

High viscosity can reduce fuel flow rates, resulting in insufficient fuel flow. A very high viscosity may cause fuel pump distortion.

Low viscosity will increase leakage from the pumping elements within the pump, and this can also result in insufficient fuel delivery and hot starting difficulties. Wear may also increase with low viscosity as lubricity tends to decrease with viscosity. As the viscosity of a fluid is temperature dependent, it is necessary to minimise the allowable range in order to optimise engine performance.

The viscosity range needs to be maintained with a reasonable range to ensure that the spray pattern generated by the fuel injectors is well controlled.

### Current New Zealand and International Specifications

Specification	Kinematic viscosity at 40°C in mm <sup>2</sup> /s	
	Min.	Max.
New Zealand	1.5	5.0
Euro 3 (2000)	2.00	4.50
World-Wide Fuel Charter	2.00	4 – 4.5
Australia (from 1 Jan 2002)	2.00	4.50
Japan	1.7 – 2.5 <sup>1</sup>	Not specified
USA	1.9	4.1

1. Minimum value dependent on grade which is climate dependent

The current NZRC and User Company specification limits are 1.9 – 4.5 mm<sup>2</sup>/s.

### Why regulate?

Some degree of regulation probably needs to be retained for consumer protection, though viscosity is very dependent on other parameters.

Units should be standardised on mm<sup>2</sup>/s rather than cSt, although the numerical value is equivalent.

Alignment with European specifications (min. 2.0 mm<sup>2</sup>/s, max. 4.5 mm<sup>2</sup>/s) would give a tighter range for better engine performance. Australia will introduce these limits from January 2002.

### Changes proposed to the Regulations

Current Regulations	Proposed changes
Viscosity at 40°C: 1.5 mm <sup>2</sup> /s minimum; 5.0 mm <sup>2</sup> /s maximum	Immediate reduction to 4.5 mm <sup>2</sup> /s maximum Stage 1 increase to 2.0 mm <sup>2</sup> /s minimum

A tighter range of viscosity would improve engine performance, and the Stage 1 proposal will align with European and Australian specifications. The proposed ranges are not particularly constraining as diesel available in New Zealand currently achieves the proposed immediate reduction.



## 8.6 Flash Point

### What is it and why is it important?

The flash point is the lowest temperature at which the vapour above a liquid will ignite when exposed to a flame (or other ignition source with sufficient energy). It is a measure of both volatility and flammability. Flash point is important primarily from the standpoint of safe handling and storage of fuel. It is used to classify flammable liquids and therefore affects the design of equipment and the control of potential ignition sources.

Flash point is a reflection of the volatility of the diesel and is therefore set by distillation parameters. It does not affect engine performance directly.

### Current New Zealand and International Specifications

The current New Zealand specification is 61°C minimum. At this level, diesel is not classed as a flammable liquid for the purposes of classification under the New Zealand Dangerous Goods Regulations nor is it classified as Dangerous Goods for transport by land or sea. Under the new HSNO (Hazardous Substance and New Organisms) Regulations it will be classified as Group 3.1D (Flammable Liquids – Low Hazard).

Both the World-Wide Fuel Charter and the European specifications require a minimum flash point of 55°C. Japan specifies a minimum of 45 or 50°C, dependent on the grade (which in turn depends on climatic conditions). The Australian limit is 61.5°C.

### Why regulate?

The current minimum specified flash point is consistent with its classification and controls under the existing Dangerous Goods Regulations (still operative under the HSNO transitional provisions) and the new HSNO requirements. It should therefore be retained at its current value.

As flash point is such an important parameter for safe storage and handling, and given that diesel is so widely used, the requirement for diesel to meet the flash point specification should be a blanket one applying to all fuel supplied, not just fuel for retail sale. This is not a current requirement in the New Zealand specifications and appears to be an anomaly.

### Changes proposed to the Regulations

Current Regulations	Proposed changes
Flash Point: 61°C minimum applies to fuel sold by retail	Immediate: 61°C minimum applies to all diesel fuel

The Regulations currently require only diesel sold by retail sale to meet the specified limit. The proposed change will ensure all diesel fuel conforms to this requirement.

## 8.7 Sulphur

Sulphur occurs naturally in crude oils and must be removed to an acceptable level during the refining process. Sulphur in diesel fuel contributes to formation of particulate matter (PM) in engine exhaust and affects the performance of vehicle emissions control equipment. It therefore has an indirect effect on emissions of CO, hydrocarbons and NOx.

Diesel fuel containing 500 ppm is generally referred to as Low Sulphur Diesel (LSD). Fuel containing 50 ppm sulphur or lower is referred to as Ultra Low Sulphur Diesel (ULSD). “Sulphur-free” diesel generally refers to levels below 10 ppm.

Lower sulphur levels in diesel can be achieved by using a combination of lower sulphur feedstocks and sulphur removal. Hydrodesulphurisation of diesel uses hydrogen to release the sulphur from the feed and form H<sub>2</sub>S which is removed and treated to recover the sulphur. A similar process occurs in hydrocracking.

The test method currently specified in the Regulations for sulphur in diesel is IP 242.

### Why is it important?

Sulphur in diesel contributes to the formation of particulate matter (PM) in engine exhaust. The impact of sulphur on particulate emissions is complex, but generally well understood. Sulphur has no direct effect on the other regulated emission species. A small proportion of the sulphur in the fuel is oxidised to sulphates that contribute to the particulate matter emitted from diesel exhaust. The sulphates absorb water that adds to the mass of particulate matter and also increase the retention of organic compounds in the particulate matter.

As PM emissions are linked to health problems, in particular respiratory conditions, their reduction is a primary driver to reduce high (>500 ppm) sulphur levels in diesel fuel. Studies show that reductions of sulphur content from 3000 ppm to 500 ppm would reduce PM emissions by 10 – 15% directly. Further reductions in sulphur would produce minimal incremental direct benefit. As PM is made up of a variety of compounds other than sulphur, reducing sulphur to zero would not reduce PM to zero.

However, sulphur also affects the performance of existing diesel engine exhaust after-treatment oxidation catalysts, and inhibits emerging diesel exhaust gas treatment technology such as NOx absorbers and particulate filters. Oxidation catalysts used to reduce CO and hydrocarbons, and the catalyst used in particulate trap technology are very efficient at converting SO<sub>2</sub> into sulphates. Current European technology light duty vehicles are often fitted with oxidation catalysts and operation of these on current New Zealand high sulphur diesel can lead to greatly increased PM emissions above the level which these same vehicles would operate without a catalyst. The sulphur can also either impair or totally block catalyst performance.

#### Current New Zealand and International Specifications

Specification	Maximum allowable level
New Zealand	3000 ppm (but no limits on fuel for marine use)
Euro 3 (2000) Euro 4 (2005)	350 ppm 50 ppm 10 ppm to be available from 2005 onwards, and required in all diesel by 2011 (proposed)
World-Wide Fuel Charter	5000 ppm (Cat. 1), 300 ppm (Cat. 2 & 3) 5 – 10 ppm (Cat. 4)
Australia	500 ppm from 31 Dec 2002 50 ppm from 1 Jan 2006
Japan	500 ppm 50 ppm from end 2004 (proposed)
USA	500 ppm for on-road diesel (except California – all diesel) 15 ppm from 2006

90% of New Zealand's diesel is produced at the Marsden Point Refinery. The same grade of diesel is used for both automotive and marine fuel. However this has only been the case since 1998 and was implemented primarily for logistics and distribution reasons. For diesel tested in New Zealand in 1998/99 the average sulphur level was around 2000 ppm with a range of 1100 – 2700 ppm.

In the United Kingdom and some other EC countries, government incentives for cleaner fuels have led to ULSD becoming available well ahead of the Euro 4 timetable. 10 ppm diesel (City Diesel) has been available in Sweden for a number of years. It is understood that Germany now intends to move to 10 ppm diesel by 2008. The introduction of sulphur-free diesel throughout Europe has been the subject of recent European Commission proposals (refer Section 5.3.3).

In Australia, where new sulphur targets have now been finalised, one of the major suppliers is looking to use a combustion improver to provide a reduction in PM formation equivalent to that achieved through sulphur reduction. This is an alternative to direct sulphur reduction, being proposed as an interim measure to meet the Australian timetable for fuel quality changes. A protocol for assessing the performance of such additives, as a basis for possible approval, has been agreed with Environment Australia (EA, 2000d).

#### Why regulate?

##### ■ Health and Environment

From a health perspective, particles smaller than 10 microns diameter (PM<sub>10</sub>) are of greatest concern as they can enter the lungs. Attention is also being focussed on particulates smaller than 2.5 microns (PM<sub>2.5</sub>). Studies show that PM<sub>10</sub> levels in Christchurch are associated with increases in daily mortality. While diesel engine emissions are not the only source of particulates in our urban air, studies in both Auckland and Christchurch show that they can be a significant contributor.

A direct reduction of PM emissions from existing vehicles can be achieved by reducing sulphur levels to around 500 ppm. Diesel oxidation catalysts which remove CO and hydrocarbons also typically require a maximum level of 500 ppm sulphur to work effectively.

Further reductions in sulphur levels below 500 ppm will contribute only a small amount to reducing PM emissions directly, but will permit the use of new and emerging emissions control technology (such as 2-way and de-NO<sub>x</sub> catalysts, continuously regenerating particulate traps and on-board diagnostics) to further reduce PM and other emissions.

Regulators in Europe and the USA are moving to specify ULSD (50 ppm or less) in order to enable the adoption of this technology to meet future emissions regulations. ULSD is becoming more widely available in Europe with refineries moving to meet Euro 4 levels (2005) well ahead of the target, in response to incentives. It is inevitable that within the next 5 – 10 years, vehicle technology will demand levels of sulphur in diesel of 50 ppm or lower and that ULSD will become commonplace.

Ultimately these fuels will have to become widely available on the New Zealand market within this timeframe, so we have to identify strategies for achieving this. As the main producer of diesel used in New Zealand, it seems logical that the Marsden Point Refinery acquires the capacity for meeting this need.

#### ■ Consumer protection

Current levels of sulphur affect the performance of emissions control equipment in new light diesels now coming into the market in Europe, such as some of the newer model Peugeot diesels for example, and are likely to prevent these vehicles being imported into New Zealand until LSD is available nationwide.

Removal of sulphur from diesel reduces its natural lubricity which can cause increased wear in fuel pumps and other engine components. This problem was first identified when ULSD was first introduced in Sweden, but minimum lubricity levels can be achieved through the use of suitable additives. Lubricity tests are now commonly being included in many diesel specifications elsewhere and a similar test is proposed for New Zealand (refer Section 8.15).

LSD may also have a lower electrical conductivity – insufficient conductivity can lead to a build-up of static charge during transfer (filling bulk storage tanks, road tankers and vehicle fuel tanks). This can be corrected through the use of additives and is primarily an operating requirement for industry, so it is not proposed to regulate at this time (refer Section 8.17).

Sulphur reduction may also assist in allowing an increase in engine oil change cycles by reducing the sulphuric acid loading in oil. However, engine design is also a significant factor in lengthening oil change intervals by giving cleaner combustion and lower soot loading of oil.

Hydrodesulphurisation can increase paraffinic content of diesel by saturating olefinic compounds, and this would tend to increase the CN a little, which is an additional benefit.

The current test method for sulphur is not sensitive enough for low sulphur levels – a new method, ASTM D 5453 is proposed. This would be the same as that proposed for sulphur in petrol (see Section 7.6).

#### ■ Timing for sulphur reduction

Low sulphur diesel is already available in New Zealand on a limited basis. BP's LSD which contains around 500 ppm maximum sulphur was introduced in Christchurch in December 2000. This product is currently produced at the Marsden Point Refinery. However the refinery's diesel HDS capacity is limited and it is unable to provide the total New Zealand diesel market with LSD using the current balance of crude feedstocks.

There is increasing public pressure for the immediate reduction of sulphur levels in diesel on a wider basis. The available options are being assessed, along with the implications, of adopting either a national specification or regional limits where vehicle emissions are a major contributor to poor local air quality. Immediate changes are therefore still under consideration.

In the medium term, a 2-stage reduction is proposed. Reduction to 500 ppm will directly reduce particulate emissions. Further reductions (to 50 ppm or less) will be needed to allow the use of new emissions-control technology for diesel vehicles. This technology is very sensitive to sulphur, and sulphur levels lower than 50 ppm are likely to be required for these vehicles.

## Changes proposed to the Regulations

Current Regulations	Proposed changes
Sulphur: 3000 ppm maximum (mg/kg) (Diesel for marine use is exempted from this Regulation)	<p>Immediate – reduction under consideration. Change test method to ASTM D 5453</p> <p>Stage 1 reduction to 500 ppm maximum</p> <p>Stage 2 reduction to 50 ppm maximum</p> <p>Signal ultimate requirement for sulphur free diesel (&lt;10 ppm)</p>

### Implications of proposed changes

- The timetable proposed recognises that refineries in the Asia-Pacific region are not all able to meet lower sulphur requirements.
- For the Marsden Point Refinery, meeting even Stage 1 specifications will require additional sulphur-removal capacity, at significant cost. While it may be possible to largely achieve some reductions through selection of lower sulphur (sweeter) feedstocks, this would have a significant impact in terms of higher feedstock costs, and the sweeter crudes required would produce lower cetane number diesel and higher benzene petrol streams.
- Supplying a much larger part of the New Zealand market with imported LSD is a possible option, but this product commands a premium and would also result in less than optimal use of the Marsden Point's capacity, potentially affecting its viability.
- The Refinery also needs to plan for Stage 2 and beyond, while ensuring that investment to meet short-term goals is not wasted. Estimates based on overseas figures indicate that additional hydrodesulphurisation plant to meet 50 ppm sulphur or lower could cost in the order of NZ\$120-150 million. There are long lead times for processing equipment and refinery shutdowns need to be programmed to allow major construction works. Production of the necessary hydrogen for new or expanded hydrodesulphurisation capacity is itself an energy intensive process with greenhouse gas implications.
- Any reduction in sulphur which results in increased cost to the consumer will also penalise non-vehicle users, who comprise a significant share of the market, unless there is some segregation of product. However segregation between road and non-road users (except possibly marine) is unlikely to be workable in the small New Zealand market.
- It is proposed to retain the current exemption for marine diesel but future limits may be considered in line with European Commission directives and International Maritime Organisation (IMO) initiatives. The EC currently imposes a maximum limit of 2000 ppm on diesel for marine use in EC waters. IMO proposals mainly relate to the much higher levels of sulphur in fuels oils and controls on marine engine design to achieve emission targets for NOx. In recent years, none of the suppliers in New Zealand has marketed a separate marine grade, so all diesel supplied is automotive grade and meets the sulphur limit specified. Given that the primary driver for sulphur reduction is urban air quality, there may in the future be advantages to once again supplying a higher sulphur marine diesel.

## 8.8 Copper Strip Corrosion

### What is it?

As for petrol, this test is a measure of the corrosivity of the fuel to metals. Corrosion can affect metallic components in vehicle fuel systems, dispenser pumps and fuel storage systems. The same test procedure, ASTM D 130, is used.

### Current New Zealand and International Specifications

The New Zealand specification calls for the test to be performed for 3 hours at 100°C (vs. 2 hours for petrol). A common test limit for petrol and diesel has been adopted in the European specifications using a lower temperature test (50°C) for 3 hours.

The neutralisation or acid number is a further measure of the fuel's acidity and ability to cause corrosion and is used in some international specifications. A test for this is currently included in the NZRC and Refinery Users specifications.

### Why regulate?

As for petrol, some measure of corrosivity needs to be retained to provide protection for fuel tanks, dispenser pumps and vehicle engine components.

Reducing the current test from 100°C to 50°C would reduce its severity, and in theory at least, the level of corrosion protection provided. Whether there is good reason to have different test conditions for petrol and diesel is questionable, unless the corrosion risk is clearly different, either due to the nature of the fuel itself or the materials it comes into contact with. Like the corrosivity test for petrol, testing at the lower temperature would be safer to carry out and align with international practice. On balance a standardised test (3 hours at 50°C) would be beneficial. No change to the test method or the required corrosion test standard is proposed.

**Changes proposed to the Regulations**

Current Regulations	Proposed changes
Copper strip corrosion test: 100°C for 3 hours, then compare with a reference sample	Immediate: Copper strip corrosion test: 50°C for 3 hours, then compare with a reference sample

## 8.9 Ash

**What is it and why is it important?**

Ash refers to the small amounts of non-combustible ash forming compounds such as suspended solids and soluble organometallic compounds which occur in crude oil and petroleum products.

Depending on size, these compounds can contribute to fuel system wear and filter and injector nozzle plugging. The metals can cause corrosion of certain high temperature alloys such as found on diesel engine valves, and lead to increased deposit levels.

**Current New Zealand and International Specifications**

The current specification is 0.01% ash by mass maximum, which is consistent with European specifications.

**Why regulate?**

For any characteristic of fuel which may affect engine performance and condition in the long term rather than one that is immediately traceable to a fuel quality problem or particular fuel source, some level of consumer protection needs to be retained. No change is proposed.

**Changes proposed to the Regulations**

Current Regulations	Proposed changes
Ash: 0.01% maximum by mass	No change

## 8.10 Carbon Residue

**What is it?**

This property is a measure of the tendency of diesel to form carbonaceous deposits in engines, which can result in hot spots leading to stress, corrosion or cracking of components. The deposits of most concern are those which build up in the nozzles of fuel injectors. The amount of carbon in fuel can be correlated with a tendency to form deposits, hence the use of a Carbon Residue test. The test is performed on the residual volume after 90% of the fuel has been boiled off (10% residual).

Methods in common use include:

- Ramsbottom IP 14/94 (ASTM D 524-94) (currently specified in the Regulations)
- Conradson IP 13/94 (ASTM D 159-95)
- Micro method MCRT IP 389 (ASTM D 4530) – equivalent to the Conradson method.

Detergents and deposit control additives are used to prevent deposit formation in fuel system components. Some may also be capable of removing existing deposits in the engine combustion chamber.

## Current New Zealand and International Specifications

Specification	Test method	Limit
New Zealand	Ramsbottom	0.20 % mass max.
Euro 3 (2000)	EN ISO 10370 / IP 398 (micro methods)	0.30 % mass max.
World-Wide Fuel Charter	EN ISO 10370 & ASTM D4530-93 (micro methods)	0.3 – 0.2 mass max. (Cat. 3&4)
Australia (proposed) <sup>1</sup>		0.16% mass max.
Japan		0.1% mass max.

1. Likely to be included in future operability specifications

### Why regulate?

For properties of diesel which may detrimentally affect engine performance and condition over time rather than immediately, some level of consumer protection needs to be retained.

Micro carbon methods (such as ASTM D 4530) are now widely in use for determination of carbon residue. These are more precise and capable of detecting lower levels than the current method specified. Adoption of this method would align with the European specifications but it is suggested that an appropriate limit on a 10% residuum is 0.10% mass max, not 0.3% max as in those specifications. The Marsden Point Refinery also routinely uses this method.

However, if particular types of cetane improvers are being used, these can give an abnormally high result. In this case the presence of a cetane improving additive needs to be confirmed as the cause, using a test such as ASTM D 4046.

### Changes proposed to the Regulations

Current Regulations	Proposed changes
Carbon Residue: Ramsbottom test on heaviest 10% of a sample; 0.2% maximum by mass	Immediate replacement with MCR test (test method IP 398 (ASTM D 4530)) with 0.1 % maximum by mass

## 8.11 Distillation – T85

### What is it?

The distillation curve (temperature vs. percentage volume recovered) characterises the volatility of the fuel. T85 is the temperature at which 85% of the fuel sample has boiled off. For diesel, the most important distillation characteristics are the temperatures at the top end of the range (T85, T90, T95 etc.) as these provide a measure of the proportion of heavier components, and correlate closely with levels of aromatics in particular. As the density is dependent on the composition of the fuel, the distillation characteristics affect the density as well as the viscosity and Cetane Index. Thus the distillation curve is an important factor in the control of fuel quality.

This property is controlled by adjusting the cut point between diesel and heavier fuel oils. The distillation is carried out in accordance with test method ASTM D 86.

### Why is it important?

The heavier components in diesel have more potential for incomplete vaporisation and combustion, resulting in increased smoke or soot. Specifying lower high end temperatures reduces the proportion of these heavy components, giving cleaner burning. It may also reduce the density and the viscosity of the fuel as these properties are closely linked. However, some studies suggest that where the effects of volatility can be decoupled from the other fuel parameters, the impact on emissions of changing the high end of the distillation curve may not be that significant.

### Current New Zealand and International Specifications

Different jurisdictions specify different distillation parameters, so direct comparisons are not always easily made, as shown below. However, there is an international trend towards lower high end boiling points for diesel, with the European T95 value being the same as the current New Zealand T85 value. T95 is becoming a more standard indicator as well.

Specification	Parameter	Limit
New Zealand	T85	350°C max.
Euro 3 (2000)	E250 <sup>1</sup> E350 T95	<65 % by volume 85% by volume min. 350°C max.
World-Wide Fuel Charter	T90 T95 Final boiling point	340°C (Cat.1) – 320°C (Cat. 3&4) 355°C (Cat.1) – 340°C (Cat. 3&4) 365°C (Cat.1) – 350°C (Cat. 3&4)
Australia	T95	370°C max. from 1 Jan 2002 360°C max. from 1 Jan 2006
Japan	T90	330 – 360°C depending on cold weather class
USA	T90	338°C max.

1. E250, E350 - % by volume evaporated at 250°C and 350°C respectively.

### Why regulate?

Reductions in high end distillation are aimed primarily at achieving environmental benefits.

