



Australian Government

Department of the Environment, Water, Heritage and the Arts

FUEL QUALITY STANDARDS ACT 2000

Review of LPG (Autogas) Fuel Quality Standard

DRAFT DISCUSSION PAPER

Prepared by

**The Department of the Environment,
Water, Heritage and the Arts**

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TABLE OF CONTENTS

1.	INTRODUCTION	3
1.1	Objectives of the discussion paper	4
1.2	Process	5
2.	BACKGROUND	6
2.1	Development of the LPG (Autogas) Standard	6
2.2	Harmonisation with the EU Fuel Standard	6
2.3	LPG vehicle technology.....	6
3.	CURRENT POLICY CONTEXT	7
4.	INCREASE IN UPTAKE OF LPG VEHICLES	7
4.1	Market penetration	7
4.2	Emissions performance of LPG vehicles	9
5.	FUEL QUALITY STANDARD FOR AUTOGAS	9
5.1	Current national standard	9
5.2	Harmonisation with EU LPG automotive fuel standard	11
5.3	LPG vehicle technology – fuel quality requirements	12
5.4	Review of individual parameters in autogas standard	15
6.	SUMMARY	22
7.	NEXT STEPS	22
8.	REFERENCES	23

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1. INTRODUCTION

The *Fuel Quality Standards Act 2000* (the Act) is administered by the Department of the Environment, Water, Heritage and the Arts (the department). The objectives of the Act are to:

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

Under the Act, the Minister for the Environment, Heritage and the Arts (the minister) has the power to set standards for the quality of fuel supplied in Australia and for information to be provided for consumers in relation to fuel supplies. The minister also has the power to approve variations to fuel standards in certain circumstances.

The standards are set in determinations made under the Act and penalties apply for breaches of the legislation. Fuel standards have been made for petrol, automotive diesel, biodiesel and autogas, and a fuel quality information standard applies to the supply of petrol with up to 10 per cent ethanol.

The *Fuel Standard (Autogas) Determination 2003* (autogas standard) regulates the quality of liquefied petroleum gas (LPG) supplied in Australia for automotive use. The standard was developed in close consultation with the Australian Liquefied Petroleum Gas Association or ALPGA (now LPG Australia). The process for developing the standard assessed those LPG fuel parameters identified as significant in managing transport-sourced air pollutants and greenhouse gases, as well as vehicle operability and performance.

Note: This paper needs to be read in conjunction with the discussion paper *Setting National Fuel Quality Standards, Paper 5, Proposed Standards for Liquefied Petroleum Gas ('Autogas')*, October 2001, which provides the technical detail relating to the current autogas standard. Paper 5 is available from the department's website at the following link: <http://www.environment.gov.au/atmosphere/fuelquality/publications/pubs/paper5.pdf>

When the requirements for autogas fuel quality were initially considered in 2001, the LPG industry acknowledged that the full realisation of the environmental potential of LPG future, may require improved vehicle technology and/or tighter fuel composition constraints than those that applied at the time.¹

There has been substantial growth of LPG vehicles in the transport sector. A 2008 census undertaken by the Australian Bureau of Statistics reported that, as at 31 March 2009,

¹ Environment Australia, 2001, *Setting National Fuel Quality Standards, Paper 5, Proposed Standards for Liquefied Petroleum Gas ('Autogas')*, p.7.

2.8 per cent of all registered vehicles used LPG fuel. With vehicle technology advancements and the need for improved vehicle performance in terms of environmental impacts – particularly from greenhouse gas emissions – there is a need to review the autogas standard to ensure that it can adequately control the quality of autogas supplied in Australia.

The Regulation Impact Statement (RIS) on the proposed autogas standard identified two strategies for the future review of a mandatory standard:

- the ongoing monitoring and review of controversial or emerging issues, and
- full-scale review of the standard on a periodic basis (e.g. every five years).

At the time, the department foreshadowed the future tightening of some parameters, for example, sulfur, and recognised that it was appropriate to put in place mechanisms for the ongoing review of certain parameters. The Liquefied Petroleum Gas Working Group, including government and industry stakeholders, agreed to a mechanism for ongoing research and review of the properties of a mandatory autogas standard.