- A change to T95 at 370°C is approximately equivalent to the current T85 of 360°C for diesel from the Marsden Point Refinery. Doing this immediately would align with international practice without a significant change in fuel quality.
- T95 would have to be set lower than 370°C to provide any benefit in terms of removing heavier fractions and a reduction to 360°C is proposed at Stage 1. This will reduce aromatics and emissions of CO, HC and PM (mainly through reducing density). It will also reduce the overall toxicity (mutagenicity and carcinogenicity) of emissions, as well as the viscosity, and may increase the Cetane Number.
- Use of a T95 distillation point limits the heavier ends, but if used as a replacement for T85 would not limit the T85 – T95 fraction. Setting other limits such as T50, or a lower value of T85 as well allows for tighter control of the proportion of heavier compounds. However, separate specifications such as total aromatics and PAH limits can also control these components, so it is not proposed to regulate further at this stage.

### Changes proposed to the Regulations.

Current Regulations	Proposed changes
Distillation: T85: 350°C maximum T95 not specified	Immediate removal of T85 specification and replacement with a maximum T95 of 370°C
	Stage 1 reduction in maximum T95 to 360°C

### Implications of proposed changes

As more of the heavier components are removed this reduces the yield of diesel from a given feedstock and increases the production of fuel oil. There is a cost impact associated with any change that reduces yield and creates more heavy material. Hence the reduction of T95 to 360°C is timed to coincide with a similar change in Australia.

## Properties Currently Not Specified

The following properties for diesel are not currently included in the New Zealand specifications but have appeared elsewhere in specifications or their inclusion is under discussion. Therefore their significance is discussed here.

## 8.12 Polyaromatic Hydrocarbons (PAH)

### What are they?

Aromatics containing multiple benzene rings are known as polyaromatic hydrocarbons (PAHs or PCAs). Whereas aromatics containing a single benzene ring are an issue with petrol, it is primarily PAHs which are of concern with diesel. Current evidence suggests that only the PAHs contribute to particulate emissions, so it is only these and not total aromatics in diesel which need be considered for regulation. Some PAHs such as benzo(a)pyrene are known to be carcinogenic.

PAHs are predominantly present in the heavier ends in diesel so their content is controlled through the distillation parameters such as T85 and T95.

### Why are they important?

Data on the impact of PAHs on regulated emissions are fairly sparse. However, it appears that there are consistent trends with decreased PAH resulting in decreased hydrocarbon and NO<sub>x</sub> emissions but no impact on CO. Reduced PAH has a significant benefit on PM for older engines which produce higher levels of particulates. For modern lower emission engines, the impact is little to none. These effects are attributed to the higher flame temperature and higher C:H ratio of aromatics. For this reason, there is a trend in international fuel specifications to placing limits on aromatics and PAHs in particular.

### Current New Zealand and International Specifications

Specification	Limit
Euro 3 (2000)	11% max. by mass
World-Wide Fuel Charter	25% max. by mass total aromatics (15% Cat. 3 & 4) 5% max. by mass PAH (2% Cat. 3 & 4)
Australia	11% max. by mass from 1 Jan 2006

### Why regulate?

No data are available on current PAH levels in New Zealand diesel (either imported or from the Marsden Point Refinery). Available information indicates positive benefits in emissions reduction from reducing PAHs in diesel and this has been the basis for introduction of limits in European and other specifications.

An ambient air quality guideline of 0.30 ng/m<sup>3</sup> (0.0003 µg/m<sup>3</sup>) for benzo(a)pyrene has been recommended for New Zealand (refer Appendix E). Based on the limited data available, there is a significant chance that existing (possibly background) levels exceed this recommendation (MfE#13, 2000). However, diesel-fuelled vehicles are not the primary source of PAHs in ambient air.

Reducing PM emissions through control of PAHs will have environmental benefits, However, the reduction in PM emissions achieved through proposed changes to T95 and sulphur levels are likely to outweigh any immediate changes to PAH levels.

Indications are that a maximum limit of 11% mass for diesel could be achieved on the same timetable as Australia (2006) or possibly earlier (2003) for diesel from the Marsden Point Refinery without being unnecessarily constraining and this would allow early alignment with European specifications. In the meantime, a watching brief should be maintained as information on New Zealand ambient air concentrations and sources of PAHs improves.

### New Regulations proposed

Current Regulations	Proposed changes
PAHs: not currently regulated	Stage 1 reduction to maximum PAH of 11% by mass, to apply to all diesel (Test method ASTM D 5186 or IP 391)

### What are implications of these changes?

As PAHs are higher density components of diesel, reduction of T95 limits and maximum density will effectively reduce the PAH content. As already noted, this reduces the overall yield of diesel and these components then have to be used elsewhere, either in heavier products or be upgraded to lighter components through further processing, so there are some cost implications in imposing any reduction in PAHs in diesel over present levels.



## 8.13 Oxidation Stability

What is it and why is it important?

As for petrol, the oxidation stability is a measure of the fuel's resistance to degradation by oxidation. Oxidation of diesel fuel can result in the formation of gums and sediments, causing plugging of filters and engine deposits. It may also lead to a darkening in colour of the fuel though this is not a problem in itself.

In the oxidation stability test, oxygen is bubbled through the fuel at an elevated temperature for a fixed time, then it is cooled and the insolubles filtered off and weighed.

For diesel fuels with low levels of natural anti-oxidants, a satisfactory level of stability can be achieved with the use of anti-oxidant additives.

### Current New Zealand and International Specifications

Oxidation stability is not currently regulated for diesel, though it is for petrol (by specifying the Oxidation Stability Induction Period). The European specifications and World-Wide Fuel Charter both set a maximum limit of 25 g/m<sup>3</sup> and it is understood that a similar limit is proposed for the Australian operability specifications.

### Why regulate?

Severe hydrotreating of crudes to produce low sulphur diesels can remove some of the natural anti-oxidants in diesel creating potential for instability problems when such fuel is stored for long periods. Therefore with the wider introduction of lower sulphur diesels in the future, oxidation stability should be regulated for consumer protection.

The immediate introduction of an oxidation stability test is proposed with a specified level in line with international specifications and using ASTM D 2274-94 as the test method.

### New Regulations proposed

Current Regulations	Proposed changes
Oxidation Stability: not currently regulated	Immediate introduction of an oxidation stability test: 25 g/m <sup>3</sup> maximum (test method ASTM D 2274 (Accelerated Method))

## 8.14 Water Content and Total Contamination

As noted in Section 8.2, It is proposed that specific limits on water and sediment be added to the regulations, to supplement the existing visual tests for colour and appearance. This will bring New Zealand into line with international specifications. Specifications for water and sediment are already included in the NZRC and Refinery Users specification so this will lock current good practice into the regulations. The limits and test methods proposed align with World-Wide Fuel Charter and current European specifications.

### New Regulations proposed

Current Regulations	Proposed changes
Water Content: not currently regulated	Immediate introduction of water content test: 200 mg/kg maximum (test method to be determined)
Total Contamination: not currently regulated	Immediate introduction of total contamination test: 24 mg/kg maximum (test method ASTM D 2276)

## 8.15 Lubricity

As noted in Section 8.7, removal of sulphur from diesel can reduce its natural lubricity, causing increased wear in fuel pumps and other engine components. This problem was first identified when ULSD was first introduced in Sweden, but adequate lubricity levels can be achieved through the use of suitable additives. Lubricity tests are now commonly being included in many diesel specifications elsewhere.

Lubricity is not easily measured in a laboratory. The High Frequency Reciprocating Rig (HFRR) test uses a laboratory rig to measure the effective wear than can be expected on fuel pump parts. This is measured as a wear scar diameter in microns (mm). The proposed specification is a maximum wear scar diameter of 460  $\mu\text{m}$  (microns) at 60°C, measured in accordance with test procedure IP450.

In view of future reductions in the sulphur content of New Zealand diesel (both in the longer term as well as in the longer term), and the availability of LSD on the market already, it is proposed that the lubricity test apply to all diesel, irrespective of sulphur content. However, if a higher sulphur marine grade of diesel again becomes available, it may be appropriate to consider an exemption.

### New Regulations proposed

Current Regulations	Proposed changes
Lubricity: not currently regulated	Immediate introduction of a lubricity test: HFRR wear scar diameter at 60°C - 460 microns maximum (test method IP 450)

## 8.16 Filter Blocking Tendency

The Filter Blocking Test measures the filterability of diesel and is proposed in response to the recent problems encountered with diesel fuel dosed with a cold flow improver. The test measures a volume of a sample through a 1.6 micron ( $\mu\text{m}$ ) filter and records the increase in pressure drop as the sample is filtered. Given the potential operating problems that poor filterability can cause in diesel engines, this requirement is being included to provide additional protection for the consumer.

The proposed test method is IP 387, with a specified maximum value of 1.41 (a dimensionless value called the filter blocking tendency). The test is already used in most refineries in Australia.

### New Regulations proposed

Current Regulations	Proposed changes
Filter Blocking Tendency: not currently regulated	Immediate introduction of a filter blocking test: 1.41 maximum (test by IP 387)

## 8.17 Conductivity

Diesel that is low in sulphur may also have a lower electrical conductivity. Insufficient conductivity is a safety issue because it can lead to a build-up of static charge during transfer (such as when filling bulk storage tanks or road tankers). Conductivity is generally not an issue for vehicle fuel tanks because of the low velocity of fuel through pump nozzles. This is primarily an operating consideration for the oil industry and it can be corrected with conductivity improving additives. There is no proposal to regulate at this stage.

Following on from the changes proposed to individual specifications for petrol and diesel, this section examines the continuing requirement for the Regulations in general terms and then changes required to the general provisions in order to make the Regulations work more effectively.

## 9.1 Why do we need the Regulations?

The Review has concluded that the Regulations are still necessary from a consumer, health and safety and environmental perspective. They provide:

- Consistency in terms of product;
- Guidelines for the suppliers and manufacturers in respect of what is acceptable;
- A signal for future developments and therefore potential expenditure; and
- Protection in terms of health, safety and the environment.

Consumers are not in a position to determine the quality of fuel at the point of purchase but good quality fuel is essential to the proper running and long life of engines. Often, problems with fuel quality may not be experienced immediately. Different brands of fuel may have been bought over a period of time before a problem is identified, and it will be very difficult to attribute effects such as engine damage to a particular source and supply.

Consumer legislation has developed since the Regulations were first introduced in 1989 and now provides a greater level of protection for the consumer than it did then. However, the Regulations provide a minimum standard for fuel, and therefore certainty as to what is acceptable. In this respect, they provide buyers of petrol and diesel with an additional layer of protection, to ensure them that fuel bought is fit for purpose while also allowing health, safety, and environmental concerns to be addressed.

Some jurisdictions (South Australia and California, for example) have adopted an alternative approach to regulating some of the properties of petrol by means of air toxics models or environmental equivalence formulae. While this approach fits well with the effects-based principles of the RMA, it covers only those properties which are being controlled primarily to meet environmental outcomes, not those for health, safety and consumer protection which, arguably, require more certainty. Given the inclusion of the latter in New Zealand's specifications, introduction of a separate method for assessing environmental compliance does not seem warranted.

## 9.2 Fit for Purpose

Fuel processing technology and additives used in petrol and diesel to control fuel quality change with time. Fuel problems in recent years have resulted from changes in fuel properties that the specifications did not adequately control or did not address, for example, the problems encountered with high aromatics in premium unleaded petrol in 1996. It is proposed that a general clause be added to Regulations requiring that all fuel be "fit for purpose". This would strengthen the level of consumer protection, particularly in relation to fuel quality problems arising from properties not directly specified.

### Changes proposed to the Regulations

Current Regulations	Proposed changes
Fit for purpose: Not specified	Immediate inclusion of a general clause requiring that all fuel be "fit for purpose".

## 9.3 Test Methods

Changes to some of the test methods have been proposed to bring them into line with current international practice and technological developments. Where new specifications have been added, appropriate test methods have been proposed. The test methods specified have been developed by internationally recognised organisations such as the American Society for Testing and Materials (ASTM) and the Institute of Petroleum (IP). The tables summarising the regulations, proposed changes and timing for petrol and diesel in the summary section, give the test method references.

## 9.4 Fines for Non-Compliance

The Regulations currently allow for a maximum fine for non-compliant fuel of \$10,000. This compares with the Fair Trading Act 1986 that prohibits false or misleading representations made in respect of the supply of goods or services. Maximum fines under the Fair Trading Act are up to \$30,000 for an individual and \$100,000 for a corporate body.

It is proposed that, as the Petroleum Products Specifications Regulations sit within the wider framework of consumer protection legislation, the maximum fines for non-compliant fuel should be consistent with maximum fines under the Fair Trading Act.

This will require an amendment to the Ministry of Energy (Abolition) Act 1989, under which the Regulations are issued. The Act currently specifies a \$10,000 maximum fine.

## 9.5 Labelling

Provisions for labelling are not a requirement of the current Regulations. General controls on labelling are provided in the Fair Trading Act 1986. The Weights and Measures Regulations 1999 require that all fixed fuel dispensers be labelled with the type of fuel dispensed, but only for inspection purposes. From time to time, consumers experience problems with misfuelling (filling the vehicle with the wrong fuel). Using regular grade where premium is required can affect vehicle performance, whereas putting petrol into a tank instead of diesel, as well as causing potential engine damage, can be quite hazardous.

Recently, there has been marketing of petrol grades other than regular and premium. “Boutique” grades of petrol have been advertised as having higher octane, or lower benzene, or lower sulphur. It is important the consumer is getting the “boutique” qualities being advertised.

To assist consumer awareness and to help avoid misfuelling, it is proposed the Petroleum Products Specifications Regulations be amended.

### Changes proposed to the Regulations

Current Regulations	Proposed changes
Labelling of dispensers: Not regulated	Immediate petrol and diesel dispensers at service stations be labelled clearly, including for petrol dispensers, clear labelling of the minimum research octane number (RON)
Boutique grades: covered by either regular or premium petrol specifications	Immediate boutique grades of petrol (that is, those grades not marketed as regular or premium petrol) meet the octane ratings and other special properties being advertised, as well as all other properties specified in the Regulations.

## 9.6 Ensuring Fuel Consistency

It is important that the variability of our fuel is kept within acceptable bounds to enable us to rely on consistent performance from a particular grade of fuel. We also expect fuel properties with public health and environmental impacts to be controlled within acceptable bounds. Consistency is achieved by setting minimum or maximum limits on key properties. In some cases where the range is critical, such as with the density and viscosity of diesel, both limits are specified.

## 9.6.1 Pool Averaging

An alternative approach to fixed limits is the use of “pool averages”. Pool averages allow variability across the national or regional fuel supply, provided that an average value or specification is met over a specified period. A cap or maximum limit is also specified, but usually at a higher value than the equivalent single flat limit.

This approach has been adopted in some other countries, primarily for those parameters, such as aromatics levels in petrol, that are controlled to minimise environmental impact. On balance, it was considered that the use of pool averages was not practical in the small New Zealand market, and that the objectives of the Review could best be achieved by setting appropriate minimum and/or maximum limits on properties.

However, the specifications do propose geographical and seasonal variations where they are appropriate to cope with different climatic conditions. An example is the cold flow properties of diesel.

## 9.6.2 Mandated Geographical Differences

Mandated geographical differences in fuel quality have been considered in the Review in response to the geographical nature of some air pollution issues. This type of approach is being used overseas to deal with specific urban air quality problems. Such an approach would be in line with the underlying principle that fuel quality standards reflect the level of risk to health and the environment, which in the case of air pollution is essentially a local problem.

The most obvious split would be fuel specifications specific to Auckland and Christchurch, say, to deal with their particular air pollution issues, or perhaps a broader urban/rural split allowing for cleaner “city fuels”. An Auckland-region specification would be the most practical to implement, given that all fuel to the region is delivered directly from the Marsden Point Refinery via the Refinery to Auckland Pipeline. However, this would require agreement between the NZRC shareholders and the regions. This option is currently under consideration, with respect to providing Auckland with lower sulphur diesel.

A wider urban/rural split was not considered practical, given the relatively short distances, the mobility of the New Zealand population and the size of the market. Where this approach is being used overseas, the population and market size is far larger than in New Zealand. The Review has therefore not recommended any geographically divided fuel specifications at this time, other than those for cold flow properties of diesel (refer Section 8.4).

## 9.7 Additives

A wide range of additives is used in petrol and diesel to improve certain properties or characteristics of the fuel. For petrol, these include dyes, detergents, stabilisers, combustion improvers and octane enhancers in petrol. Similar sorts of products are used in diesel along with cetane number and cold flow improvers. Some are added at the refinery during blending and others, such as those used for branding or product differentiation may be added during distribution.

The recent problems associated with the use of a particular cold flow improver in diesel have raised public awareness of the use and regulation of additives in fuel. For the most part, the use of additives is neither required or prohibited by the Regulations. However, there are exceptions to this rule for cases where a specific additive or component of an additive is harmful to vehicle systems or to human health and the environment. Lead, for example, was banned in 1996 because of health concerns. Manganese and phosphorus have been identified in this Review as capable of causing engine and catalyst damage. The use of these substances has been regulated by specific limits on their concentrations in petrol.

There are no requirements under the Regulations to obtain specific approval to be able to use an additive in petrol or diesel. However, the use of any new additive requires approval to be obtained from the Environmental Risk Management Authority (ERMA) which must now approve the use of new hazardous substances in New Zealand. In doing so, it does a thorough product lifecycle assessment, including taking into account the use to which a substance will be put and any impacts on health and the environment.

ERMA maintains a register of additives that are allowed to be used in petrol and diesel. It also lists petrol and diesel, and their components, on its register. New additives may be included on the list following an approval process. Any changes to the registered composition of petrol and diesel also must be approved.

It is not considered that the Petroleum Products Specifications Regulations also need to provide for the use of additives to be restricted. The Regulations do need to define clearly the performance required from petrol and diesel. Whether these are best met by using additives is best determined by the supply industry, subject to complying with ERMA’s requirements. As a result of the recent diesel filter blocking problems, a filterability test is proposed to be added to the Regulations (see Section 8.16). This is an example of regulating to provide a desired outcome.

There may be merit, however, in clearly defining in the Regulations that petrol and diesel additives are intended to improve fuel performance or fuel distribution.

New Regulation proposed

Current Regulation	Proposed changes
Additive: referenced in the definitions of diesel and petrol as allowed.	Immediate include new definition – additive means dyes, markers or other additives used to improve performance in the engine, physical properties, safety, odour, viscosity, lubricity, wear and tear, emissions and emissions control durability, and distribution of diesel or petrol.

The intention is that such a definition will enhance the Regulations by making the purpose of using additives clear. It will still enable industry innovation in the use of additives.

## 9.8 Fuel for Retail Sale and All Other Fuel

The Regulations distinguish between all fuel “supplied, or available or intended for supply” and fuel that is sold by retail. Retail sale is defined by the Regulations as the sale of fuel “to an end user who has no written supply agreement or written contract with the supplier”. Fuel for retail sale must meet all the specification requirements of the Regulations. Petrol and diesel for all other types of sale must meet only those specifications that protect the environment, public health, and human safety; for example, the restriction on the use of lead.

This differentiation enables specially blended petrol and diesel fuel to be sold through commercial agreements, where there is a written agreement between the buyer and the supplier to supply fuel to specific requirements. (In practice, it is understood that the supply of special blends happens very rarely and all fuel sold usually meets all the specifications, irrespective of its intended use.)

Some of the proposed changes to the Regulations are to properties that originally were regarded as primarily performance properties, and therefore only applicable to retail sale. These changes are now intended to manage health, environmental, or safety impacts as well. There are also additional specifications proposed to manage health or environmental impacts.

The Regulations that are proposed to apply to all fuel and just to fuel sold by retail are:





## 9.9 Strategy for Ongoing Changes to the Regulations

In the eight months since this review was commissioned there have been a number of significant developments in fuel quality standards and policy overseas, notably in Europe, Australia and the United States. Here in New Zealand the issue of fuel quality has also received significant media attention through recent performance problems (related to diesel filterability) and public discussion of environmental and health issues (primarily related to diesel sulphur content). Fuel price has continued to be a sensitive issue over the period, as has competition, with one independent player having effectively disappeared from the retail fuel market. There is no suggestion that the pace of change is likely to slacken off and regular reviews of the Regulations are therefore recommended.

## 10.1 Competition and Security of Supply

One of the underlying principles of the Review is to promote a competitive environment and to ensure that there are no unjustified barriers to entry to the petroleum supply market in New Zealand. There are two aspects of this competition: competition in the retail and commercial fuel sectors and competition in the refining sector. The two are inextricably linked.

There is already competition in New Zealand's retail and commercial fuel sectors. Retailers are competing for market share, creating pressure on retail margins, that in turn leads to pressure to minimise wholesale fuel costs.

Competition in the refining sector extends from New Zealand throughout the Pacific Rim, where there is excess refining capacity. New Zealand has one refinery at Marsden Point, and most of our fuel is sourced from there (refer Section 3.1.1). The Marsden Point Refinery is relatively small by comparison to new refineries in the Asia-Pacific region. It is located alongside a deep water port and is a significant employer in the Northland area.

The heavy reliance on fuel from the Refinery means New Zealand is vulnerable to interruptions from this supply source, as evidenced by recent diesel problems. On the other hand, having a New Zealand refinery gives a degree of security of supply. For example, the Refinery could be used to refine New Zealand crude if international supply disruption occurred.

The extent and timing of the changes proposed in the Review have considered the Refinery's configuration and processing capability, the cost of upgrading, lead times for new equipment, and the economics of refining in a very competitive market. If the costs of complying with new specifications become too great, the Refinery users may choose to have their crude oils processed elsewhere or to buy all their finished products directly. However the four Refinery users are also significant shareholders so they have an interest in seeing the Refinery operating to capacity.

Not all retailers operating in the New Zealand market have access to petrol and diesel produced at the Marsden Point Refinery. Most fuel imported to New Zealand is sourced from refineries throughout Australia and Asia. Specifications designed to complement the configuration of the Marsden Point Refinery may be a barrier to competition and may constrain imported fuel sources. Some refineries in the region can already supply New Zealand with fuel that meets some, if not all, of the proposed changes to the specifications.

These issues, many of which bring competing tensions, have been considered in the development of the proposals. The Review recognises that there is a role for independent suppliers and that both they, and the major suppliers, must be able to acquire fuel from a range of sources. This consideration has been balanced against the need to recognise the contribution to supply from the Marsden Point Refinery and the need to provide it with a reasonable opportunity to meet proposed changes to the Regulations.

Australia, in its review of petrol and diesel specifications, has similarly had to take into account competition issues and the ability of its refineries to meet proposed changes.

One further aspect that must be considered is the interdependence of specification parameters and the integration between products produced in a single refinery. Refineries produce a wide range of products from each crude oil, so that the quality constraints on one product will directly affect another. This limits the ability to pick and choose specifications for individual fuels when they are produced from one source. This constraint applies to imports as well as Marsden Point Refinery product and has been another consideration in the development of the proposals.

It is acknowledged that because of these interdependencies, there may be significant scope for optimising both the changes to specified limits on fuel properties as well as the timetables for their adoption. This will vary with fuel source/processor. This review has focussed primarily on signalling the desired changes with due regard to their implications, so providing a basis for the market to choose the best solution for implementing them.



## 10.2 Financial Implications of Proposed Changes

Relatively little information was available from New Zealand’s fuel suppliers on the potential cost impacts “at the pump” of the proposed changes in the fuel specifications. To understand the potential implications, it is necessary to understand the make-up of fuel costs in New Zealand. This is discussed in Section 10.2.1 below.

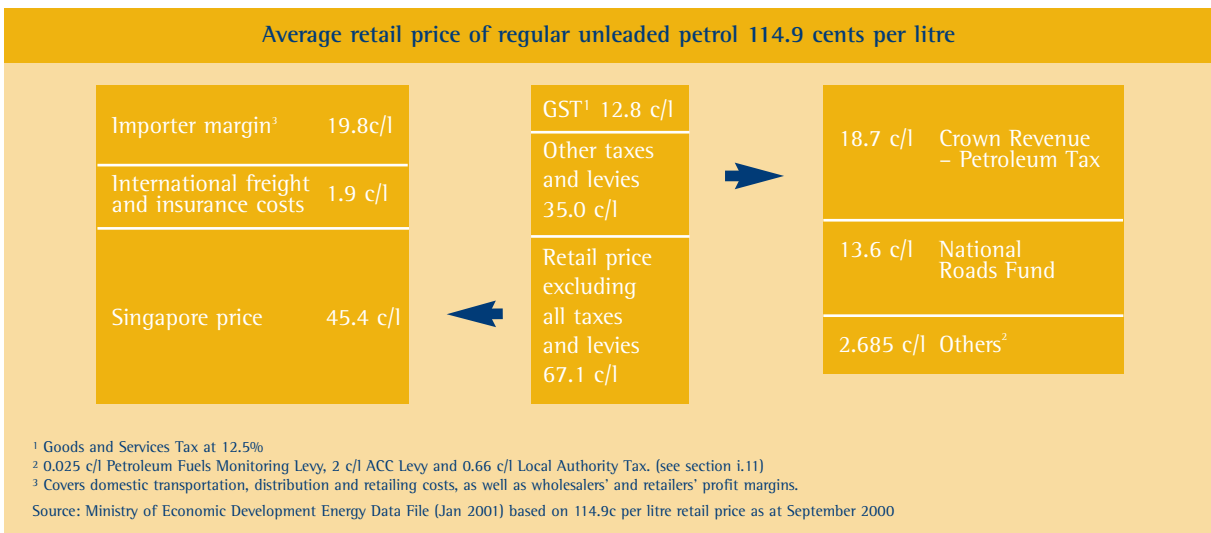
In view of the lack of New Zealand specific information, the costs of similar changes in Australia and Europe were considered, to provide an indication of the likely cost implications for New Zealand’s market. This is covered in Sections 10.2.3 and 10.2.4.

### 10.2.1 The Price of New Zealand Petrol and Diesel

The cost of petrol and diesel at the pump in New Zealand is the sum of many individual components including crude oil prices, foreign exchange rates, shipping and distribution costs, refining costs, taxes and operating costs for both wholesaler and retailer.

MED’s Energy Data File (MED, 2001a) provides information on retail and imported petrol prices and compares regional and international prices. MED’s analysis relates pump prices to the Singapore spot market price. Singapore is a major refinery centre, considered to be operating at industry best practice levels, and is widely used as a benchmark for pricing in the Asia-Pacific region. New Zealand taxes and levies, international freight and insurance costs may be added to the spot price to derive a New Zealand import price for petrol. This is shown in Figure 10.1, based on a retail price for regular grade in the September 2000 quarter.

Figure 10.1: Breakdown of Retail Petrol Costs



Source: MED, 2001a (Chart 1-9c).

It should be noted that the total tax rate is a combination of a fixed percentage (GST) and a fixed rate per litre. Other data from MED indicate that retail margins on petrol (the difference between the wholesale and retail price) were of the order of 3c per litre for the September 2000 quarter (MED, 2001). On some occasions, the largest contributor to changes in fuel prices in New Zealand is movement in the \$US/\$NZ exchange rate.

MED also tracks Singapore spot prices and New Zealand retail prices for diesel and a similar breakdown can be derived, however a much smaller proportion of diesel sales are through retail outlets.

MED’s website is regularly updated to show weekly average prices of crude oil, petrol and diesel (see [www.med.govt.nz/ers/oil\\_pet/prices/index.html](http://www.med.govt.nz/ers/oil_pet/prices/index.html) ).

### 10.2.2 Implications for Marsden Point Refinery

The tolling arrangements that the Marsden Point Refinery operates under have been described briefly in Section 3.1. The refining margin (the cost to the Refinery user of having crude oil processed) is determined by a complex formula, and is principally controlled by refining margins elsewhere in the Asia Pacific region. In simple terms, for the Refinery to be competitive, the cost of purchasing crude, shipping it to Marsden Point, refining it and distributing products to New Zealand ports has to be less than the cost of purchasing and shipping imported products directly.

For the Refinery, meeting new specifications is likely to necessitate a mixture of capital investment (modifications to existing and/or new processing plant), increased operating costs, and potentially lower revenue, as a result of:

- Lower refining margins resulting from use of more expensive feedstock (crude oil);
- Reduced throughput as a result of greater processing being required and lower yields;
- Higher maintenance, downtime and catalyst costs associated with this greater processing (eg. more removal of sulphur, conversion of benzene to other products); and
- Potential downgrading of product to lower value products.

Capital investment in new processing plant can be significant and there can be long lead times – not only for design and fabrication of the equipment itself, but in selecting suitable windows for refinery shutdowns to allow its installation. In view of this, the Refinery's continued viability is dependent on its being able to process fuel within a defined band (the difference between the cost of the feedstock and the price of landed product).

Whether the increased costs are passed onto the consumer is the choice of the marketing companies (the Refinery users).

### 10.2.3 Costs from Australian Review

The Environment Australia review of fuel quality (EA, 2000a) considered a number of scenarios for fuel quality changes, including that of meeting Euro 4 requirements for diesel and petrol by 2006. Data supplied by Australia's oil refineries were used to develop a financial model to predict likely cost impacts for each scenario. Key points from this analysis were:

- Costs were based on required changes to all eight Australian refineries;
- The specification changes now adopted by Australia are generally similar to those proposed in this Review (alignment over time with Euro 4). The main challenges for Australian refineries are meeting sulphur limits for both petrol and diesel, and RVP and benzene limits for petrol. These are similar to the challenges for the Marsden Point Refinery, with the exception of sulphur limits in petrol, the limits for which are currently easily met by Marsden Point.
- Estimated costs to meet Euro 4 specifications, relative to a base case specification, were averaged over the eight refineries. The base case reflected current fuel quality plus allowances for changes already in train (particularly in relation to sulphur and benzene). All costs are in Australian dollars.

Average operating cost increase	\$A17M per refinery
Average capital cost	\$A185M per refinery (range \$A80M - \$A280M)
This translates to:	1.5 centsA per litre for Euro 4 diesel 1.1 centsA per litre for Euro 4 petrol

### 10.2.4 European Costings

The Australian review indicated that Australian costs would be similar to that for European refineries. It quoted a 1999 CONCAWE study on European Union refining industries costs to achieve Euro 4 specifications. Average costs (again in Australian dollars) were:

- 1.6 centsA per litre for Euro 4 diesel
- 0.9 centsA per litre for Euro 4 petrol

### 10.2.5 Implications for New Zealand Petrol and Diesel Prices

In general terms, the changes proposed for New Zealand are broadly in line with the Australian and Euro 4 proposals. The cost increases would be seen as an increase in the cost of product to the wholesaler, and the level of increase, if any, to be passed on to the motorist would be decided by the retailer. It is reasonable, however, to expect that cost increases at the pump might be of the order of magnitude of 1-2 cents per litre.

However, as a staged approach to specification changes is proposed, it is likely that these costs may be seen as a number of incremental steps over a period of years. This may not be easily visible, against a background of exchange rate movements and crude oil price movements. For example, the Singapore spot market price for petrol ranged from 31cNZ to 55cNZ per litre over the year 2000 (source: MED).

It is, therefore, very difficult to determine what the true cost of any changes to fuel quality might be, or to translate this into a price impact at the pump. For example, the 1996 conversion to premium unleaded petrol did not result in a significant cost increase to the consumer, although an increase had been predicted prior to its implementation.

# references

- ARC, 1997. *Auckland Air Emissions Inventory*. Prepared for the Auckland Regional Council by the Victorian Environmental Protection Authority. July 1997.
- ANZECC, 2000. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000)*. Australian and New Zealand Environment and Conservation Council
- BS EN 590:2000. *Automotive fuels – Diesel – requirements and test methods*. British Standard. 2000.
- BS EN 228:2000. *Automotive fuels – Unleaded petrol – requirements and test methods*. British Standard. 2000.
- CONCAWE, 1999a. *Proposal of Revision of Volatility classes in EN 228 Specifications in Light of EU Fuels Directive*. Prepared for the CONCAWE Automotive Emissions Management Group by its AD-Hoc Gasoline Volatility Group, Brussels. January 1999.
- CONCAWE, 1999b. *Fuel Quality, Vehicle Technology and Their Interactions*. Prepared for the CONCAWE Automotive Emissions Management Group by its Ad Hoc Group on Fuels and Vehicle Interactions, Brussels. CONCAWE. May 1999.
- CONCAWE, 1999c. *Potential Of Exhaust After Treatment And Engine Technologies To Meet Future Emissions Limits*. Based on work carried out by the Special Task Force on Gasoline/Diesel After-Treatment Devices, Brussels. CONCAWE. September 1999.
- DISR, 2001. *Australia's Move To Cleaner Fuels*. Presented at the 7th Annual Fuels and Lubes Asia Conference. Department of Industry, Science and Resources Australia. January 2001.
- EA, 2000a. *Review Of Fuel Quality Requirements For Australian Transport (Vols. 1 & 2)*. Prepared by Coffey Geosciences Pty Ltd. Environment Australia. March 2000.
- EA, 2000b. *Proposed Standards for Fuel Parameters (Petrol and Diesel), Revised Commonwealth Position*, Environment Australia, September 2000.
- EA, 2000c. *Setting National Fuel Quality Standards*. Paper 2A Proposed Management of Petrol Octane Enhancing Additives/Products. Environment Australia. November 2000.
- EA, 2000d. *Protocol for the Assessment of the Environmental Impact of High Sulphur (1300 ppm) Diesel Fuel Treated with the Fuel Additive Cleanerburn™*. Environment Australia. December 2000.
- EA, 2001a. *National Fuel Quality Standards for Australia*, paper presented to Energy Federation of New Zealand Conference, Wellington, 28th June 2001 by Kathleen Mackie, Environment Australia.
- EA, 2001b. *Media release from Minister for the Environment and Heritage*, 15th July 2001.
- EN ISO 4259:1995. *Petroleum products – Determination and application of precision data in relation to methods of test (ISO 4259:1992/Cor 1:1993)*. British Standard. August 1995.
- EW, 1997. *Motor Vehicle Exhaust Emissions Testing Project: Hamilton, New Zealand*. TR97/2. Environment Waikato. February 1997.
- EW, 1999. *Diesel Vehicle Exhaust Emissions Testing Programme: Hamilton, New Zealand*. TR99/13. Environment Waikato. October 1999.
- EW, 2000. *New Zealand Diesel Fuel and its Relationship to Smoke Emissions from Diesel Motor Vehicles*. TR2000/3. Environment Waikato. February 2000.
- Fisher *et al.*, 1997. *Transport Emissions Study*. G Fisher, N Gimson, G Kuschel, J Petersen, NIWA. Prepared for the Ministry of Transport and the Ministry of Health. September 1997.
- Jones, 2000. *New Zealand Diesel Fuel And Its Relationship To Smoke Emissions From Diesel Motor Vehicles*. Technical Report for Environmental Waikato Land Transport Programme. GM Jones, Energy and Fuels Research Unit, Auckland Uniservices Limited. March 2000.

Kar, 2000. *Evaporative Emissions from Petrol-Powered Vehicles in New Zealand and their Contributions towards Air Pollution*. Project in Mechanical Engineering Report, Department of Mechanical Engineering, University of Auckland. K Kar. 26 September 2000.

Lilley, 2000. *Assessing Fuel And Vehicle Impacts On Air Quality Using The IPIECA Tool-kit: A Case Study For New Zealand*. LC Lilley Fuels Business Group, Shell Global Solutions. September 2000.

L TSA, 2001. *New Zealand Motor Vehicle Registration Statistics 2000*. Transport Registry Centre, Land Transport Safety Authority. March 2001.

MED, 2000. *Petroleum Fuel Quality In New Zealand 1992 - 1999*. Vallabh Patel, Ministry of Economic Development. July 2000.

MED, 2001a. *New Zealand Energy Data File*. Ministry of Economic Development. January 2001.

MED, 2001b. *Petroleum Fuel Quality in New Zealand: Update for the Year 1999 - 2000*. Paul Stannard, Ministry of Economic Development. June 2001.

MfE, 2001. *GEMS Air Monitoring Programme Annual Report 2000*. Ministry for the Environment. To be published.

MfE#12, 2000. *Health Effects of Five Air Contaminants and Recommended Protective Ranges*. Air Quality Technical Report 12. L Denison, K Rolfe, and B Graham. Ministry for the Environment. 2000.

MfE#13, 2000. *Health Effects of Priority Hazardous Air Contaminants and Recommended Evaluation Criteria*. Air Quality Technical Report 13. J Chiodo and K Rolfe. Ministry for the Environment. 2000.

MfE#14, 2000. *Preliminary Assessment of Strategies for Managing Air Quality*. Air Quality Technical Report 14. T A'Hearn, W Robins and K Rolfe. Ministry for the Environment. 2000.

MfE#15, 2000. *Effects of Air Contaminants on Ecosystems and Recommended Critical Levels and Critical Loads*. Air Quality Technical Report 15. C Stevenson, V Hally and M Noonan. Ministry for the Environment. 2000.

MfE#16, 2000. *Proposal for Revised and New Ambient Air Quality Guidelines*. Discussion Document. Ministry for the Environment, December 2000.

MfE#22, 2000. *Meeting Notes and Analysis of Reviewers' Comments*. Air Quality Technical Report 22. Ministry for the Environment. 2000.

MfE#23, 2000. *Recommended Amendments to the Ambient Air Quality Guidelines 1994*. Air Quality Technical Report 23. K Rolfe. Ministry for the Environment. 2000.

MfE, 1999. *Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand*. Ministry for the Environment. August 1999.

MfE, 1998. *Environmental Guidelines for Water Discharges from Petroleum Industry Sites in New Zealand*. Prepared by a joint working group of the Ministry of Environment, local authorities and the petroleum marketing companies. December 1998.

MfE, 1997. *The State of New Zealand's Environment 1997*. Published by Ministry for the Environment.

MOC, 1996. *Fuel Quality Monitoring in New Zealand 1989-1995*. Vallabh Patel Ministry of Commerce. 1996.

MOC, 1999. *Cetane Number of New Zealand Diesel*. Ministry of Commerce. April 1999.

MOT, 1997. *Stage 1 Carbon Monoxide Emissions From Petrol Vehicles*. Vehicle Fleet Emissions Control Strategy for local Air Quality Management. Ministry of Transport. September 1997.

MOT, 1998a. *Local Air Quality Management - Impacts from the road transport sector*. Vehicle Fleet Emissions Control Strategy - Final Report. Ministry of Transport November 1998.

MOT, 1998b. *Ambient Air Quality And Pollution Levels in New Zealand; Targets For Vehicle Emissions Control*. A technical report in support of the Vehicle Fleet Emission Control Strategy. Ministry of Transport. December 1998.

MOT, 1998c. *Traffic Corridor Air Quality Survey*. A technical report in support of the Vehicle Fleet Emission Control Strategy. Ministry of Transport. December 1998.

MOT, 1998d. *Traffic Network Analysis; Development Of An Integrated Environmental Capacity Analysis Procedure*. A technical report in support of the Vehicle Fleet Emission Control Strategy. Ministry of Transport. December 1998.

MOT, 1998e. *Vehicle Emissions Testing Programmes; Petrol And Diesel Vehicles*. A technical report in support of the Vehicle Fleet Emissions Control Strategy. Ministry of Transport. December 1998.

- MOT, 1998f. *Vehicle Fleet Emissions Model; New Zealand Vehicle Fleet Database And Model Development*. A technical report in support of the Vehicle Fleet Emission Control Strategy. Ministry of Transport. December 1998.
- MOT, 1998g. *Engines And Emissions; Processes And Technology Developments*. A technical report in support of the Vehicle Fleet Emission Control Strategy. Ministry of Transport. December 1998.
- MOT, 1999. *Summary of Submissions*.- Vehicle Fleet Emissions Control Strategy. Ministry of Transport. July 1999.
- MSA, 1998. *New Zealand Marine Oil Spill Risk Assessment 1998*, Woodward-Clyde (NZ) Ltd. for Maritime Safety Authority. December 1998.
- NZ Govt, 2001. *Cabinet Business Committee Minute of Decision on Transport and Climate Change*. CBC Min (01)1/4. 23 January 2001.
- NHT, 2000. *Setting National Fuel Quality Standards; Proposed Standards for Fuel Parameters (Petrol and Diesel)*. Revised Commonwealth Position. Natural Heritage Trust (Commonwealth of Australia). September 2000.
- PPSR, 1998. *Petroleum Products Specifications Regulations 1988*.
- RTF, 1999. *Road Transport FACTS*. Road Transport Forum New Zealand Incorporated. Undated (thought to be 1999).
- RTF, 2000. *Economy-Wide Impacts Of Changes In Freight Rates*. Infometrics Consulting. Prepared for Road Transport Forum of New Zealand. 2000.
- SAGG, 2001. *Draft Environment Protection (Motor Vehicle Fuel Quality) Policy 2000*. The South Australia Government Gazette. February 2001.
- Stevenson and Narsey. 1999. *Survey Of Benzene, And Other Toxic Organic Compounds in Air: July 1996 – May 1999 Summary Report*. CD Stevenson, H Narsey. Prepared as part of a Ministry of Health contract for scientific services. September 1999.
- US EPA, 1999. *Control of Diesel Fuel Quality. US EPA Advance notice of proposed rulemaking*. Federal Register (Vol 64/92). May 1999.
- WHO, 2000. *Transport, Environment and Health*. World Health Organisation. 2000. WHO Regional Publications, European series, No 89.
- Woodward-Clyde, 1996. *Petrol Vapour Exposure – Service Station Attendants and Tanker Drivers*. Woodward-Clyde (NZ) Ltd (now URS New Zealand Limited). Prepared for the Companies of the New Zealand Oil Industry. June 1996.
- Woodward-Clyde, 1997a. *Hydrocarbon and Carbon Monoxide Occupational Exposure Monitoring – Motor Trades*. Woodward-Clyde (NZ) Ltd (now URS New Zealand Limited). Prepared for Motor Trades Association. June 1997.
- Woodward-Clyde, 1997b. *Fuel Losses in Distribution*. Woodward-Clyde (NZ) Ltd (now URS New Zealand Limited). Prepared for Motor Trades Association. December 1997.
- WWFC, 2000. *World-Wide Fuel Charter*. World-Wide Fuel Charter Committee (European Automobile Manufacturers Association, Alliance of Automobile Manufacturers, Engine Manufacturers Association, Japan Automobile Manufacturers Association). April 2000.

# glossary

## Acute Exposure

Exposure of short duration, usually in the order of hours or minutes.

## Adverse effect

Any biochemical change, functional impairment, or pathological lesion which impairs and reduces the ability of an organism to respond to additional change.

## Alkanes

Also known as paraffins. Aliphatic hydrocarbons (ie. compounds having carbon atoms in chains rather than closed rings) of the general formula  $C_nH_{2n+2}$ .  $C_{1-4}$  (Methane, ethane, propane and butane) are gases at ambient temperatures and pressures; higher members are liquids (up to  $C_{16}$ ); and those above  $C_{16}$  are waxy solids.

## Alkenes

Also known as olefins. Aliphatic hydrocarbons of the general formula  $C_nH_{2n}$  containing one double bond. They closely resemble alkanes in physical properties.

## Alkylation

Alkylation is a refinery operation which takes smaller (more volatile) hydrocarbon molecules and converts them to larger (less volatile) ones. Specifically it reacts light olefins (alkenes) such as propene and butene with iso-butane to form iso-paraffins which are a good source of octane that does not contain olefins or aromatics. The Marsden Point Refinery does not have an alkylation plant but some Australian refineries do.

## Ambient Air

The air outside buildings and structures. It does not refer to indoor air, air in the workplace, or contaminated air discharged from a source.