Good regulatory practice, as promoted by the Office of Best Practice Regulation and other regulatory review arrangements, encourages the fundamental review of standards and regulatory arrangements at regular intervals – e.g. five-year review requirements are common. At the time, the Australian Government did not indicate an intention to periodically review of the standard, however, the RIS recommended a full-scale review should be undertaken not more than five years after the standard was implemented.

1.1 OBJECTIVES OF DISCUSSION PAPER

The objectives of this paper are to:

1. Review the adequacy of the current fuel quality standard for LPG autogas.
2. Identify potential issues with the current standard in adequately controlling the quality of autogas supplied in Australia.
3. Facilitate consultation with the industry and other stakeholders on the issues identified and any proposed amendments to the standard.
4. Assist the department in determining:
 - (a) whether the *Fuel Standard (Autogas) Determination 2003* should be amended
 - (b) if so, what amendments are required, and
 - (c) an appropriate timeframe for implementing any amendments identified.

Please note: The information and options contained in this paper do not represent a final Australian Government position. The department recognises there may be other issues that have not been identified in this paper. Stakeholders are invited to comment on the issues set out in the paper and to identify other issues with the autogas standard that may need to be considered in this review.

1.2 PROCESS

The process will involve a two-month public consultation period, including written submissions on the issues identified in the paper. Key stakeholders will be consulted, including LPG Australia and state and territory agencies. Departmental officers will arrange meetings to discuss the issues directly with key stakeholders if necessary.

Due to the technical nature of the issues, independent advice may be sought on any proposals to amend the determination.

Comment: In order to determine the impacts of any proposed amendments to the autogas standard, stakeholders are asked to provide an indication of potential costs to industry from the tightening of any parameters discussed in this paper.

Any necessary amendments to the determination that are identified through this process can be implemented by the minister in consultation with the Prime Minister and other relevant ministers, including the ministers responsible for industry and transport issues.

Comment: Stakeholders are asked to comment on what they consider to be a reasonable timeframe for introduction of any amendments to the autogas fuel standard that result from this process.

Written submissions on the issues outlined in this discussion paper must be provided to the contact officer below by **31 March 2010**.

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2. BACKGROUND

2.1 DEVELOPMENT OF THE LPG (AUTOGAS) STANDARD

The key policy drivers for the development of a fuel quality standard for LPG (autogas) included the need to ensure that the emission performance of LPG vehicles was not compromised by the quality of the fuel, as well as a range of government policies at the time which promoted alternative fuels. A decision to harmonise Australian vehicle emission standards with UNECE (United Nations Economic Commission for Europe) emission standards, made it apparent that Australian fuel standards should also be harmonised with EU fuel specifications.

While the starting premise for developing the autogas fuel standard was harmonisation with the European standard, a set of guiding principles aimed to ensure that the final set of standards were appropriate for the Australian context.

2.2 HARMONISATION WITH THE EU FUEL STANDARD

LPG is produced from the same sources in Europe and Australia i.e. from natural gas sources and refinery by-product. As in Europe, the composition of LPG in Australia varies. The European standard, therefore, appeared to be the most appropriate for Australia particularly in light of the policy to adopt the 'Euro' vehicle emission standards - see section 5.1.

As there was no European Union directive for LPG fuels, European member countries adopted the industry standard produced by the European Committee for Standardization (CEN). EN 589 2000 provided a basis for the development of an autogas fuel standard for Australia, however, when work commenced on developing the fuel standard, autogas supplied in Australia was meeting more stringent specifications than the European standard.

2.3 LPG VEHICLE TECHNOLOGY

At the time the autogas standard was first developed, LPG vehicle technology in Australia relied on Generation 2 technology comprising a carburettor or venturi mixer for vaporised gas and closed loop air-fuel ratio control. This technology regulates the control of fuel from closed looped oxygen sensor readings, and is not as sophisticated as the Generation 3 single or multi-port fuel injection technology used in Europe.

It was recognised that Generation 3 and 4 technology relies on direct liquid injection and any move to introduce this technology to the Australian market might require lower vapour pressures. Generation 2 and some Generation 3 technology performs better with higher vapour pressure fuels. (See section 5.3.1 for an explanation of the technology 'generations'.)

Motor octane number (MON), vapour pressure and hydrocarbon composition are used to define the vaporisation and combustion characteristics of LPG. These parameters impact on the overall environmental and operability performance of LPG. Other critical

parameters include residue content, copper corrosion, sulfur content, moisture content and free water content. The implications of new vehicle technology for the current autogas standard are discussed in section 5.3 below.