## Aromatic

A hydrocarbon based on a six-membered benzene ring. Aromatic hydrocarbons were so called because some of these compounds have a pleasant "aromatic" odour. However, the term is now applied to those hydrocarbons based on a six-membered ring having three apparently conjugated double bonds. The simplest member is benzene. The aromatic rings can be fused together to give polynuclear aromatics (also called polyaromatic hydrocarbons) (PAHs).

## Benzene

This is the basic aromatic hydrocarbon. It has a high chemical reactivity and is highly volatile and flammable. Its ability to dissolve some rubbers leads to problems with gaskets in pumps and fuel lines. Benzene causes a number of human health problems, most notably cancer, and is toxic when inhaled, swallowed or absorbed through skin. However, it has a high octane rating.

## Carcinogenic Agent

Any substance that incites or produces cancer.

## Catalytic cracker (cat cracker)

A refinery processing unit. The most widely used method of producing gasoline from heavy petroleum distillates is to subject the heavy fractions to catalytic cracking. Fluidized bed catalytic cracking, where the powdered catalyst is moved through the system in a fluidized state, is now almost universally used.

Many catalysts have been used but the standard catalysts are generally mixtures of silica and alumina or natural or synthetic aluminium silicate zeolites.

The major product is gasoline but gases and light and heavy gas oils are produced in proportions depending on feedstocks and operational conditions. The gasoline obtained is usually of a fairly high octane number due to the high proportion of unsaturated hydrocarbons.

## Cetane Index (CI)

An approximation of Cetane Number based on an empirical relationship with API gravity and volatility parameters such as the mid-boiling point.

### **Cetane Number (CN)**

A measure of the fuel's ignition quality (suitability for spontaneous self-ignition in a diesel engine).

Because diesel engines dispense with an externally-generated ignition spark, the fuel must ignite spontaneously and with minimal delay (ignition lag) upon being injected into the hot, compressed air in the combustion chamber. The higher the cetane number, the greater the fuel's tendency to support self-ignition. The cetane number 100 is assigned to n-hexadecane (cetane), which ignites very easily, while heptamethyl nonane, with a low ignition quality, carries the cetane number 15. Cetane number is determined using a test engine.

### **Chronic Exposure**

Exposure which occurs over a long time, usually one or more years.

### **Cloud Point (CP) and Cold Filter Plugging Point (CFPP)**

CP is the temperature at which wax crystals start to precipitate out and the fuel becomes cloudy, according to the test method specified in ASTM D2500.

CFPP is the lowest temperature at which the fuel can pass through a standard test filter under standard test conditions.

The precipitation of paraffin crystals at low temperatures can result in fuel-filter blockages, ultimately leading to interruption of the fuel flow. Under unfavourable conditions paraffin particles can start to form at temperatures as high as 0°C. Special selection and manufacturing procedures are necessary for winter diesel fuels in order to ensure trouble-free operation in cold weather.

### **Density**

Mass of substance per unit volume. Density can provide useful indications of the fuel's composition and performance related characteristics such as ignition quality, power economy, low temperature properties and smoking tendency.

### **Diesel**

As defined in the Regulations: *A refined petroleum distillate having a viscosity and distillation range intermediate between those of kerosene and light lubricating oil, whether or not it contains additives, intended for use as fuel in internal combustion engines ignited by compression.*

### **Diurnal Loss**

The loss of fuel vapour from vehicles that results from the daily ambient temperature increase. Increases in fuel tank temperature causes enhanced vaporisation of liquid fuel and expansion and expulsion of the vapour stored in the tank.

### **Dose Response Curve**

A graphical representation of the quantitative relationship between the dose and a specific biological response.

Two approaches are followed in the dose-response evaluation: a threshold approach, and a non-threshold approach. In the threshold approach, it is assumed that a level exists below which no adverse effects are likely to occur (NOAEL), and above which the effect is related to dose. The aim of the dose-response evaluation is to identify the NOAEL for each health endpoint being considered.

The non-threshold approach assumes that there exists no threshold for adverse effects: there is a finite probability that some adverse effect will occur as a result of exposure at any level. This approach is usually applied to carcinogens. The aim of the dose-response evaluation is to determine a curve that relates the exposure dose or concentration to the probability of an effect occurring at that dose. The results of evaluation of carcinogenic risks are usually expressed as unit risk factors. The unit of risk is the additional risk of cancer incidence in a population from continuous lifetime exposure to a concentration of 1 mg/m<sup>3</sup> in the air breathed.

Health data can come from animal studies, opportunistic data from accidental or occupational human exposures, controlled human exposure studies, or epidemiological studies.

### **Driveability Index (DI)**

A measure of cold weather performance which is based on distillation parameters.

### **Emission**

The discharge of contaminants into air.

### **E70, E100 and E180**

The volume percentage of a liquid which evaporates up to 70°C, 100°C and 180°C respectively (ie. defines the evaporation characteristics of a liquid).

Highly volatile liquids boil at low temperatures and evaporate rapidly. Fuel must contain a large enough proportion of highly volatile components for good cold starts, but the volatility must not be so high as to impair operation (vapour lock) and starting when the engine is hot. In addition, environmental considerations demand that evaporative losses be held low.



### **Flexible Volatility Index (FVI)**

A measure of the likelihood of a gasoline to cause vapour lock in vehicles on the road (a combination of the Reid Vapour Pressure and the Percentage Evaporated at 70°C).

Vaporisation of the fuel in the supply line to the engine that prevents the fuel pump from delivering an adequate supply of fuel is known as vapour lock. Factors contributing to vapour lock are high ambient temperatures, low ambient pressure, volatile fuel and vehicle designs where heat from the engine can give high fuel line temperatures.

### **Fuel**

Diesel or petrol, as defined in the Regulations.

### **Gasoline Direct Injection (GDI)**

A developing technology for petrol engines of direct injection of petrol in the combustion chamber. This improves fuel economy by cooling the air-fuel charge (caused by the vapourisation of the fuel) which allows increase in compression ratio without reaching the knock limit. A significant improvement in efficiency is gained through stratified charge operation which allows fast rates of combustion despite overall lean air fuel ratios. This technology is not expected to be in the market until 2005+.

### **Genotoxic Agent**

Any substance that interferes with genes or gene structure.

### **Haemotoxic Agent**

Any substance that effects the blood or blood-forming tissues.

### **Hot Soak Loss**

The loss of fuel vapour immediately after the vehicle has been operated due to the input of residual pressure and heat into the fuel system. Hot soak emissions occur within one hour or less following vehicle shutdown.

### **Isomerase, Isomerism**

Compounds possessing the same composition and the same molecular weight, but differing in their chemical structure, are said to be isomeric, and each is an isomer of each other. Isomerisation is the conversion of a compound to an isomer of that compound.

### **Lead**

Added to petrol as a knock inhibitor and valve lubricant.

Organic lead compounds are the most cost effective knock inhibitors, particularly the lead-alkyl compounds tetraethylene lead (TEL) and tetramethylene lead (TML). These can raise the octane number by several points, with the exact amount of improvement depending upon the specific hydrocarbon combination.

Lead also serves as a valve lubricant in engines. There is a world-wide trend to eliminate lead from petroleum fuels because of the known adverse affects on general health.

### **Lean Burn**

When applied to air-fuel ratio in petrol engines, means that combustion occurs in a regime of excess air, similar to a diesel engine.

### **LOAEL**

Lowest Observed Adverse Effect Level: the lowest exposure level at which there are statistically or biologically significant increases in the frequency or severity of adverse effects between the exposed population and its appropriate control group.

### **Marine Use**

As defined in the Regulations: *The use or intended use of diesel on a boat or ship.*

### **Motor Octane Number (MON)**

A measure of the antiknock quality of a fuel as measured by ASTM D2700 or equivalent methods. It is a guide to the antiknock performance of a fuel under relatively severe driving conditions, such as can occur under full throttle, ie. when the inlet mixture temperature and the engine speed are both relatively high.

### **Naphtha**

A description of a light distillate feedstock for gas or petrochemical manufacture, boiling range generally about 40-150°C.

### **NOAEL**

No Observed Adverse Effect Level: the exposure level at which there are no statistically or biologically significant increases in the frequency or severity of adverse effects between the exposed population and its appropriate control group. Some effects may be produced at the level but they are not considered as adverse nor precursors to the adverse effects.



### Octane Number

A measure of petrol's antiknock quality, in other words its resistance to pre-ignition. The higher the octane number, the greater the fuel's resistance to knock.

When petrol vapour and air is compressed by the piston in the hot cylinder of an internal combustion engine, the hydrocarbons may be so easily oxidised that the mixture ignites before the spark is passed by the spark plug. This premature ignition is effectively a detonation which produces shock waves (a characteristic knocking or pinging sound), causing the engine to overheat and lose power.

Vehicles are designed for a certain octane value. Using a petrol with a lower octane rating than that required can cause damage to the engine. Using petrol with a higher octane rating than that required does not improve a vehicle's performance.

There are two main measures of octane number, the Research Octane Number (RON) and the Motor Octane Number (MON).

Colloquial use of the phrase octane number generally refers to the RON. In New Zealand, regular petrol is 91 RON; premium petrol is 95 RON. Higher octane fuels, such as 98 RON are available.

### Olefins

See alkenes.

### Oxygenates

As defined in the Regulations: *Alcohols and ethers added to fuel.*

### PAH or PCA

Polyaromatic or polycyclic hydrocarbons. Hydrocarbons with more than one aromatic ring. These include compounds such as naphthalene and benzo(a)pyrene.

### Paraffins

See alkanes.

### Petrol

As defined in the Regulations: *A refined petroleum distillate, normally boiling within the limits of 30°C to 220°C, whether or not it contains additives, intended for use in spark-ignition internal combustion engines.*

### Petroleum

As defined in section 2 (1) of the Crown Minerals Act 1991:

*Any naturally occurring hydrocarbon (other than coal whether in a gaseous, liquid, or solid state); or*

*Any naturally occurring mixture of hydrocarbons (other than coal) whether in a gaseous, liquid, or solid state; or*

*Any naturally occurring mixture or one or more hydrocarbons (other than coal) whether is a gaseous, liquid, or solid state, and one or more of the following, namely hydrogen sulphide, nitrogen, helium, or carbon dioxide –*

*And, except in sections 10 and 11, includes any petroleum as so defined which has been mined or otherwise recovered from its natural condition, or which has been mined or otherwise recovered but which has been returned to a natural reservoir for storage purposes in the same or an adjacent area.*

### Platformate

A high octane petrol blend stock produced through a reforming process using a platinum catalyst. The Marsden Point Refinery has a catalyst of this type.

### PM, PM<sub>10</sub>, PM<sub>2.5</sub>

Particulate matter (less than 10 or 2.5 microns; local air pollutant).

### Reid Vapour Pressure

The pressure exerted by the vapours derived from a liquid at a given temperature and pressure

### Research Octane Number (RON)

A measure of the antiknock quality of a fuel as determined by ASTM D2699 or equivalent methods. It is a guide to the antiknock performance of a fuel when vehicles are operated under mild conditions such as at low speeds and low loads.

When octane number is used colloquially, it is usually the RON which is being referred to (in NZ, 91 RON for regular petrol; 95 RON for premium petrol).

**Resting Loss**

The loss of vapour from the fuel system or the evaporative control system as a result of permeation through various non-metallic fuel system components (e.g. rubber vapour routing hoses), vapour migration allowed by design features such as open-bottom carbon canisters and evaporating liquid fuel leaks. Resting losses can be affected by ambient temperature changes but they are relatively constant in comparison with other types of vapour loss.

**Retail Sale**

As defined in the Regulations: *A sale to an end user who has no written supply agreement or written contract with the supplier in respect of the sale.*

**Running Loss**

The loss of fuel vapour while the engine is running. These losses occur when the rate of fuel vapour formation exceeds the capacity of the vapour storage and purge systems. The critical factors affecting running losses for vehicles with evaporative emission control systems based on carbon canisters, are fuel temperature and canister purging strategy. Typical sources of running losses include the vapour canister vent, the fuel cap and fuel tank pressure relief valves.

**Stoichiometric Ratio**

When applied to air-fuel ratio in petrol engines, means the amount of O<sub>2</sub> available is exactly equal to the amount required for complete combustion.

**Sulphur**

Sulphur is present to a greater or lesser extent in all crude oils and, consequently, sulphur compounds remain present in distillate streams used for petrol and diesel fuel blending.

Its presence in petrol and diesel is controlled for a number of reasons including its contributions to odour, its corrosivity, its antagonistic effect on lead based octane enhancers and the acidic by-products (ie sulphur dioxide and trioxide) formed during combustion. Sulphur significantly reduces the performance of most "tailpipe" emission control technologies, such as catalytic converters, and also affects heated exhaust gas oxygen sensors.

To reduce sulphur concentrations in fuels and emissions, sulphur must be removed from the source during the refining process.

**Threshold**

The dose or exposure below which an adverse effect is not expected.

**Unit Risk**

The upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 µg/litre in water, or 1 µg/m<sup>3</sup> in air.

## Appendix A

### How the Review was Undertaken

#### Contents

A.1	Terms of Reference
A.2	Information Sought
A.3	Interviews and Discussions
A.4	Technical Questions
A.5	Preparation of Draft Consultation Paper
A.6	Peer Review
A.7	Stakeholders Meeting
A.8	Public Consultation Document and Resource Document

### A.1 Terms of Reference

#### A.1.1 Introduction

*The Ministry of Economic Development is responsible for policy relating to energy resources and energy markets. In undertaking these responsibilities, the Ministry administers the Petroleum Products Specifications Regulations 1998, established under the Ministry of Energy (Abolition) Act 1989.*

*Market conditions are constantly changing. Since 1988, when the petroleum market was deregulated, the market has become increasingly competitive with the entry of new players. In addition, there have been ongoing policy developments both domestically and internationally that impact on how the market operates.*

Accordingly the Ministry initiated the Review of the specifications to ensure that consumers have access to the petroleum products they demand, and that these are affordable, of a reliable quality, and meet recognised standards. URS New Zealand Limited was contracted by the Ministry of Economic Development in December 2000 to undertake this work.

#### A.1.2 The Review Requirements

- 1. Undertake a Review of the Petroleum Products Specifications Regulations 1998, addressing the following issues:*
  - a. The purpose of the current specifications and whether this purpose is still appropriate*
  - b. Whether the specifications are meeting present needs or need to be revised*
  - c. Whether the specifications are relevant for the medium and long term*
  - d. Whether New Zealand needs a strategy for changing the specifications over time*
- 2. Present the Review in the form of a public consultation paper*
- 3. Include in the Review a discussion of:*
  - a. Environmental, health and safety issues and the most appropriate way of addressing them;*
  - b. The effect of the specifications on consumer access to petroleum fuel products;*
  - c. Whether the specifications create barriers to the development of new products and/or the adoption of new technology;*
  - d. Whether the specifications reflect international trends; and*
  - e. Changes in the wider legislative regime.*
- 4. Take into account in the Review:*
  - a. Government decisions relating to work undertaken by the Ministry of Transport and the Vehicle Fleet Emissions Control Strategy and by the Ministry for the Environment on ambient air quality; and*
  - b. The impact, if any, on the present of a competitive market for petroleum.*

## A.1.3 Underlying Principles

*The revised Regulations should ensure that:*

- *Regulation is avoided if there is little or no benefit to the consumer, the environment or public health;*
- *A conservative approach should be taken if the risk is still unknown or there is significant certainty;*
- *Innovation and responsiveness to consumer demands are promoted;*
- *Compliance costs are minimised;*
- *Flexibility to respond to developments in the domestic and international environment is achieved;*
- *Consistency with any international obligations, for example in relation to trade and the environment, is achieved;*
- *A competitive environment is promoted and that unjustified barriers in the petroleum industry (both domestic and international) do not result; and*
- *Consistency, where appropriate, with similar international petroleum product regulations is attained.*

The proposed changes outlined in Sections 7, 8 and 9 of the report have been tested against these principles.

## A.1.4 Overview of review process

*The Review is being undertaken by the Ministry of Economic Development, in association with the Ministry for the Environment, the Ministry of Transport, the Ministry of Health, and the Ministry of Consumer Affairs. The Review comprises the following steps:*

### *1. Information Gathering and Consultation Paper Preparation*

This Resource Document, and the companion Discussion Document (Petrol and Diesel – Delivering Quality) comprise the suite of consultation documents. A more detailed description of the process of preparing these documents is given in the following sections.

### *2. Public Consultation*

Public submissions on the proposed recommendations are sought, and should be forwarded to the Ministry of Economic Development by 15 October 2001. The Discussion Document contains a cut-out submission form and details on how to have your say.

### *3. Receipt and Analysis of submissions from the public*

### *4. Presentation to the Associate Minister of Energy and Cabinet Ministers of findings and public consultation*

### *5. Finalisation of policy and changes to the regulations*

### *6. Promulgation of amendments*

## A.2 Information Sought

A review of documentation, technical papers and other relevant material was undertaken to identify key issues within New Zealand, additional information sources and overseas trends.

The information initially sought in this search comprised:

- Background to and experience with the current specifications, and the significance of specified parameters;
- Issues driving change internationally and their relevance to New Zealand;
- International trends in policy, fuel specifications, engine and fuel technology, refining and processing capability;
- Options for regulation together with an analysis and evaluation of the attendant risks;
- Information on the likely impacts of changes (eg. vehicle performance, economic, environmental, health);
- Information on vehicles and fuels as they exist in the New Zealand context;
- Environmental, health and regulatory information in respect of petrol and diesel use in New Zealand;

## A.3 Interviews and discussions

Information gathering to define the key issues was undertaken in a series of interviews, either in person or by telephone. Due to the potential for changes to the Regulations to have an impact on a wide range of interested parties, these initial informal discussions canvassed a relatively broad group of people and organisations covering the general categories below, though it was by no means intended to be exhaustive.

- *Government agencies (local and national)*  
To identify other research related to this work and to identify key issues.
- *Fuel suppliers (oil companies)*  
Significantly affected by any changes to the specifications, due to their role as producers and suppliers of petroleum products. It was considered that they may also be able to provide information on marketing and pricing issues arising out of possible future “greener” specifications for existing fuels.
- *The New Zealand Refining Company Limited.*  
Operators of the Marsden Point Refinery, the only refinery operating in New Zealand.
- *Consumer Groups*  
These groups provide a “watch dog” role in respect of consumers or specific user groups.
- *Vehicle manufacturers and associated motor industry organisations*
- *Other Interested Parties*  
Organisations or individuals who expressed a wish to contribute at this stage or who were referred to URS as having a specific interest.

Stakeholders contacted at this stage include the following:

Anchor Ethanol Limited	Gull Petroleum New Zealand Limited
Auckland Regional Council	Industrial Research Limited
Australian Institute of Petroleum	Land Transport Safety Authority (LTSA)
Automobile Association (AA)	Maritime Safety Authority
BP Oil New Zealand Limited	Ministry for the Environment
Bus and Coach Association	Ministry of Consumer Affairs
Caltex New Zealand Limited	Ministry of Health
Challenge Petroleum	Ministry of Transport
Consumers’ Institute of New Zealand	Mobil Oil New Zealand Limited
Energy Efficiency and Conservation Authority (EECA)	Motor Industry Association
Environmental Risk Management Authority (ERMA)	Motor Trade Association
Environment Canterbury	Occupational Safety & Health Service ( <i>part of Department of Labour</i> )
Environment Waikato	New Zealand Refining Company Limited (NZRC)
Energy Efficiency and Conservation Authority (EECA)	Road Transport Forum
Ford Motor Company	Shell New Zealand Limited

## A.4 Technical Questions

A list of technical questions was then prepared and formal responses from NZRC and the six fuel supply companies sought. These questions addressed possible changes to specified properties of petrol and diesel and the technical and logistical feasibility of implementing those changes.

## A.5 Preparation of Draft Paper

The information gathering process led to the preparation of a draft paper (similar to the structure and content of this document) containing an initial set of proposed changes to the Regulations and specifications.

## A.6 Peer Review

The draft paper was reviewed by an external expert panel comprising people with expertise in vehicle technology, air quality and environmental and consumer issues.

The peer review group comprised:

Professor Ray Meyer (Chair)	formerly Dean of Engineering, University of Auckland and energy and engineering specialist, formerly chairperson of Consumers Institute, member of Standards NZ council.
Wallace Simmers	Simmers and Associates, Wellington
Peter Waring	formerly Principal Engineer, Compliance, Land Transport Safety Authority (LTSA) and motor vehicle and fuels specialist
Dr. Gerda Kuschel	Regional Manager, National Institute of Water and Atmospheric Research Ltd. (NIWA)

The draft paper was also independently reviewed by the Review Interdepartmental Advisory Committee and the Ministry of Economic Development.

## A.7 Stakeholders Meeting

Following the peer review, the proposed changes were revised and summarised, and distributed to a wider range of stakeholders. A stakeholders meeting was convened in late June, at which a presentation on the proposals was made. This provided an opportunity for further stakeholder input ahead of the release of the public consultation documents.

## A.8 Public Discussion Document and Resource Document

This Resource Document, and the companion Discussion Document (Petrol and Diesel – Delivering Quality) comprise the suite of consultation documents for public review. Public submissions on the proposed recommendations are sought, and should be forwarded to the Ministry for Economic Development by 15 October 2001. The Discussion Document contains a cut-out submission form and details on how to have your say.

# Appendix B

## Petroleum Products Specifications Regulations 1998

Michael Hardie Boys, Governor-General

Order in Council

At Wellington this 14th day of September 1998

*Present:*

The Right Hon. Jenny Shipley presiding in Council

Pursuant to the Ministry of Energy (Abolition) Act 1989, His Excellency the Governor-General, acting by and with the advice and consent of the Executive Council, makes the following regulations.