3. CURRENT POLICY CONTEXT

On 10 November 2008, the Prime Minister announced a \$6.2 billion plan to make the automotive industry more economically and environmentally sustainable by 2020 [*A New Car Plan for a Greener Future*]. In response to a recommendation from the Bracks Review, under the plan, the Green Car Innovation Fund will be increased to \$1.3 billion. The fund has been established to encourage the development and production of low-emission, fuel-efficient vehicles and components.

The plan also includes a \$10.5 million expansion of the LPG Vehicle Scheme which doubles payments to purchasers of new private-use vehicles that are factory-fitted with LPG technology.² The LPG Vehicle Scheme was established by the Australian Government to provide financial assistance for the purchase of a new LPG vehicle, or for the conversion of a petrol or diesel vehicle to LPG. The objective of the scheme was to assist motorists with rising fuel costs and did not embody specific environmental objectives. This initiative will however, encourage the early adoption of new technologies, such as more efficient direct-injection LPG engines.³

On 2 July 2009, the Council of Australian Governments (COAG), agreed to a detailed assessment of possible vehicle efficiency measures, such as CO₂ emission standards. International studies have indicated that efficiency measures have the capacity to reduce fuel consumption by 30 per cent over the medium term, and significantly contribute to emissions reductions over time.⁴ COAG agreed to undertake a Regulatory Impact Statement to assess the costs and benefits of introducing CO₂ emissions standards for light vehicles.

Given this policy context and the potential for more stringent standards relating to vehicle emissions, it is important to ensure that the autogas fuel quality standard facilitates key vehicle technologies that will improve the performance of LPG vehicles in terms of noxious and greenhouse gas emissions. The review of the current autogas fuel standard is being undertaken in this context.

4. INCREASE IN UPTAKE OF LPG VEHICLES

4.1 MARKET PENETRATION

LPG is the most dominant transport fuel after petrol and diesel. The LPG industry has invested over \$3 billion dollars in infrastructure and advises that LPG is readily available to Australian motorists at over 3,000 outlets across Australia⁵ which is approximately

² *A New Car Plan for a Greener Future*, announcement by the Prime Minister, The Hon Kevin Rudd MP, 10 November 2008.

³ *A New Car Plan for a Greener Future*, 10 November 2008, p.11.

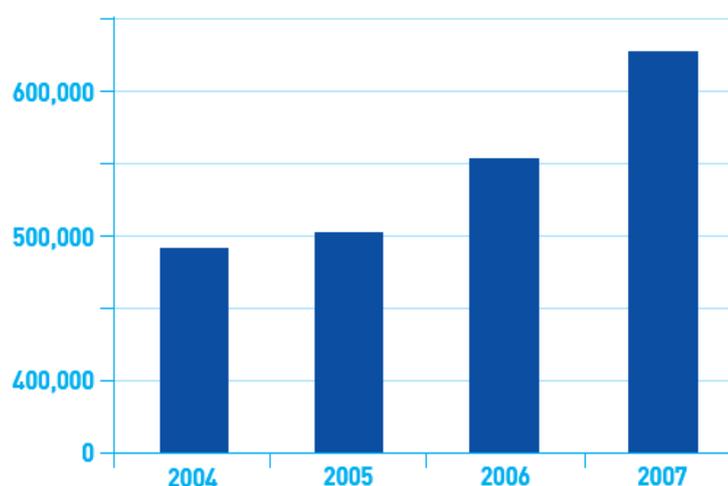
⁴ COAG Communique, 2 July 2009.

⁵ LPG Australia, Pers. Comm, 17 September 2008.

51.7 per cent of total sites⁶. LPG Australia estimates at mid-2009, LPG usage in Australia for transport fuel purposes was between seven and eight per cent of the total transport fuel market. Autogas is mainly used in high-mileage vehicles such as taxis, and light duty delivery vehicles in or close to the major cities. Market penetration in regional areas is much lower.

The industry has advised that autogas in Australia is currently supplied to more than 600,000 motorists. Australia's current gas reserves indicate that for the foreseeable future, LPG will make an important contribution to Australia's transport fuel security. The estimates provided in figure 4.3 below are from the Australian Liquefied Petroleum Gas Association's 2008 *Supply and Demand Study*.