### Analysis

1.	Title and commencement	<b>Schedules</b>
2.	Interpretation	Schedule 1
3.	Requirements relating to fuel sold by retail	Requirements for Regular Grade Petrol
4.	Requirements relating to all fuel	Schedule 2
5.	Test procedures	Requirements for Premium Grade Petrol
6.	Sampling of fuel, etc	Schedule 3
7.	Accreditation	Requirements for Diesel
8.	Withdrawal of fuel from sale, etc	
9.	Offences	
10.	Revocations	

### Regulations

1. **Title and commencement** – (1) These regulations may be cited as the Petroleum Products Specifications Regulations 1998.  
(2) These regulations come into force on the 28th day after the date of their notification in the Gazette.

2. **Interpretation** – (1) In these regulations, unless the context otherwise requires, –  
“Diesel” means a refined petroleum distillate having a viscosity and distillation range intermediate between those of kerosene and light lubricating oil, whether or not it contains additives, intended for use as fuel in internal combustion engines ignited by compression:  
“Fuel” means diesel or petrol:  
“Marine use” means the use or intended use of diesel on a boat or ship:  
“Oxygenates” means alcohols and ethers added to fuel:  
“Petrol” means a refined petroleum distillate, normally boiling within the limits of 30°C to 220°C, whether or not it contains additives, intended for use as a fuel in spark-ignition internal combustion engines:  
“Petroleum” has the same meaning as it has in section 2 (1) of the Crown Minerals Act 1991:  
“Retail sale” means a sale to an end user who has no written supply agreement or written contract with the supplier in respect of the sale.

- (2) In these regulations, –  
“ASTM” means the American Society for Testing and Materials:  
“BS” means British Standard:  
“DIN” means the German Institute for Standardisation:  
“IP” means the Institute of Petroleum, London:  
“ISO” means the International Organization for Standardization.

- (3) In these regulations, the letter “D” and a series of numerals, or a series of numerals immediately following an expression referred to in subclause (2), means the latest version of the document identified by that serial number.

- (4) Where a test method prescribed in these regulations provides for a joint method, each of the alternative methods have equal standing, and either of those methods may be used.

3. **Requirements relating to fuel sold by retail** – (1) The requirements imposed by subclauses (2), (3), and (4) apply to all fuel, however described, supplied, or available or intended for supply, by way of retail sale, except to fuel that is to be used –

- (a) As an aviation fuel; or
- (b) For motor car racing; or
- (c) For powerboat racing and jet boats; or
- (d) For motorcycle racing.

(2) Regular grade petrol must have properties that conform to the limits specified in Schedule 1, when tested by the methods specified in that schedule.

(3) Premium grade petrol must have properties that conform to the limits specified in Schedule 2, when tested by the methods specified in that schedule.

(4) Diesel must have properties that conform to the limits specified in Schedule 3, when tested by the methods specified in that schedule.

**4. Requirements relating to all fuel** – (1) The requirements imposed by subclauses (2), (3), and (4) apply to all fuel supplied or available or intended for supply (whether by way of sale or otherwise) for any end use other than –

- (a) As an aviation fuel; or
- (b) For motor car racing; or
- (c) For powerboat racing and jet boats; or
- (d) For motorcycle racing.

(2) Regular grade petrol must have properties in respect of sulphur, lead, benzene, and total aromatic compounds that conform to the limits specified in Schedule 1, when tested by the methods specified in that schedule.

(3) Premium grade petrol must have properties in respect of sulphur, lead, benzene, and total aromatic compounds that conform to the limits specified in Schedule 2, when tested by the methods specified in that schedule.

(4) Diesel must have properties in respect of sulphur that conform to the limit specified in Schedule 3, when tested by the methods specified in that schedule.

**5. Test procedures** – (1) The procedure for obtaining a representative sample of fuel for testing by the test methods set out in these regulations is set out in Part 1 of BS 3195 and in Section 2.2 of BS 4040, Section 3 of BS EN 228, and Section 3 of BS EN 590.

(2) In the event of a dispute as to the appropriate value, nature, or rating of any of the properties listed in the schedules or referred to in these regulations, the relevant procedures specified in ISO 4259 are to be used to interpret the laboratory results.

**6. Sampling of fuel, etc** – The importer or wholesale supplier or retailer of any fuel to which these regulations apply must, at the request of a person authorised by the Secretary,

- (a) Permit the authorised person to take a sample of the fuel before it is discharged from a vessel or pipeline or pump for distribution or sale; or
- (b) In the case of an importer or wholesale supplier, supply the authorised person with a certificate describing the properties and value of any such fuel.

**7. Accreditation** – A person authorised by the Secretary to take samples or to conduct testing of fuel for compliance with these regulations must, unless the person is an employee of the Ministry of Economic Development, be ISO 9001 certified for fuel sampling or testing, or be accredited by International Accreditation New Zealand, or by an overseas accreditation agency recognised under New Zealand's mutual recognition arrangements.

**8. Withdrawal of fuel from sale, etc** – If the Minister is satisfied that the properties of any fuel to which these regulations apply do not comply with the relevant provisions of these regulations, the Minister may, by written notice given to any distributor of the fuel, require the distributor to –

- (a) Withdraw the fuel from retail sale or cease making it available for retail sale; or
- (b) Withdraw the fuel from availability, or cease making it available, for any end use, other than use as an aviation fuel.

**9. Offences** – A person commits an offence and is liable on summary conviction to a fine not exceeding \$10,000 who –

- (a) Supplies, or makes available for supply, any fuel other than in accordance with regulation 3 or regulation 4; or
- (b) Fails to comply with a request made under regulation 6; or
- (c) Fails to comply with a requirement made under regulation 8.

**10. Revocations** – The following regulations are consequentially revoked:

- (a) The Petroleum Products Specifications Regulations 1995
- (b) The Petroleum Products Specifications Regulations 1995, Amendment No.1
- (c) The Petroleum Products Specifications Amendment Regulations 1997

*S.R. 1995/270*  
*S.R. 1996/51*  
*S.R. 1997/29*



# Schedules

## Schedule 1

Regs. 3 (2), 4 (2)

Requirements for Regular Grade Petrol

Property	Limit	Test Method
Research octane number	91.0 minimum	ASTM D 2699
Motor octane number	82.0 minimum	ASTM D 2700
Colour	Not to be mistaken for a harmless substance	Visual
Percentage volume evaporated at 70°C (E 70)	25 minimum 45 maximum	ASTM D 86
Percentage volume evaporated at 100°C (E 100)	45 minimum 67 maximum	ASTM D 86
Percentage volume evaporated at 180° (E 180)	90 minimum	ASTM D 86
End point (degrees Celsius)	220 maximum	ASTM D 86
Residue (percentage volume)	2 maximum	ASTM D 86
Flexible volatility index [RVP (kPa) + (0.7 X E 70)] <sup>1</sup>	77.5 minimum 115.0 maximum	ASTM D 323 and ASTM D 86
Copper strip corrosion (2 hours at 100°C)	Class 1 maximum	ASTM D 130
Sulphur (percentage mass)	0.05 maximum	ASTM D 1266 or IP 336
Existent gum (solvent washed) (mg/100ml)	5 maximum	ASTM D 381
Oxidation stability induction period (minutes)	240 minimum	ASTM D 525
Lead (grams per litre)	0.013 maximum	IP 224
Benzene (percentage mass)	5 maximum	ASTM D 5580
Total aromatic compounds (including benzene) (percentage volume)	48 maximum	ASTM D 5580
Oxygenates (percentage mass) <sup>2</sup>	0.1 maximum	DIN 51 413-01

<sup>1</sup> Specifications cover broad range of summer and winter grades.

<sup>2</sup> Does not apply where the added oxygenate is methyl tertiary butyl ether (MTBE). Up to 11% volume MTBE may be added.

## Schedule 2

Regs. 3 (3), 4 (3)

Requirements for Premium Grade Petrol

Property	Limit	Test Method
Research octane number	95.0 minimum	ASTM D 2699
Motor octane number	85.0 minimum	ASTM D 2700
Colour	Not to be mistaken for a harmless substance	Visual
Percentage volume evaporated at 70°C (E 70)	25 minimum 45 maximum	ASTM D 86
Percentage volume evaporated at 100°C (E 100)	45 minimum 67 maximum	ASTM D 86
Percentage volume evaporated at 180°C (E 180)	90 minimum	ASTM D 86
End point (degrees Celsius)	220 maximum	ASTM D 86
Residue (percentage volume)	2 maximum	ASTM D 86
Flexible volatility index [RVP (kPa) + (0.7 X E 70)] <sup>1</sup>	77.5 minimum 115.0 maximum	ASTM D 323 and ASTM D 86
Copper strip corrosion (2 hours at 100 degrees Celsius)	Class 1 maximum	ASTM D 130
Sulphur (percentage mass)	0.05 maximum	ASTM D 1266 or IP 336

Existent gum (solvent washed) (mg/100ml)	5 maximum	ASTM D 381
Oxidation stability induction period (minutes)	240 minimum	ASTM D 525
Lead (grams per litre)	0.013 maximum	IP 224
Benzene (percentage mass)	5 maximum	ASTM D 5580
Total aromatic compounds (including benzene) (percentage volume)	48 maximum	ASTM D 5580
Oxygenates (percentage mass) <sup>2</sup>	0.1 maximum	DIN 51 413-01

<sup>1</sup> Specifications cover broad range of summer and winter grades.

<sup>2</sup> Does not apply where the added oxygenate is methyl tertiary butyl ether (MTBE). Up to 11% volume MTBE may be added.

## Schedule 3

Regs. 3 (4), 4 (4)

Requirements for Diesel

Property	Limit	Test Method
Density at 15°C (kg per litre)	0.810 minimum 0.860 maximum	ASTM D 1298
Appearance at 15°C	Clear and bright	ASTM D 4176(B)
Colour (ASTM colour)	3.0 maximum	ASTM D 1500
Cetane number or Cetane index	45 minimum 47 minimum	ASTM D 613 ASTM D 976
Cloud point (degrees Celsius) <sup>1</sup> - Summer	4 maximum	ASTM D 2500
Cloud point or Cold filter plugging point (CFPP) (degrees Celsius) <sup>2</sup> - Winter	-6 maximum	ASTM D 2500 or IP 309
Viscosity (centistokes at 40°C)	1.50 minimum 5.00 maximum	ASTM D 445
Flash point (degrees Celsius)	61 minimum	ASTM D 93
Sulphur (percentage mass) <sup>2</sup>	0.30 maximum	IP 242
Copper strip corrosion (3 hours at 100°C)	Class 1 maximum	ASTM D 130
Ash (percentage mass)	0.01 maximum	ASTM D 482
Carbon residue-Ramsbottom on 10% volume residuum (percentage mass)	0.20 maximum	ASTM D 524
Distillation-85% volume recovered to (degrees Celsius)	350 maximum	ASTM D 86

<sup>1</sup> Applies at time of manufacture in New Zealand or, for imports, date of discharge into port storage at a New Zealand port. Summer: 1 September to last day of February. Winter: 1 March to 31 August. Sales for marine use may be summer grade at any time of the year.

<sup>2</sup> The limit for sulphur does not apply to sale for marine use.

Marie Shroff, Clerk of the Executive Council.

## Explanatory Note

*This note is not part of the regulations, but is intended to indicate their general effect.*

These regulations consolidate and amend the Petroleum Products Specifications Regulations 1995 and its amendments.

The regulations come into force on the 28th day after the date of their notification in the *Gazette*.

They specify technical requirements to be met by petroleum fuels distributed in New Zealand.

The substantive changes implemented by these regulations are as follows:

(a) To remove any specific colouring requirements for petrol, and substitute the requirement that petrol be coloured to distinguish it from a harmless substance. Currently, regular grade petrol has to be purple/bronze (Schedule 1) and premium grade petrol has to be yellow (Schedule 2):

- (b) Changes to test methods for lead, sulphur, benzene, and total aromatic compounds (Schedules 1 and 2):
- (c) Regular grade petrol is required to comply with the 48% volume limit for total aromatic compounds which was formerly imposed only on premium grade petrol (Schedule 1):
- (d) The removal of the exemption for the retail sale of premium grade petrol from compliance with the 48% volume limit for total aromatic compounds (current regulations 3 (3A) and 4 (3A)):
- (e) Certain changes to test procedures (regulation 5):
- (f) A certification requirement for any person, other than a Ministry of Economic Development employee, sampling or testing fuel for the Ministry of Economic Development (regulation 7):
- (g) An increase in the maximum fine level for an offence from \$1,000 to \$10,000 (regulation 9).

Issued under the authority of the Acts and Regulations Publication Act 1989.

Date of notification in *Gazette*: 17 September 1998.

These regulations are administered in the Ministry of Commerce.

# Appendix C

## Internal Combustion Engine Basic Operating Principles and Technology Trends

- C.1 Basic Operating Principles
- C.2 Relative Efficiency of Diesel and Petrol Engines
- C.3 Engine Design
- C.4 Diesel Engine Technology
- C.5 Petrol Engine Technology
- C.6 Bibliography
- C.7 Acknowledgements

This Appendix outlines the basic operation of petrol and diesel engines, and how this relates to basic fuel characteristics. The impact of engine design factors and condition on fuel consumption and emissions is presented. The trends and technologies employed to minimise fuel consumption and emissions, and the impacts on fuel quality requirements of these technologies are reviewed.

### C.1 Basic Operating Principles

Internal combustion engines convert chemical energy contained in fuel into mechanical power. The combustion process is, however, quite different between a petrol engine and diesel engine, and this impacts on the required properties of the fuel for each type of engine. Although it is common to refer to engines as either petrol or diesel, the more correct distinction is between the nature of the ignition and combustion. The relative quantities of the various exhaust emission materials that are formed vary as a result of the difference in the combustion process.

In petrol engines the air and fuel are usually premixed before initiation of combustion, and the mixture then burns progressively as a flame front moves across the combustion chamber. In diesel engines the fuel burns primarily as a diffusion flame as the injected fuel mixes with air to produce a combustible mixture. The respective fuels have developed to suit the requirements of each type of combustion process, rather than by their nature defining the combustion process.

In addition to classification by fuel/combustion type, engines may further be described by the number of piston strokes to complete a full cycle. Thus a **four cycle**, or **four stroke engine**, performs the four basic phases of a cycle, induction, compression, combustion and expansion, and exhaust in four piston strokes. A **two stroke engine** performs the four basic phases of operation condensed into two piston strokes. Two stroke spark ignition engines have historically had significantly higher fuel consumption and exhaust emissions, but higher power to weight ratio, and are therefore primarily used in small mobile equipment and motor cycles.

#### C.1.1 Diesel Engines (Compression Ignition)

**Light-duty (LD)** diesel engines are generally defined as of displacement less than 4.0 litres and power output of up to 100 kW, and are characterised by relatively high engine speeds of up to 5000 rpm. LD engines would normally be found in passenger vehicle and light commercial vehicle applications.

**Heavy duty (HD)** diesel engines may be generally defined as of displacement greater than 8 litres and power outputs of greater than 150 kW with maximum engine speeds of less than 3000 rpm. HD engines are found in heavy road transport, industrial and marine applications. Medium duty engines fill the gap in the middle and are found in medium size trucks, buses and light industrial equipment.

A **diesel engine** is referred to as a **compression ignition engine**. Air alone is drawn into the cylinder on the downward induction stroke of the piston. No throttling of the intake is used; therefore, for a non-turbocharged engine, the amount of air drawn into the cylinder at a certain engine speed is relatively independent of the engine output, or load. The air is compressed and therefore heated in the combustion chamber before injection of the fuel which, as a result of the temperature and pressure within the combustion chamber, spontaneously ignites shortly after it is injected. The amount of fuel injected is varied to change the output power of the engine.

Fuel may be injected either directly into the main combustion chamber formed between the piston and the cylinder head, termed **direct injection (DI)**, or into a smaller separate prechamber located in the cylinder head, and connected to the main combustion chamber by a small passage. This second configuration is termed **indirect injection (IDI)**. The IDI system achieves high mixing rates as the fuel injected into the prechamber ignites and the expanding gases pass through the orifice in a high-speed jet. This allows higher engine speeds to be utilised and thus IDI is used extensively for small light-duty engines, while DI engines are used almost exclusively in larger heavy-duty engines that operate at lower engine speeds.

The fuel is injected under high pressure (of order 30-100 MPa) through fine holes to form a spray of fuel droplets that are typically of order 10-50 $\mu$ m in diameter. This must mix with the air in the combustion chamber until the local air-fuel ratio is within flammability limits before combustion can occur. The time taken from the start of injection to the start of combustion is termed the ignition delay.

Once ignition occurs the portion of the fuel injected that has mixed to a flammable air-fuel ratio burns rapidly in **premixed** combustion. This rapid combustion of the initial portion of the charge causes a rapid pressure rise and causes the characteristic “diesel knock”. It is desirable to minimise the ignition delay and resulting proportion of premixed combustion in order to reduce the intensity of diesel knock. The autoignition characteristic of the diesel fuel, specified by the cetane number, is an important parameter contributing to the time taken to initiate combustion after fuel injection. A higher cetane number reduces the ignition delay and the premixed combustion.

The rate of subsequent diffusion combustion is primarily controlled by the rate of injection of fuel and the rate of mixing of the fuel in the air. The rate of mixing is in turn dependent on the motion of the air in the combustion chamber and fuel injection parameters such as injection pressure and number and size of injector holes. These are therefore important design parameters in order to maximise the efficiency of diesel engine combustion and reduce emissions.

## C.1.2 Petrol Engines (Spark Ignition)

In contrast, a petrol engine is defined as a **spark ignition engine**. Air and fuel are normally mixed together in the intake, and compressed in the combustion chamber. As the air-fuel ratio needs to be kept within certain flammability limits, the intake of the mixture is throttled to change the engine output, while the air-fuel ratio is kept relatively constant. The correct amount of fuel is metered into the incoming airstream by either a carburettor or by fuel injection. A timed spark ignites the air-fuel mixture which then burns progressively but rapidly across the combustion chamber. The timing of the spark is adjusted over the range of operating conditions, and the optimum timing is dependent on factors such as the combustion chamber geometry, compression ratio and fuel octane rating. Spark timing and the air-fuel ratio have strong effects on the efficiency and emissions produced by spark ignition engines.

The fuel is required to evaporate in order to be mixed thoroughly with the air prior to combustion, and needs to resist autoignition (or “knock”) as the mixture is compressed. Therefore essential characteristics of the fuel include appropriate volatility and resistance to premature ignition (measured by the octane rating). A higher octane fuel is more resistant to knock. In terms of engine performance, carburettor equipped engines are generally more sensitive to fuel volatility.

Two stroke engines may have lower octane requirements than four stroke, but are also more prone to spark plug fouling and combustion chamber deposit formation. Petrol specification impacts on this problem, however any changes (improvements) in petrol specifications are more likely to provide benefit in this area rather than cause additional problems.

## C.2 Relative Efficiency of Diesel and Petrol Engines

The overall efficiency of internal combustion engines may be defined as the ratio of useful work output to the amount of fuel energy consumed.

As the diesel engine operates on the self-ignition principle (achieved by the high pressure and temperature in the chamber) the compression ratio is much higher than in the case of a petrol engine. The requirement to prevent uncontrolled combustion (commonly experienced as “knock”) in a petrol engine limits the compression ratio. The compression ratio for a diesel engine is normally around 15-20 whereas for a petrol engine it is in most cases between 8 and 10. The high compression ratio of the diesel engine is one reason for its higher efficiency. The octane rating of the petrol has a direct influence of the maximum compression ratio that can be used in petrol engines.

The unthrottled intake of the diesel engine also contributes to an efficiency advantage over the spark ignition engine, by decreasing the work required to “pump” the charge in and out of the engine. Heat losses from diesel engines are less at part loads also, as the overall gas temperature in the combustion chamber is lower, and this also contributes to the efficiency advantage over petrol engines.

These factors combine to give diesel engines approximately a 15 to 25% increase in efficiency over spark ignition engines, and about the same percentage improvement in fuel economy over comparable sized vehicles powered by petrol engines whilst sacrificing some acceleration and maximum speed performance.

### C.3 Engine Design

Over the history of the internal combustion engines, the design of both petrol and diesel engines has evolved, initially to meet demands for increased performance, fuel consumption and driveability, but in the past few decades primarily driven by legislated requirements to reduce emissions. Current and future European and United States legalisation requires large reductions in emissions, while increasing concerns of global warming continue to drive the need for improved fuel efficiency and hence reduced CO<sub>2</sub> emissions.

The regulated emissions species of internal combustion engines are carbon monoxide (CO), unburnt hydrocarbons (HC), oxides of nitrogen (NO<sub>x</sub>), and for diesel engines particulate matter (PM). In the ideal situation, all of the carbon in the fuel would be oxidised to CO<sub>2</sub>, while all the hydrogen would be oxidised to H<sub>2</sub>O. CO, HC and PM are products of incomplete combustion which may occur due to a rich mixture and/or inefficient combustion. NO<sub>x</sub> is formed in the high temperature burnt gases in the combustion chamber by reactions between oxygen and atmospheric nitrogen. NO<sub>x</sub> formation is highly sensitive to temperature, time and oxygen concentration.

For diesel engines the current and future challenge is to significantly reduce emissions of PM and NO<sub>x</sub>, while for petrol engines significant reductions of all regulated emissions are required. Section C.4 and C.5 describe some of these technical developments and their impact on fuel efficiency and emissions for diesel and petrol engines respectively. Future developments to meet the proposed large reduction in emissions required are also discussed.

### C.4 Diesel Engine Technology

Engine design technologies which impact on the fuel efficiency and emissions of diesel engines are summarised below.

Table C.1: Diesel Engine Technology

Mechanical Design Features/Technology	Fuel Sensitivity <sup>1</sup>	Status <sup>2</sup>	
		Light-duty	Heavy-duty
Multi-valve heads	None	Production	Production
Variable valve timing	None	Emerging	N/A
Turbocharging and after/intercooling	Low	Production	Production
Combustion chamber/charge air motion optimisation	Low	Production	Production
<b>Engine Control Technology</b>			
Electronic engine management	Low	Emerging	Production
Common rail injection	Low	Production	Production
Exhaust gas recirculation	Low	Production	Emerging
<b>Exhaust Aftertreatment</b>			
Oxidation catalysts	High (S<500 ppm)	Production	Production
Particulate filters/traps	High (S<30 ppm)	Emerging	Emerging
NO <sub>x</sub> reduction technology	High (S<30 ppm)	Emerging	Emerging

1. Low fuel sensitivity means that effectiveness of the technology can be enhanced to a small degree by the optimisation of the fuel specification

2. Production means widely available now, however may be still undergoing development and achieving greater sophistication. Emerging means under final stages of development and starting to be introduced into production

## C.4.1 Mechanical Design

In general, all the mechanical design developments discussed here do not have significant impacts on fuel specification requirements.

### Friction

Continuing small incremental improvements are being made to reduce the energy losses to friction within engines. Modern designs are highly evolved in this area, and hence future gains are likely to be limited to of order a few percent. Future developments for diesel engines are likely to include the increased use of roller cam followers and overhead camshafts, and low friction bearing and piston design.

### Volumetric Efficiency

Volumetric efficiency is the measure of how completely an engine cylinder is filled with air or air-fuel mixture in each operating cycle. A volumetric efficiency of 100% means that in each operating cycle the engine cylinders are completely filled with mixture at atmospheric pressure. Improved volumetric efficiency and air availability improve the performance of diesel engines in several ways.

Pumping losses are typically reduced with features that improve volumetric efficiency, resulting in small improvements in overall engine efficiency. The increased air availability means that more fuel may be burnt, thus increasing power density. Hence engine size for a specific application may be reduced, which typically will result in higher overall efficiency when operating at the same loads. The greater air availability may also be used to increase excess air to ensure complete combustion and lower combustion chamber temperatures, leading to reduced emissions of all regulated species. The term excess air refers to air availability in the cylinder in excess to that theoretically required to burn all HC to CO<sub>2</sub> and H<sub>2</sub>O. Where the generalisation “reduced emissions” is used in this discussion, there is some beneficial impact on all species, but the magnitude may vary between species.

Several technologies have developed to increase volumetric efficiency:

**Multi-valve cylinder heads** have become common on heavy-duty diesel engines and are starting to become more prevalent in light-duty applications also.

**Variable valve timing** offers increased volumetric efficiency and torque increases across the entire speed range. Control of residual burnt gas remaining in the cylinder from the previous cycle is possible by control of valve overlap, and this can reduce NO<sub>x</sub> emissions in the same manner as exhaust gas recirculation (EGR). This technology offers greater potential to light-duty engines, where the higher speed range over which they operate results in a greater compromise when fixed valve timing is used, than to heavy-duty.

**Turbocharging** is now common with both heavy-duty and light-duty engines. This provides significantly increased air for combustion resulting in higher power outputs, and can contribute to reduced emissions and specific fuel consumption through increasing excess air. Significant advances have been made in turbocharging technology resulting in higher boost pressures, greater efficiency and improved engine response and hence driveability. Current and future development is in variable geometry turbochargers and electronic boost control.

Associated with turbocharging, **aftercooling** and **air to air intercooling** of the boosted intake air has become almost universal in modern engines. This increases air availability for combustion by increasing the density of the intake air. This also results in higher power density and improved efficiency. NO<sub>x</sub> emissions are decreased by the reduction in combustion temperatures.

## C.4.2 In-Cylinder Air Motion and Combustion Chamber Design

The design of the inlet tract and combustion chamber has a major influence on the performance and particularly, emissions, of diesel engines. A high level of air motion and turbulence is required within the combustion chamber in order to promote rapid and complete mixing of the injected fuel with air to combustible proportions. It is desired to optimise the in-cylinder air motion to provide smooth, complete combustion within the time available, and to minimise resulting emissions. However there are often volumetric efficiency tradeoffs in some design approaches to generating the desired air motion.

The combustion chamber contributes to the air motion achieved, and is also required to be as compact as possible with minimal crevices and quench areas where fuel may escape complete combustion. There are many ways of achieving this and many types of air motion including swirl, tumble, reverse tumble, and swish, and combinations of these.

Continual developments in design techniques have contributed significantly to reduced fuel consumption. Emissions have decreased by an order of magnitude over the last 20 years as a result of improved air motion and chamber design, in conjunction with improved fuel injection. Extensive research efforts continue and ever more sophisticated modelling

techniques are developing in this area. Small fuel consumption benefits will continue to be gained along with larger emission reductions.

Recent significant developments in the area of combustion chamber design include the application of direct injection (DI) designs to light-duty engines. Historically high (engine) speed light-duty engines have been required to be of indirect injection (IDI) design in order to provide high enough levels of charge air motion to mix and combust the fuel in the short time available. DI engines offer reductions of 10-20% in fuel consumption and improved emission control over IDI engines. Heavy-duty engines are almost exclusively of DI design.

### C.4.3 Engine Control Technology

#### Fuel Injection Systems

The design of the fuel injection system is an area where significant improvements have been gained in the last 10-15 years. Diesel injection pressures have increased to of order 150-200 MPa using electronically controlled unit injectors (HD engines) and injectors have tended towards multiple smaller orifices. This results in improved fuel atomisation and mixing with the compressed air within the cylinder, and ability to vary injection timing to a greater degree than mechanically controlled systems. This has resulted in significant reductions in PM mass emissions of up to 60%, and smaller reductions in HC and NO<sub>x</sub>. However the size of particles generated has decreased and there is growing concern that the number of ultra fine particles may be more important than particle total mass in determining health impacts.

#### Electronic Injection Controls and Common Rail Injection Systems

Greater control over injection timing through electronic control has become common in modern HD engines, and this technology is now being applied to LD engines also. Much research is being conducted in systems to provide injection rate shaping and multiple injections to further control the combustion process. The latest technology currently emerging is that of common rail systems. In these systems high pressure diesel is supplied to all injectors continuously via a "common rail" and the individual injectors are electronically actuated. Very high speed actuation allows for precise timing of the injection and for techniques such as pilot injection and multiple injections.

The decoupling of the generation of the injection pressure from engine speed allows high pressures to be consistently available even at low engine speeds. This technology provides significant decrease in combustion noise, NO<sub>x</sub> and PM emissions, and allows for "post" injection late in the combustion process to enable the use of emission aftertreatment technologies such as passively regenerating PM traps and NO<sub>x</sub> adsorbers. These systems are now entering the market in LD vehicles but are also applicable to HD applications.

#### Exhaust Gas Recirculation

Exhaust gas recirculation (EGR) has been used for many years in both petrol and diesel LD engines to reduce NO<sub>x</sub> emissions by diluting the charge air/fuel mixture and thereby reducing peak gas temperatures and decreasing oxygen concentrations. A portion of the exhaust gas is recirculated to the combustion chamber through a control valve and mixed with the incoming air in the inlet system. The application of EGR is being continuously refined with more sophisticated electronic systems to give greater control over EGR ratios, and thereby further reducing NO<sub>x</sub>. In order to meet future emission regulation levels this technology is being extended to HD applications, in particular using cooled EGR systems. As well as NO<sub>x</sub> reductions of up to 50%, fuel consumption reductions of 2% have also been achieved.

### C.4.4 Exhaust Aftertreatment

Although advances in mechanical design, advanced fuel injection systems and electronic controls have made large reductions in emissions, and small incremental gains in fuel consumption, in order to meet future emission regulations aftertreatment devices are considered indispensable. In general, all of these devices are very sensitive to fuel specification, in particular requiring a very low sulphur content.

#### Oxidation Catalysts

Oxidation catalysts have been fitted to European LD diesel vehicles for several years to reduce emissions of HC, the SOF content of PM (soluble organic fraction; the HC adsorbed onto the surface of particles), and CO. Oxidation catalysts promote the oxidation of HC and CO with oxygen in the exhaust to form CO<sub>2</sub> and H<sub>2</sub>O. Fuel sulphur levels of maximum 500 ppm are required to avoid excessive production of sulphate based PM and to minimise catalyst deactivation by sulphur poisoning. Lower levels of sulphur (50 ppm) can increase the effectiveness of oxidation catalysts by up to 50% and contribute to greater durability. Oxidation catalysts have not generally been used in HD vehicles with the exception of urban buses, and are not considered necessary to meet HC and CO requirements of future HD emission regulations.

#### Particulate Traps

Much development has been directed towards filtration systems for trapping diesel PM. Most systems developed use



filters based on ceramic monoliths, but the key to achieving commercial practicality is the development of regeneration methods to either periodically or continuously “burn” off the PM trapped to avoid build up of excessive exhaust back pressure. Very high PM reduction efficiencies of >90% are possible. This technology is considered essential for attaining future PM emissions standards.

Several variations of these traps are near to or have reached commercial production status (such as the Johnson and Mathey Continuously Regenerating Trap (CRT)). Most are based on catalyst technology and require fuel sulphur levels of less than 30 ppm.

#### NOx Reduction Catalysts

Similarly to PM traps, NOx catalyst or adsorbers are considered necessary to attain the large reductions of NOx in future regulations. As diesel engines run on excess air, the highly efficient three way catalysts used on petrol engines are not effective to reduce NOx. Much work is ongoing to develop lean NOx catalysts using a variety of catalytic technologies.

#### Selective Catalytic Reduction

This uses reducing agents such as urea or ammonia to catalytically reduce NOx to N<sub>2</sub>. This highly effective technology has been used for many years in industrial processes and stationary engines, but has been limited in application to vehicles due to the large size and complexity of the technology. There are also safety concerns using ammonia. However, it is beginning to emerge on some light duty vehicles (Peugeot) and systems developed by Siemens are being trialled on HD also.

#### NOx Adsorbers

Unlike catalysts, which continuously convert NOx to N<sub>2</sub>, NOx adsorbers are materials which store NOx under lean conditions and release and catalytically reduce the stored NOx under rich conditions. NO and NO<sub>2</sub> (together referred to as NOx) are acidic oxides and can be trapped on basic oxides. Periodic rich operation of the engine is used to generate the necessary conditions to convert the stored NOx at programmed intervals. Common rail fuel systems offer the potential of “post” (combustion) injection to produce the required reductants for adsorber regeneration.

#### Lean NOx Catalysts

These use catalyst formations to reduce NOx with HC. Due to the low levels of HC available in diesel exhaust, passive systems are limited in their reduction capability, and active systems using periodic rich running or post injection using common rail injection technology has the greatest potential, although NO<sub>x</sub> reduction is still limited to around 35-50%. This strategy also carries a small fuel consumption penalty. Low sulphur fuel (<30 ppm) is required to limit sulphate generation and catalyst poisoning.

## C.5 Petrol Engine Technology

Engine design technologies which impact on the fuel efficiency and emissions of petrol engines are summarised below.

Table C.2: Petrol Engine Technology

Mechanical Design Features/Technology	Fuel Sensitivity	Status
Multi-valve heads	None	Production
Variable valve timing	None	Production
Turbocharging and after/intercooling	Low	Production
Combustion chamber/charge air motion optimisation	Low	Production
<b>Engine Control Technology</b>		
Electronic engine management	Low	Production
Exhaust gas recirculation	Low	Production
Direct Fuel Injection	High (S<30 ppm)	Production
Lean burn	High (S<30 ppm)	Emerging
<b>Exhaust Aftertreatment</b>		
Advanced catalysts	High (S<30 ppm)	Production

1. Low fuel sensitivity means that effectiveness of the technology can be enhanced to a small degree by optimisation of the fuel specification.

2. Production means widely available now, however may be still undergoing development and achieving greater sophistication. Emerging means under final stages of development and starting to be introduced into production.

## C.5.1 Mechanical Design

In general, all the mechanical design developments discussed here do not have significant impacts on fuel specification requirements.

### Friction

The same general comments as for diesel engines apply, see Section C.4.1.

### Volumetric Efficiency

Similar comments to those for diesel engines in Section C.4.1 apply, with the exception that excess air is not used in homogeneous charge spark ignition applications.

Several technologies have developed to increase volumetric efficiency:

**Multi-valve cylinder heads** are now almost standard in automotive applications.

**Variable valve timing** offers increased volumetric efficiency and torque increases across the entire speed range. Control of residual burnt gas remaining in the cylinder from the previous cycle is possible by control of valve overlap, and this can reduce NO<sub>x</sub> emissions in the same manner as exhaust gas recirculation (EGR).

### Variable Intake Geometry

By using variable length inlet tracts, the air flow can be improved across the engine speed range. This results in a flatter torque curve and higher power output. Thus smaller displacement engines may be possible.

Turbocharging while common in performance based petrol vehicles is not generally utilised for any fuel efficiency or emissions benefit. However, by increasing the specific power output, smaller engines can be used which may give some vehicle mass benefit and associated fuel savings.

## C.5.2 Combustion Chamber Design

While the main focus and the biggest reductions in emissions for spark ignition engines has come from catalyst technology, development of combustion chamber geometry has contributed much to improved engine out emissions and fuel consumption. Minimising crevice volumes where fuel can escape primary combustion, and achieving stable robust combustion with low variability are the main objectives. More robust combustion allows higher levels of EGR to be used to reduce NO<sub>x</sub> emissions and also provides some small fuel consumption benefits. Future impacts of further refinement in conventional spark ignition engines are however, limited in further gains attainable.

## C.5.3 Engine Control Technology

### Carburettor Fuel Systems

A large proportion of the NZ vehicle fleet use carburettors for fuel metering. Due to the generally poorer fuel atomisation of carburettors than fuel injectors, carburettor engines may be more sensitive to fuel parameters such as high-end volatility and heavy aromatics content. Although carburettors were developed intensely through the late 70's and 80's, they are unable to provide the close air-fuel ratio control required to effectively reduce CO, HC and NO<sub>x</sub> using three way catalyst technology. They were thus phased out rapidly overseas as this technology became prominent. Many Japanese cars of the 1980's were still produced with carburettors and were fitted with oxidation catalysts to effectively reduce CO and HC levels.

### Fuel Injection Systems

The control of air-fuel ratio and spark timing is critical to minimising both fuel consumption and emissions production in spark ignition engines. Multi-point fuel injection (MPFI) systems are now standard and sequential fuel injection (SFI) is becoming more common, initially on higher specification vehicles. SFI allows individual optimising for each combustion event and more precise control of fuelling, particularly during transient events.

### Gasoline Direct Injection (GDI)

Direct fuel injection in spark ignition engines allows fuel injection directly into the cylinder (rather than into the manifold as with conventional fuel injection systems) during the compression stroke to create a stratified, or non-homogeneous charge. This allows ultra lean burn conditions under part load conditions (AF ratio ~50 compared to stoichiometric AF ~14.5) which give large fuel consumption and emissions benefits. Pumping losses are greatly decreased by reducing the degree of throttling required at part loads. At high loads the GDI engine can operate in a homogeneous mode in the same manner as a conventional engine. Although engine out NO<sub>x</sub> is reduced compared to a conventional homogeneous

charge engine, the lean operation renders conventional 3-way catalysts ineffective, and NO<sub>x</sub> adsorber type catalysts with periodic stoichiometric operation regeneration may be required to meet Euro IV limits. This requires a very low sulphur fuel (<30 ppm) to enable this technology to meet this NO<sub>x</sub> level. Both Mitsubishi and Toyota have GDI powered vehicles in production.

#### Homogeneous Charge Lean Burn Engines

Lean burn engines offer high fuel efficiency and low engine out HC and CO emissions. However, engine out NO<sub>x</sub> emissions are higher than allowable. Difficulty in effective aftertreatment to reduce NO<sub>x</sub> in lean burn engines has limited their development in favour of stoichiometric 3-way catalyst technology. Development of this technology has continued however, and improved high swirl combustion chamber design leading to better combustion stability has extended the lean limit to air–fuel ratios of around 25:1. Further developments in NO<sub>x</sub> adsorber and lean NO<sub>x</sub> reduction technologies (see diesel engine section) may see this technology enter the market. As for diesel engines, a low sulphur fuel is required to enable the NO<sub>x</sub> aftertreatment technologies. Toyota produced a lean burn vehicle in 1994 which was claimed to reduce fuel consumption by as much as 20% over certification test cycles. Subaru and Hyundai have also produced lean burn engines in production vehicles.

#### Exhaust Gas Recirculation

Exhaust gas recirculation (EGR) has been used for many years in petrol automotive engines to reduce NO<sub>x</sub> emissions by diluting the charge air/fuel mixture and thereby reducing peak gas temperatures. Pumping losses are decreased by use of EGR in spark ignition engines, as wider throttle openings are required to obtain the desired power. The application of EGR is being continuously refined with more sophisticated electronic systems to give greater control over EGR ratios, and thereby lower NO<sub>x</sub>. Improved combustion chamber designs allow higher EGR ratios without causing combustion instability. Future developments will also extend EGR to higher engine operating loads. As well as large NO<sub>x</sub> reductions, fuel consumption benefits also results from EGR.

### C.5.4 Exhaust Aftertreatment

Although advances in mechanical design, advanced fuel injection systems and electronic controls have made large reductions in emissions, and small incremental gains in fuel consumption, in order to meet future emission regulations aftertreatment devices are considered indispensable. In general, all of these devices are sensitive to fuel specification, in particular requiring a very low sulphur content.

#### Oxidation Catalysts

Oxidation catalysts were the first application of catalyst exhaust aftertreatment in automobiles. These catalysts promote oxidation of CO and HC in the exhaust to CO<sub>2</sub> and H<sub>2</sub>O. As oxygen is required for this process, a stoichiometric or leaner mixture is required. Initial engines fitted with oxidation catalysts had carburettor fuel systems which provide adequate air–fuel ratio control for this technology. Oxidation catalysts were fitted to many of the 1980's Japanese vehicles that have been imported second hand into New Zealand, but this technology is largely outdated now in application to petrol engines.

#### Advanced Three Way Catalysts

As emission limits have reduced, the proportion of emission produced in the cold operation phase before the catalyst reaches “light-off” has become increasingly significant. Catalysts having faster warm-up and lower light-off temperatures are necessary. Close coupling of catalysts to the exhaust manifold decreases warm up time, but increases thermal stress on the catalyst under high load conditions which may result in accelerated catalyst ageing and failure. Other approaches, such as electrically heated catalysts and adsorbers, have proved feasible to reduce cold start emissions, but are not yet production technology partly due to cost implications.

Increased tolerance to fuel sulphur has also been a significant focus of development of advanced catalysts to provide high conversion efficiencies over an extended life, to meet durability regulations. Reduction of sulphur levels in petrol will aid this area. European work has shown that reductions in sulphur from 380 ppm to 18 ppm decreased CO, HC and NO<sub>x</sub> emissions by 10%. Similar work in the United States showed reduction of between 10–20% in the various species using 1983–89 technology vehicles with sulphur reductions from 450 to 50 ppm.

Much of the development work of existing catalyst technology is focussing on improved formulations including optimum washcoats and the type and concentrations of the precious metals used, in order to provide improved performance in the areas discussed above.

#### NO<sub>x</sub> Reduction Catalysts

These have been discussed in the diesel section and also in the lean burn and GDI petrol engine sections. Again, low levels of sulphur are required to enable this technology, which for petrol engines is in turn a technology enabler for lean burn and GDI, with their associated fuel efficiency benefits.

## C.6 Bibliography

Coffey Geosciences Pty Ltd,: “Review of Fuel Quality Requirements for Australian Transport”, Environment Australia, 2000.

Degobert P.: “Automobiles and Pollution”, SAE, 1995.

Heywood J.B., 1988, : “Internal Combustion Engine Fundamentals”, MacGraw-Hill International Editions, 1988

DieselNet Technology Guide, [www.dieselnets.com](http://www.dieselnets.com)

EFRU, 1998,: “Recent and Expected Technical Developments for the Road Transport Sector”, Auckland UniServices report 6943.17.

Ministry of Transport, 1998, : “Vehicle Fleet Emissions Control Strategy – Final Report”

Heisler, H.: “Vehicle and Engine Technology”, SAE, 1999.

## C.7 Acknowledgements

This Appendix was prepared by:

Energy and Research Fuels Unit (ERFU)

Auckland UniServices Limited

University of Auckland

# Appendix D

## Vehicle Fleet Emissions Control Strategy

- D.1 Background
- D.2 Vehicle Fleet Emissions Model
- D.3 Environmental Capacity Analysis
- D.4 VFECs Policy Outcomes
- D.5 Acknowledgements

### D.1 Background

The impact of vehicle traffic on local air quality in New Zealand has come under much attention in the last five years. To a large extent, the general perceptions of the public at large on how vehicle emissions affect the environment, and what should be done about it, are drawn from what is seen to be happening overseas. Internationally efforts to regulate vehicle emissions started over 30 years ago, but urban air quality is still a problem in many countries.

In 1996 the MOT embarked upon the Vehicle Fleet Emissions Control Strategy (VFECs), a programme of work to define how road transport affects local air quality, thereby giving direction to the appropriate means for its control. The relevance of this to the fuel quality debate is that the work has indicated that fuel quality, engine and emissions control technology are only some of the factors contributing to the vehicle-related air quality problem. Vehicle numbers, traffic density and driving conditions are all significant factors, and increasing congestion may even outweigh the benefits from improvements in vehicle and fuel technology.

This work involved the development of two main outputs:

- The Vehicle Fleet Emissions Model (VFEM)
- Environmental Capacity Analysis (ECA)

### D.2 Vehicle Fleet Emissions Model

The Vehicle Fleet Emissions Model (VFEM) was developed to predict the average fleet performance, or “fleet weighted average emissions rate” of the key exhaust contaminants (CO, NO<sub>x</sub> and PM) and their projection over time in response to fleet turnover.

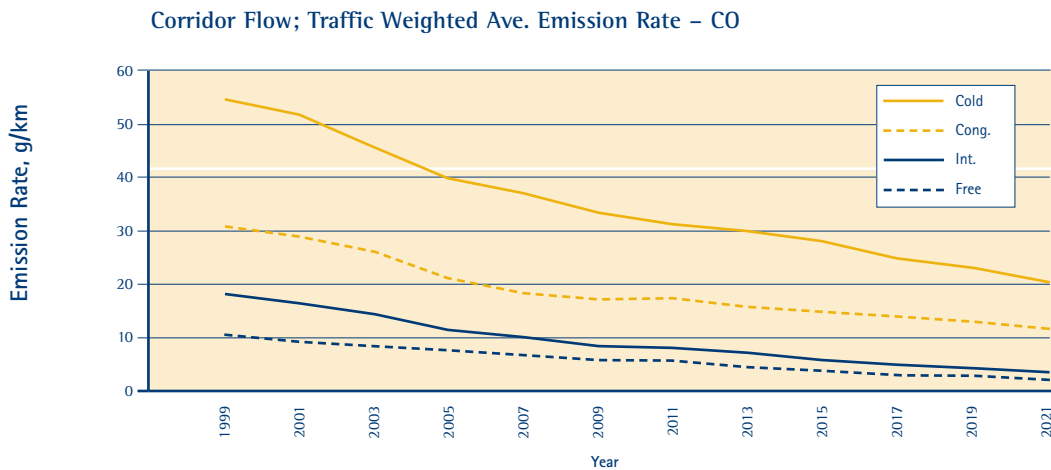
The fleet weighted “average” vehicle, at a particular date, reflects the full range of vehicle types, fuels, age and engine/emissions control technology in the vehicle fleet at that time. For example the model predicts that in 1999 for instance, the “average” vehicle under freely flowing central urban driving conditions emitted 11 g/km of CO. For 2005 say, the corresponding emissions rate for the average vehicle under the same driving conditions will be lower (around 8 g/km) because of the introduction of cleaner vehicles due to fleet turnover.

The primary structure of the VFEM is not the age or source of the vehicle, or other such factors conventionally used to characterise emissions performance, but the interaction of the engine technology with road design and traffic driving conditions. In this, the characterisation process for emissions measures relates directly to road types and driving conditions. This is combined with fleet profiles which consider vehicle type, age and emissions control technology (both what is installed on any particular vehicle and how effectively it actually functions), fuel type and fuel economy.

The projections from this model indicate that the emission rate of a particular pollutant per kilometre increases significantly and exponentially with the degree of traffic congestion. For the above example of central urban driving conditions, the emission rate of CO per kilometre from the “average” vehicle in 1999 under free-flow conditions increases by a factor of three in congested flows, when the traffic volume approaches the capacity of the roadway. This is illustrated in Figure D.1 below. There is a significant increment again for the running period immediately after a cold start, which can represent a significant proportion of a typical local urban trip.

The projections are based upon the New Zealand fleet evolving generally as per international practice in emissions standards through the future, for new entrants to the fleet. The effect of improving vehicle technology on overall emissions rates, is governed by the rate of turnover of the fleet, so it takes time for the net effect to make a contribution to what is essentially a local area air quality problem. The direct benefits of the new, cleaner vehicles are not captive to the area of need.

Figure D.1 : Predicted CO Emission Rate (VF ECS)



The conclusion drawn might be that, in contrast to improvements in vehicle technology, improvements in fuel quality would be immediate and be effective nationwide but as discussed elsewhere, the direct impacts of fuel quality on emissions are fairly limited. The more important effect is that they “enable” new emissions control technology. However, the fleet turnover is influenced by a number of factors, which have often have much more to do with affordability and availability of vehicles (economic and trading considerations) than transport policy or fuel quality.

In summary, what the VFEM points to is that the emissions output of vehicle traffic as a collective source in the local airshed is dependent on more than tailpipe performance indicators. It is the product of three factors;

- Vehicle technology: the average “Fleet Performance”.
- Road network density: the amount of potential traffic activity within a given area air-shed.
- Traffic density: on each road corridor in the network, the congestion influence on actual per kilometre vehicle emission rates.

It can be seen from Figure D.1, for the CO example, that the benefits of fleet improvement over 10-15 years can be countered by the local increase in traffic volumes, moving the corridor flow from the interrupted to the congested condition, and this is a contemporary trend with the increasing demand for travel in our cities.

New Zealand’s air quality is discussed in more detail in Section 4.2. Appendix E presents an overview of the primary air contaminants and their sources.

## D.3 Environmental Capacity Analysis

The main outcome of the VF ECS programme has been the concept of “Environmental Capacity Analysis” (ECA). Traffic engineers refer to the “capacity” of the road network, that is, it can carry a finite volume of traffic before reaching the congested state. By analogy, reference may also be made to the capacity of the urban air-shed, which can absorb only so much vehicle emissions loading before concentrations reach pollution levels of concern. This capacity is at its lowest under calm, or stable air conditions.

This concept of capacity can be used to represent a limiting benchmark for managing the emissions activity in a given urban airshed, in a manner that recognises the different circumstances of different localities, both currently and as they change through the future.

The ECA framework is built around the city traffic network modelling process, a facility routinely maintained by every urban management authority. The emissions factors produced by the VFEM are designed to be integrated with any traffic model, in a way that can calculate the vehicle emissions loading for each link in the network, for the current and future projected traffic flows. The road network provides the skeletal structure in this inventory process, allowing direct comparison of the local emissions outputs from the various sources in the vicinity, for each pollutant.

## D.4 VFECS Policy Outcomes

The primary objective of VFECS was to ensure that the right solutions are employed, to suit the nature of the air quality problems attributed to vehicles. The greater part of New Zealand does not experience air quality problems, so the policy recommendations were designed to target the improvement where it was needed. A number of measures were advocated at the national level, aimed at ensuring that fleet-wide performance improved over time in line with global auto technology developments. These mainly concerned the formalisation of new vehicle emissions standards, and review of fuel specifications to ensure they would be compatible with current and prospective engine technologies.

## D.5 Acknowledgements

This appendix was based on an article prepared for New Zealand Science Review by:

Ian Moncrieff  
Fuels & Energy Limited

# Appendix E

## Air Contaminants

- E.1 Carbon Monoxide
- E.2 Nitrogen Dioxide
- E.3 Sulphur Dioxide
- E.4 Particulates
- E.5 Ozone
- E.6 Benzene
- E.7 Toluene and Xylene
- E.8 1,3-Butadiene
- E.9 Formaldehyde and Acetaldehyde
- E.10 Benzo(a)pyrene

This Appendix presents an overview of the key air contaminants arising from use of petrol and diesel in New Zealand. They are, the five key contaminants (CO, NO<sub>2</sub>, SO<sub>2</sub>, particulates and O<sub>3</sub>), plus a number of hazardous air pollutants (benzene, toluene, xylene, 1,3-butadiene, formaldehyde, acetaldehyde and benzo(a)pyrene). For each contaminant a discussion of its sources, health effects, ambient air levels and emission control strategies is presented.

Further information may be found in the VFECs reports, including Appendix A of the VFECs Final Report which contains a useful summary table of the ambient air quality, pollution levels and emission reduction targets for vehicles (MOT, 1998a).

The suite of technical reports commissioned by Ministry for the Environment for the review of the 1994 Ambient Air Quality Guidelines provide detailed information on the health effects of air pollutants, strategies for managing air quality and effects on ecosystems (MfE#12-16, 2000).

### E.1 Carbon Monoxide

Carbon monoxide (CO) is a colourless, odourless and tasteless gas that is poisonous to humans in high concentrations. CO is a trace constituent in the atmosphere, produced by both natural processes (eg. volcanoes) and human activities, (eg. the incomplete combustion of carbon-containing fuels).

Petrol-fuelled motor transport is the major source of CO in urban airsheds. CO emitted from vehicles is solely the result of a lack of available oxygen within the combustion zone, caused by an over rich mixture or poor fuel volatilisation/mixing with air. Studies indicate that mobile sources make up approximately 90% of CO emissions in the Auckland region (MfE#14, 2000). Domestic fires also contribute a significant proportion of CO emissions in winter, possibly up to 50% in Christchurch (MfE#14, 2000).

#### Adverse Effects

CO affects human health by reducing the amount of oxygen that can be carried in the blood to the body tissues. When inhaled, CO combines with haemoglobin (Hb), the blood's oxygen-carrying protein molecule, to form carboxyhaemoglobin (COHb). In this state the Hb is unable to carry oxygen.

CO levels are of concern from a human health perspective if they exceed recommended air quality guidelines, which are generally based on a No Observed Adverse Effect Level (NOAEL) of 2.5% carboxyhaemoglobin in blood.

#### Ambient Air Quality Guidelines and Typical CO Concentrations

The Review of the Ambient Air Quality Guidelines has recommended that the ambient air quality guidelines for carbon monoxide remain unchanged, at 30 mg/m<sup>3</sup>, 1-hour average, and 10 mg/m<sup>3</sup>, 8-hour average. It is recommended that these guidelines be reviewed no later than 2002 in view of the emerging research on adverse health effects at lower than expected carboxyhaemoglobin levels in blood.

NZ AAQ Guideline	10 mg/m <sup>3</sup> , 8-hour average
Typical NZ Urban Actual	5-10 mg/m <sup>3</sup> , 8-hour average
Typical NZ Rural Actual	<0.1 mg/m <sup>3</sup> , 8-hour average
Typical NZ Peak	12 mg/m <sup>3</sup> 8-hour average

Source: EPI Web Site ([http://aqdb.niwa.cri.nz/indicators/airpoll\\_indicators.htm](http://aqdb.niwa.cri.nz/indicators/airpoll_indicators.htm)), March 2001



Most air quality monitoring to date has targeted CO, and there is now sufficient long term air quality monitoring data to clearly define the nature and extent of CO pollution. In New Zealand, CO levels can approach guideline levels (8-hour average) in “residential” urban areas (“alert” category), however, concentrations in specific traffic corridors have been found to exceed the guidelines.

VF ECS developed the “traffic corridor” concept to isolate the effects of traffic pollution from other sources (MOT, 1997). Two particular sites have been confirmed as representative of the worst case traffic pollution environments: Khyber Pass Road in Auckland and Riccarton Road in Christchurch (MOT, 1997). In these cases, reductions in concentrations of CO of between 60-80% are required to meet the criteria of “acceptable” air quality, and reductions of greater than 80% are required to meet the “good” target.

### Emission Control Strategies

Stage 1 of the VF ECS focused on addressing CO emissions from vehicles. This stage included a detailed analysis of the potential costs and benefits of pursuing various control options (MOT, 1997).

In essence, to minimise CO emissions, vehicles must run at their optimal efficiency, and create CO<sub>2</sub> instead of CO. Oxygenate content has a direct impact on CO emissions. Adding oxygenates induces a lean shift (ie. introduces oxygen) which reduces CO emissions. Oxygenate levels (including MTBE) are currently specified by the Regulations and under review. Reducing the aromatic content of petrol could also reduce CO emissions, but tends to increase NO<sub>x</sub> emissions by a similar rate (MOT, 1997).

The VF ECS reached the following conclusions (MOT, 1997):

- Of the technical control measures assessed, only two provide the necessary reductions in CO emissions, and over an extended timeframe:
- Introducing a progressive system of emissions standards for new vehicles. This is currently being formalised as a regulatory requirement through the LTSA Rules process, but it will be 15-20 years before the impacts are fully realised.
- Adopting a wholesale change to diesel fuelled light vehicles (diesel engines operate under excess air at all conditions). This would have an impact on particulate levels.
- Non-technical measures applied to traffic corridor management appear to provide the best means of preventing local air quality CO exceedances in the near term.

## E.2 Nitrogen Dioxide

In the high temperature zones of combustion processes, nitrogen in air and in the fuel reacts with oxygen in air to form nitrogen oxides: nitric oxide (NO), nitrogen dioxide (NO<sub>2</sub>), and nitrous oxide (N<sub>2</sub>O). These are collectively referred to as NO<sub>x</sub>. For most combustion processes nitrogen oxides are emitted primarily in the form of NO, which slowly oxidises to NO<sub>2</sub> in the atmosphere. Nitrogen dioxide is a pungent, acidic, reddish-brown gas, that is corrosive and strongly oxidising.

Sources of nitrogen oxides include “all types of road vehicles ... domestic burning of wood, coal, natural gas and LPG and certain industrial processes. Depending on the presence of other local sources such as thermal power stations and industry using significant combustion processes, motor vehicles are estimated to contribute up to 80 to 95% of total emissions” of nitrogen oxides (MOT, 1998a). NO<sub>x</sub> emissions are a consequence of the thermodynamics of the combustion cycle, rather than fuel chemistry. The extent of NO<sub>x</sub> formation is determined by residence time at high temperatures in the presence of excess oxygen.

### Adverse Effects

NO<sub>2</sub> in the human respiratory system causes increases in both the susceptibility to and the severity of infections and asthma. Recent epidemiological studies have shown an association between ambient NO<sub>2</sub> exposure and increases in daily mortality and hospital admissions for respiratory disease (MfE# 12, 2000).

NO<sub>2</sub> is a significant pollutant not only because of the health effects it directly causes, but also as a result of the role it can play in the generation of photochemical smog events and the production of secondary particles that cause visibility degradation. NO<sub>2</sub> does have some synergistic effects, but the mechanisms are poorly understood.

### Ambient Air Quality Guidelines and Typical NO<sub>2</sub> Concentrations

The Review of the Ambient Air Quality Guidelines has recommended that the 1-hour average ambient air quality guideline for NO<sub>2</sub> be reduced to 200 µg/m<sup>3</sup> (from 300 µg/m<sup>3</sup>), and that the 24-hour average guideline remain unchanged at 100 µg/m<sup>3</sup>.

NZ AAQ Guideline	100 µg/m <sup>3</sup> , 24-hour average
Typical NZ Urban Actual	5-30 µg/m <sup>3</sup> , 24-hour average
Typical NZ Rural Actual	<1 µg/m <sup>3</sup> , 24-hour average
Typical NZ Peak	50 µg/m <sup>3</sup> , 24-hour average

Source: EPI Web Site ([http://aqdb.niwa.cri.nz/indicators/airpoll\\_indicators.htm](http://aqdb.niwa.cri.nz/indicators/airpoll_indicators.htm)), March 2001

In New Zealand, NO<sub>2</sub> levels within urban areas may be categorised as “good” (up to 30% of guideline value), for 24-hour periods. The maxima one-hour average recorded to date for traffic corridor locations have been up to 200 µg/m<sup>3</sup> (equal to the guideline level; “alert” category), and 60-90 µg/m<sup>3</sup> in urban areas (“acceptable” category).

### Emission Control Strategies

#### Petrol

For petrol engines, tailpipe NO<sub>x</sub> emissions are predominantly controlled with the use of three-way catalysts, although exhaust gas recirculation (EGR) will also provide some benefit. Changes in fuel quality can influence the NO<sub>x</sub> emissions performance, but generally the magnitude is small. The main fuel parameters which can influence NO<sub>x</sub> emissions from gasoline cars are sulphur and aromatics, and to a lesser extent, olefins (CONCAWE, 1999).

Reducing sulphur levels in petrol (to 100 ppm or less) increases catalyst efficiency and may reduce NO<sub>x</sub> emissions by up to 10%. Currently, New Zealand’s petrol contains very low sulphur levels (sometimes less than 50 ppm), although the Regulations permit higher levels.

Reducing the aromatic content of fuels also increases NO<sub>x</sub> emissions, as catalysts are thought to work more efficiently with relatively high aromatic fuels (CONCAWE, 1999).

Of the future technologies, lean-burn gasoline direct injection (G-DI) vehicles (favoured due to reduced fuel consumption and CO<sub>2</sub> emissions) are expected to have higher NO<sub>x</sub> emissions than conventional petrol vehicles (CONCAWE, 1999). This will require new generation “lean de-NO<sub>x</sub>” catalysts to be developed, which are also expected to require low sulphur content fuels.

#### Diesel

For diesel engines, a number of fuel quality parameters have competing effects on NO<sub>x</sub> emissions. Changes in diesel engine technology which can reduce NO<sub>x</sub> emissions will generally increase particulate emissions and fuel consumption (CONCAWE, 1999). However, increasing cetane number has been found to reduce NO<sub>x</sub> emissions. The cetane number can be related to the aromatic content of the fuel; as the aromatic content decreases the cetane number increases. Therefore, decreasing the aromatic content of diesel may reduce NO<sub>x</sub> emissions. Currently, the aromatic content of diesel is unregulated.

Future after treatment systems are likely to require low sulphur content diesel, 50 ppm or lower, significantly lower than current New Zealand levels.

## E.3 Sulphur Dioxide

Sulphur dioxide (SO<sub>2</sub>) is a colourless, soluble gas with a characteristic pungent smell. It reacts with water in air to form sulphuric acid aerosol (H<sub>2</sub>SO<sub>4</sub>).

SO<sub>2</sub> is primarily produced through the combustion of fuels that contain sulphur, but can also be emitted from a number of specific industrial operations, such as sulphuric acid manufacturing, the roasting or smelting of mineral ores containing sulphur, and oil refining. Petrol can have a significant sulphur content, but this varies widely depending upon the source of the fuel. The sulphur content of petrol used in New Zealand is generally very low. The sulphur content of diesel fuels available in New Zealand is, however, comparatively high (see Section 8). The Auckland emissions inventory estimated that 27% of SO<sub>2</sub> was from mobile sources (ARC, 1997).

### Adverse Effects

The health effects of SO<sub>2</sub> have been recognised for many years. SO<sub>2</sub> is a potent respiratory irritant when inhaled and ambient levels of SO<sub>2</sub> have been associated with increases in daily mortality, hospital admissions for respiratory and cardiovascular disease, increases in respiratory symptoms, and decreases in lung function. Due to the high correlation between ambient SO<sub>2</sub> levels and other pollutants, especially particles, it is difficult to attribute the observed effects to SO<sub>2</sub> alone.

### Ambient Air Quality Guidelines and Typical SO<sub>2</sub> Concentrations

The Review of the Ambient Air Quality Guidelines has recommended that the 1-hour and 24-hour average ambient air quality guidelines for SO<sub>2</sub> remain essentially unchanged at, respectively, 350 µg/m<sup>3</sup> and 120 µg/m<sup>3</sup>.

SO<sub>2</sub> is monitored at two sites (in Auckland and Christchurch) as part of MfE's air quality management programme. Their 2000 report (MfE, 2001) shows that annual concentrations are less than 33% of the Ambient Air Quality Guideline and air quality in relation to SO<sub>2</sub> levels is good.

### Emission Control Strategies

While SO<sub>2</sub> from vehicles is not considered to be of significant concern in New Zealand per se, SO<sub>2</sub> is a significant pollutant because of the role it can play in the production of secondary particles. As such, any assessment of the benefits of reduction measures must also take into account the benefits that may be derived as a result of reduced levels of particles.

Ensuring that fuel is compatible with the future emissions control and fuel-efficient technologies (particularly catalytic converters) is a key issue. Sulphur reduces the efficiency of the catalysts used to remove a number of the other key air contaminants, namely NO<sub>x</sub> and hydrocarbons (ie. sulphur "poisons" the catalyst). This is particularly relevant for diesel after treatment technologies, and will become increasingly important in the future for petrol engines.

In essence, to reduce sulphur emissions and to enable technologies to work optimally, sulphur levels in fuel must be reduced.

## E.4 Particulates

Particles are emitted from motor vehicles (particularly diesel vehicles), domestic fuel burning, fossil fuel-based electricity generation, some industrial processes, and industrial and domestic incinerators. Secondary production of particles can be significant, with the most important being:

- Sulphates, which derive primarily from SO<sub>2</sub> emissions.
- Nitrates, which derive primarily from NO emissions.
- Organic aerosols, which derive primarily from volatile organic compound emissions.

Natural sources of particles include dust (which can be exacerbated greatly by human activities), pollens and sea spray.

Airborne particles can occur in a range of different sizes. From a health perspective, particles smaller than 10 microns in diameter are of greatest concern as they are able to enter the lungs. Most air-quality monitoring is for particles less than 10 microns in diameter (PM<sub>10</sub>), although increasingly attention is turning to particles less than 2.5 microns in diameter (PM<sub>2.5</sub>).

The Auckland emissions inventory showed that, on a "typical winter day", domestic sources contribute approximately 48% of the annual total emissions, commercial sources contribute approximately 5%, major industry contributes 32% and mobile sources contribute the remaining 15% (ARC, 1997).

In Christchurch, where the extent of domestic fuel burning in winter is more significant than in Auckland, home heating contributes approximately 82% of the PM<sub>10</sub> on a typical winter day, with motor vehicles contributing 10% and industry 8%. The "winter smoke" phenomenon is also experienced in some other South Island urban areas (MfE#14, 2000).

### Adverse Effects

The major effects of concern with regard to airborne particles are increased mortality, aggravation of existing respiratory and cardiovascular disease, hospital admissions and lost work days.

Studies into the health effects of air pollution in Christchurch have focussed on particles (as PM<sub>10</sub>), NO<sub>2</sub> and CO. A recent study into the effects of air pollution and weather on daily mortality showed that PM<sub>10</sub> levels in Christchurch are associated with increases in daily mortality (MfE#14, 2000). The results of this study are consistent with international studies.

### Ambient Air Quality Guidelines and Typical Particulate Concentrations

The Review of Ambient Air Quality Guidelines has recommended that the 24-hour average ambient air quality guideline for PM<sub>10</sub> be reduced to 50 µg/m<sup>3</sup> (from 120 µg/m<sup>3</sup>) and the annual average guideline be deleted. This proposed guideline has already been adopted by a number of regional councils.

Monitoring of PM<sub>2.5</sub> is to be encouraged and the results compared with an ambient air quality guideline of 25 µg/m<sup>3</sup>, 24-hour average. In view of the emerging research on the relationship between PM<sub>2.5</sub> and mortality, the PM<sub>2.5</sub> guideline will be reviewed no later than 2004.

Proposed NZ AAQ Guideline, PM <sub>10</sub>	50 µg/m <sup>3</sup> , 24-hour average
Typical NZ Urban Actual	25-35 µg/m <sup>3</sup> , 24-hour average
Typical NZ Rural Actual	2-10 µg/m <sup>3</sup> , 24-hour average
Typical NZ Peak	>500 µg/m <sup>3</sup> , 24-hour average

Source: EPI Web Site ([http://aqdb.niwa.cri.nz/indicators/airpoll\\_indicators.htm](http://aqdb.niwa.cri.nz/indicators/airpoll_indicators.htm)), March 2001

In New Zealand, PM<sub>10</sub> levels in urban areas are typically “acceptable”, however, they can exceed the guidelines on occasions, particularly on winter days in urban areas where home heating fires and adverse meteorological conditions combine.

### Emission Control Strategies

Emissions of particulate matter are generally associated with diesel vehicles.

The VF ECS contains specific initiatives aimed at reducing the direct emission of particles from motor vehicles, which constitutes one of the most visible air pollution issues in New Zealand, even though the relative contribution of motor vehicles to direct PM<sub>10</sub> emissions is minor. These include emission standards for new diesel vehicles, an education programme to improve tuning and maintenance of diesel fuel vehicles, and introduction of the “10-second rule” which is aimed at removing excessively smoky vehicles from the road (MOT, 1998a).

Changes in particulate pollution levels depend both on changes in emission of primary particulate and gaseous pollutants (NO<sub>x</sub>, SO<sub>2</sub> and hydrocarbons), given the as yet unquantifiable contribution of other vehicle emission species to secondary particle formation. Specific (diesel) fuel parameters which affect PM emissions are density (reduced density will reduce PM emissions, but at the expense of fuel consumption) and sulphur (directly via SO<sub>2</sub> emissions, and indirectly via the performance of after-treatment catalysts).

### Visible Smoke

Distinction must be made between particulates and visible smoke: particulate matter is defined as anything that is collectable on a filter (particulates may be present in exhaust even though no visible smoke is apparent); the defining character of exhaust smoke is that it is comprised of solid or liquid aerosol particles that absorb or deflect light.

While visible smoke is a visible and important environmental issue, testing has shown that smoke puff emissions contribute no greater amounts of key air pollutants than many vehicles which appear to be well maintained (MOT, 1998a). The VF ECS Final Report contains a thorough discussion of the causes of and control strategies for visible smoke (MOT, 1998a).

## E.5 Ozone

Ozone (O<sub>3</sub>) is a secondary air pollutant formed by reactions of primary pollutants (nitrogen oxides and photochemically reactive organic compounds) in the presence of sunlight. O<sub>3</sub> is the principal component of photochemical smog.

The primary pollutants that can lead to the generation of O<sub>3</sub> arise from a range of sources. Nitrogen oxides come from motor vehicles, and commercial, industrial and domestic combustion activities. Sources of reactive organic compounds include industrial and domestic uses of solvents and coatings (for example, paints), and other combustion activities. Biogenic emissions or reactive organic compounds from vegetation can also be important.

### Adverse Effects

Epidemiological evidence indicates that a wide variety of health outcomes are possible from exposure to O<sub>3</sub>: short-term effects on mortality, hospital admissions, respiratory symptoms and lung function. At an experimental level, evidence suggests that short-term effects present a greater risk than long-term effects.

### Ambient Air Quality Guidelines and Typical O<sub>3</sub> Concentrations

The Review of Ambient Air Quality Guidelines has recommended that the ambient air quality guidelines for ozone remain unchanged, at 150 µg/m<sup>3</sup>, 1-hour average, and 100 µg/m<sup>3</sup>, 8-hour average.

There is limited information available regarding O<sub>3</sub> levels in New Zealand. However, studies have found that atmospheric conditions suitable for photochemical reactions occur around 10 days per year in Auckland, 15 days in Hamilton and 4 days in Christchurch. In 1977/78 in Auckland, breaches of the guideline values were found at sites 35-40km north and south of the city (MfE#14, 2000). Further O<sub>3</sub> monitoring is required to gain a better understanding of its extent and significance.

## Emission Control Strategies

The control of O<sub>3</sub> requires management strategies that target reductions in nitrogen oxides and/or reactive organic compounds.

One component (either nitrogen oxides or reactive organic compounds) is likely to be the 'limiting' pollutant, and it may be that targeting these emissions will provide the most effective mechanism to reduce O<sub>3</sub> levels. In the absence of an understanding of which pollutant is 'limiting', it may be appropriate to take a precautionary approach and instigate measures to reduce the range of precursor pollutants. This is likely to be achieved as a result of any programmes adopted to reduce emissions of the other key air pollutants.

## E.6 Benzene

Based on the Auckland emissions inventory, the total 1993 VOC emissions in the Auckland region were estimated at 65,000 tonnes: 63% from motor vehicles; 13% from domestic solid fuel combustion; and 9% from surface coating operations (MfE#13, 2000). Emissions of benzene were estimated at about 7% of total VOCs, of which 80% originated from motor vehicles, and the remainder from domestic solid-fuel heating (MfE#13, 2000).

Motor vehicle exhaust emissions of benzene derive partly from evaporative emissions or unburnt benzene in the fuel (primarily from petrol engines), and partly from the dealkylation of other aromatic hydrocarbons in the petrol.

### Adverse Effects

Adverse health effects arising from exposure to benzene are well documented. The most significant effects are haemotoxicity, genotoxicity and carcinogenicity. Benzene has been classified as a Group 1 (known human) carcinogen by the International Agency for Research and Cancer (IARC) and is assessed as a carcinogen by the World Health Organisation (WHO), which recommends jurisdictions establish their own guideline values by considering the unit risk factors and the level of risk deemed acceptable.

Acute exposures to very high levels of benzene can affect the nervous system, producing a range of symptoms such as headaches, dizziness, nausea, lack of co-ordination, and unconsciousness.

### Ambient Air Quality Guidelines and Typical Benzene Concentrations

The Review of the Ambient Air Quality Guidelines has recommended benzene guidelines of 10 µg/m<sup>3</sup>, annual average, reducing to 3.6 µg/m<sup>3</sup>, annual average in year 2010. Compliance with the criteria would be assessed by monitoring at "residential" sites, with modelling or other assessment tools employed to characterise population exposure.

Proposed NZ AAQ Guideline	2000: 10 µg/m <sup>3</sup> , annual average 2010: 3.6 µg/m <sup>3</sup> , annual average
Typical NZ Urban Actual	1.0-6.2 µg/m <sup>3</sup> , annual average
NZ Proximity to Heavy Traffic	6.3-20.1 µg/m <sup>3</sup> , annual average

Source: MfE#13, 2000

Based on current monitoring data, most cities in New Zealand are in compliance with the year 2000 criterion (MfE#13, 2000). However, there are hot spots adjacent to major roads where levels have been measured close to double the criterion. Areas in Auckland, Christchurch and possibly other cities do not appear to meet the proposed 2010 criterion.

### Population Exposure to Benzene

The annual average air concentration would be equivalent to the annual average exposure of an individual, if that individual spent all of their time for a year at the sample location. As people move around however, their exposure to benzene (or any contaminant), throughout a day/week/year, changes.

A study undertaken by the MOH over the period 1996-1999 was designed to establish current exposure levels to benzene and other toxic organic compounds in air for typical New Zealand populations (Stevenson and Narsey, 1999). The study involved monitoring of benzene and other aromatic compounds at 26 sites, covering both indoor and outdoor environments in a range of urban and suburban zones. It focused on typical situations in which most people are likely to be exposed, rather than specific (such as occupational) or unusual exposures.

The results indicated that (Stevenson and Narsey, 1999):

- Cigarettes are, by far, the largest source of benzene exposure for people smoking or non-smokers living in homes with smokers.

- Benzene concentrations in indoor air in non-smoking homes are essentially the same as outdoor air at the same location, except where the house has an in-built garage.
- The highest concentrations for any site (about 20 times typical ambient air levels) were from a home with an internal double garage, and almost certainly resulted from evaporative emissions from two petrol-fuelled carburetted cars, regularly used and parked in the garage.
- Benzene concentrations in vehicles while being driven are typically 10-50 times higher than ambient air (and sourced primarily from the traffic corridor rather than from the vehicle in question). For most non-smokers, vehicle travel for 2.5-10 hours per week contributes up to half of their overall benzene exposure.

Overall annual average benzene exposures were estimated for a range of scenarios by calculating the time- and scenario-weighted annual average concentrations, based on the annual average benzene concentrations found in the study. Estimated annual average benzene exposures for non-smokers in New Zealand cities and suburbs are in the range 1-40 mg/m<sup>3</sup> (Stevenson and Narsey, 1999).

- The lower end of this range (<2 µg/m<sup>3</sup>) is representative of a person spending all of their time in the outer suburbs and less than 2.5 hours per week travelling in a motor vehicle.
- Exposure in the mid-range (2.5-10 µg/m<sup>3</sup>) is representative of a person living and working in a suburb of a major city, and spending 5-10 hours per week travelling in a motor vehicle in city and suburban traffic.
- The top end of this range (10-40 µg/m<sup>3</sup>) corresponds to exposures received by people living in houses significantly affected by evaporative emissions from petrol-fuelled cars in internal garages, and/or spending a high proportion of their time in vehicles in city and suburban areas eg. couriers and taxi drivers.

The study indicated that, because benzene exposures in motor vehicles, where vehicle emissions are essentially the only benzene source, are a major exposure for most people, vehicle emissions make an even larger contribution to overall personal exposures than indicated by their estimated contributions to ambient air.

For a “typical” New Zealand population exposure to benzene of 3 µg/m<sup>3</sup>, the WHO cancer potency estimate for additional lifetime leukaemia risk suggests that up to 0.8 additional leukaemia deaths per year may occur in the total population (Stevenson and Narsey, 1999). This may be compared with the current annual total of about 250 deaths from all types of leukaemia in New Zealand (Stevenson and Narsey, 1999).

#### Emission Control Strategies

Both the benzene and the total aromatics content of petrol are important when addressing possible control measures. Reductions in benzene and total aromatic levels in petrol will have a direct effect on benzene emissions from motor vehicles. However, as discussed in Section 7.10, aromatics are an important source of octane number and must be replaced with either olefins or branched chain alkane content.

Fitting catalysts to cars is the most effective tail-pipe treatment to reduce benzene emissions. Maintaining low levels and/or reducing the sulphur content in petrol will also, indirectly, assist in minimising benzene emissions by ensuring that catalysts can work efficiently.

## E.7 Toluene and Xylene

Based on the Auckland emissions inventory, toluene and xylene together accounted for just over 20% of the total 1993 VOC emissions (MfE#13, 2000). Emissions from motor vehicles accounted for 75% and 85% of toluene and xylene emissions respectively. Toluene and xylene are used as solvents, and the balance of their emissions come from surface-coating operations.

(Xylene exists as different isomers, however for the purposes of monitoring and assessing toxicology, mixtures and individual isomers are normally treated as equivalent).

#### Adverse Effects

A range of health effects have been associated with chronic and acute exposure to toluene, the most significant being those on the central nervous system. The range of health effects associated with chronic and acute exposure to xylene includes breathing difficulties, nose and throat irritation, and neurological effects (such as headaches, dizziness and fatigue).

Ambient air quality guidelines have been derived from the WHO LOAEL. Neither toluene nor xylene are considered carcinogenic.

#### Ambient Air Quality Guidelines and Typical Toluene and Xylene Concentrations

The Review of the Ambient Air Quality Guidelines has recommended toluene and xylene guidelines of 190 and 950



$\mu\text{g}/\text{m}^3$ , annual average, respectively. Compliance with the criteria would be assessed by monitoring at “residential” sites, with modelling or other assessment tools employed to characterise population exposure.

Proposed NZ AAQ Guideline Toluene	190 $\mu\text{g}/\text{m}^3$ , annual average
Typical NZ Urban Actual	3.4-17.1 $\mu\text{g}/\text{m}^3$ , annual average
NZ Proximity to Heavy Traffic	20.0-49.9 $\mu\text{g}/\text{m}^3$ , annual average

Source: MfE#13, 2000

Proposed NZ AAQ Guideline Xylene	950 $\mu\text{g}/\text{m}^3$ , annual average
Typical NZ Urban Actual	2.3-14.3 $\mu\text{g}/\text{m}^3$ , annual average
NZ Proximity to Heavy Traffic	17.0-52.9 $\mu\text{g}/\text{m}^3$ , annual average

Source: MfE#13, 2000

Based on current monitoring data, the proposed criteria are unlikely to be exceeded, and air quality may be categorised as “excellent”. As with benzene, the data illustrate the influence of motor vehicles as well as regional and local meteorology on pollutant levels.

Both toluene and particularly xylene have a distinctive odour. The guideline documents contain recommendation for levels which may be protective of odour nuisance, however it is not proposed that these be adopted formally as guideline values.

#### Emission Control Strategies

For petrol handling and combustion, the aromatics content is the relevant fuel-quality parameter in managing emissions of toluene and xylene. Reductions in total aromatic levels in petrol will have a direct effect on toluene and xylene emissions from motor vehicles. However, as discussed in Section 7, aromatics are an important source of octane number and must be replaced with either olefins or branched chain alkane content.

## E.8 1,3-Butadiene

1,3-Butadiene is a VOC, like benzene, toluene and xylene. The atmospheric half-life of 1,3-butadiene is quite short (several hours), compared with benzene (several days). There is little or no pre-formed 1,3-butadiene in petrol; its major source is combustion of petrol.

Emissions of 1,3-butadiene are believed to vary with the level of olefins in petrol, although one study has concluded that over 90% of 1,3-butadiene emissions originate from the common alkane and aromatic fractions of petrol (MfE#13, 2000).

There is little New Zealand data for quantifying 1,3-butadiene emissions. The most recent Australian inventory indicates that 76% of 1,3-butadiene emissions come from motor vehicles, 15% from industrial sources (including rubber and resin production), and the balance from domestic/commercial sources (MfE#13, 2000).

#### Adverse Effects

Adverse health effects arising from exposure to 1,3-butadiene are well documented. Chronic non-cancer effects include cardiovascular and blood diseases, and neurological effects (blurred vision, headaches). 1,3-Butadiene has been classified as a Group 2A carcinogen by IARC (*probably carcinogenic to humans*). New Zealand has therefore adopted a precautionary approach to setting ambient criteria.

#### Ambient Air Quality Guidelines and Typical 1,3-Butadiene Concentrations

The Review of the Ambient Air Quality Guidelines has recommended an annual average criterion of 2.4  $\mu\text{g}/\text{m}^3$  (equivalent to a one-hour value of 15  $\mu\text{g}/\text{m}^3$ ). Compliance with the criteria would be assessed by monitoring at “urban residential” sites.

There is little New Zealand monitoring data for 1,3-butadiene. Data indicates that ambient air concentrations of 1,3-butadiene in urban areas could be around 10-20% of benzene concentrations (Stevenson and Narsey, 1999). The maximum 24-hour value, equivalent to 1.1  $\mu\text{g}/\text{m}^3$ , recorded in Christchurch, is less than half the recommended annual average concentration (MfE#13, 2000). This suggests that cities within New Zealand appear to be well within the recommended criteria.

### Population Exposure to 1,3-Butadiene

The annual average air concentration would be equivalent to the annual average exposure of an individual, if that individual spent all of their time for a year at the sample location. As people move around however, their exposure to contaminants changes, throughout a day/week/year.

The study undertaken by the MOH to establish current exposure levels to benzene and other toxic organic compounds in air also assessed 1,3-butadiene exposure (Stevenson and Narsey, 1999).

Estimated annual average 1,3-butadiene exposures for non-smokers in New Zealand cities and suburbs are in the range 0.2-2.6  $\mu\text{g}/\text{m}^3$  (Stevenson and Narsey, 1999). Based on US EPA toxicity data, this is equivalent to an additional lifetime leukaemia risk of  $7 \times 10^{-7}$  to  $1 \times 10^{-5}$ , approximately an order of magnitude less than that for benzene (Stevenson and Narsey, 1999).

### Emission Control Strategies

Olefins, along with aromatic compounds, are an important source of octane number. Lowering olefin content while maintaining octane levels requires an increase in either the aromatic content or the branched chain alkane content of petrol. However, based on the findings of a recent New Zealand study, lowering olefin content may not reduce 1,3-butadiene emissions (MfE#13, 2000).

Catalytic converters are efficient at reducing 1,3-butadiene emissions.

## E.9 Formaldehyde and Acetaldehyde

Formaldehyde and acetaldehyde are carbonyls. They are both emitted as primary air pollutants, formed during the combustion of petrol and diesel, and are also formed by secondary photochemical reactions in the atmosphere.

Sources include motor vehicles, domestic solid-fuel combustion, and various types of industry, such as the manufacture of particle board, which would be a significant source at a local level. Auckland inventory data indicates that the two compounds together form less than 2% of total VOC emissions, roughly equivalent to that emitted from domestic solid-fuel consumption (MfE#13, 2000).

### Adverse Effects

Chronic non-cancer effects arising from exposure to formaldehyde include respiratory symptoms, eye, nose and throat irritation. Formaldehyde has been classified as a Group 2A carcinogen by IARC (probably carcinogenic to humans). WHO does not assess formaldehyde as a carcinogen, recommending a guideline value based on the NOAEL, an approach adopted by New Zealand.

Chronic non-cancer effects arising from exposure to acetaldehyde are similar to those for formaldehyde. Acetaldehyde has been classified as a Group 2B carcinogen by IARC (possibly carcinogenic to humans). WHO has assessed acetaldehyde as a carcinogen, recommending a guideline value based on the unit risk factor, an approach adopted by New Zealand.

### Ambient Air Quality Guidelines and Typical Formaldehyde and Acetaldehyde Concentrations

The Review of the Ambient Air Quality Guidelines has recommended annual average criteria of 15 and 30  $\mu\text{g}/\text{m}^3$  for formaldehyde and acetaldehyde respectively. Compliance with the criteria would be assessed by monitoring at "urban residential" sites.

Monitoring data for Khyber Pass Road (Auckland) indicate an annual average of 1-5  $\mu\text{g}/\text{m}^3$  formaldehyde, which is well below the proposed criterion (MfE#13, 2000). There is no available acetaldehyde data for New Zealand, but similar levels to those of formaldehyde are expected, meaning that they also should be well below the proposed criterion (MfE#13, 2000).

Photochemical smog reactions can generate significant levels of formaldehyde in the atmosphere. Given the relatively low smog potential of most New Zealand cities, control of VOC concentrations is likely to ensure that carbonyl ambient air levels remain below the recommended criteria.

### Emission Control Strategies

There are no specific control strategies for formaldehyde and acetaldehyde. Controlling VOC emissions should ensure ambient air levels remain below the recommended criteria, and this will be ascertained by further monitoring (MfE#13, 2000).



## E.10 Benzo(a)pyrene

Benzo(a)pyrene is one of over 40 polyaromatic hydrocarbons (PAHs), but is considered the most hazardous and is commonly used as an indicator species for the group. PAHs arise from the incomplete combustion of solid and liquid fuels. They are semi-volatile compounds, and occur both in the gas phase or attached to fine particles.

The primary sources of PAHs in the New Zealand urban environment are domestic solid-fuel consumption and motor vehicles (primarily diesel), with industrial sources providing potentially significant local sources.

### Adverse Effects

Chronic non-cancer effects arising from exposure to benzo(a)pyrene include dermatitis and eye irritation. Epidemiological studies have reported increases in lung cancer in humans exposed to coke oven and roof tar emissions, and cigarette smoke, all of which contain PAH mixtures (MfE#13, 2000). Benzo(a)pyrene has been classified as a Group 2A carcinogen by IARC (probably carcinogenic to humans). WHO has assessed benzo(a)pyrene as a carcinogen, recommending a guideline value based on the unit risk factor, an approach adopted by New Zealand.

### Ambient Air Quality Guidelines and Typical Benzo(a)pyrene Concentrations

The Review of the Ambient Air Quality Guidelines has recommended an annual average criterion of 0.30 ng/m<sup>3</sup> (0.0003 µg/m<sup>3</sup>) for benzo(a)pyrene.

Based on the limited data for New Zealand, and typical levels found elsewhere, there is a significant chance that existing (possibly background) levels exceed this recommendation (MfE#13, 2000).

### Emission Control Strategies

Domestic solid-fuel consumption is the primary target for reducing (wider) benzo(a)pyrene emissions (MfE#13, 2000). PAH levels affect PM and PAH emissions, therefore reducing total PAH content and, to a lesser extent, aromatics, will reduce PAH emissions. Published data also indicate that exhaust treatment systems are highly effective at reducing PAH emissions (CONCAWE, 1999).

---

August 2001

ISBN 0-478-24259-X

#### ACKNOWLEDGEMENTS

This report was prepared for the Ministry of Economic Development by URS New Zealand Limited, with assistance from the Energy and Fuels Research Unit, UniServices Ltd, University of Auckland.

We would also like to thank all the stakeholders and other interested parties who assisted with their advice and feedback, as well as the members of the Review Advisory Group and the Peer Review Group. The Group members are listed in Appendix A of this document.

Published by Resources and Networks Branch, Ministry of Economic Development, 33 Bowen Street, PO Box 1473, Wellington, New Zealand.  
Ph: +64-4-472 0030 Fax: +64-4-499 0969 Email: [FuelQuality@med.govt.nz](mailto:FuelQuality@med.govt.nz)

Design and printing by Adams Design Group.