Figure 4.3: Estimated LPG Vehicles on Australian Roads



Source: ALPGA

The *Vehicle Fuel Efficiency* public discussion paper reports that LPG vehicles represent around three per cent of the total vehicle fleet.⁷ According to the discussion paper, just over one per cent of all new passenger and light commercial vehicles in 2005 were factory-fitted LPG models, with annual sales in 2007 of 12,900 representing an increase to 1.6 per cent. The industry estimates that 92,000 vehicles were converted to LPG in 2007. A 2008 census undertaken by the Australian Bureau of Statistics reported 31 March 2009, 2.8 per cent of all registered vehicles used LPG fuel – that is 426,498 from a total of 15,296,542 vehicles.

Initially the LPG vehicle scheme provided a \$2000 grant for the conversion of a new or used petrol or diesel vehicle and a \$1,000 grant for the purchase of a factory-fitted LPG unit. Measures outlined in *A New Car Plan for a Greener Future* include a \$10.5 million expansion of the LPG vehicle scheme which doubles payments to \$2000 for purchases of new vehicles using LPG technology. The 2009 budget measures continue this doubled payment for purchases of new LPG vehicles and makes an incremental reduction of grants available for the conversion of new or existing petrol or diesel vehicles to LPG from \$2000 to \$1000 per vehicle over the next four years. At 30 June 2009, the scheme resulted in

⁶ A 2008 Australian Institute of Petroleum Survey estimated that there are a total of 5,800 fuel supply sites.

⁷ ATC/EPHC, *Vehicle Fuel Efficiency*, Public Discussion Paper, September 2008, p.14.

226,619 additional LPG-fuelled vehicles on the road at an estimated cost to the Australian Government of \$451.9 million.

Assistance from the Australian Government through plans such as the LPG vehicle Scheme, combined with the relatively cheaper price of LPG compared to petrol and diesel, has resulted in an increase in the use of LPG as a transport fuel and a higher penetration of LPG vehicles in the Australian transport fleet.

Ford Australia has produced Australia's first dedicated LPG vehicle. Ford claims that the vehicle "...offers reduced operating costs, while at the same time providing similar performance to petrol-powered vehicles. It will also help improve air quality and reduce greenhouse gas emissions".⁸ Ford has supplied in excess of one hundred thousand E-Gas Ford Falcons to the Australian market over the last decade.⁹ These vehicles utilise Generation 2 LPG technology. Holden continues to supply its dual-fuel LPG Commodore which utilises Generation 3 technology. General Motors (GM) who manufacture Holden vehicles has advised they are investigating alternative technology for the future.¹⁰ There are also other vehicle manufacturers who supply dual-fuel LPG vehicles.

4.2 EMISSIONS PERFORMANCE OF LPG VEHICLES

As mentioned, autogas is mainly used in high-mileage vehicles in or close to the major cities. This makes any detrimental emissions from autogas usage, either directly or resulting from lower catalytic converter performance, more significant in high-population centres.

The *Vehicle Fuel Efficiency* public discussion paper reports that, compared to petrol and diesel, the lower carbon to hydrogen ratio and higher octane rating of LPG, can achieve reductions in CO₂ emissions from LPG vehicles.¹¹ The discussion paper points out that this potential has not generally been realised in Australia due to less than optimal engine and fuel delivery technologies in both mono-fuel and bi-fuel vehicles. According to the discussion paper, future adoption of emerging LPG engine and fuel delivery technologies – for example, liquid injection – has the potential to improve the CO₂ emissions performance of LPG vehicles. However, the full potential of LPG vehicle technology will not be realised if the quality of the fuel used in LPG vehicles is not adequate for their optimum performance.

5. FUEL QUALITY STANDARD FOR AUTOGAS

5.1 CURRENT NATIONAL STANDARD

The current standard for autogas supplied in Australia, as specified in the *Fuel Standard (Autogas) Determination 2003*, commenced under the *Fuel Quality Standards Act 2000* on 1 March 2004 (see table 1 below). The standard was developed in consultation with the LPG industry through the (then) Australian Liquefied Petroleum Gas Association Ltd. The impacts of the proposed standard on the industry were also examined through a Regulation Impact Statement.

⁸ Ford Australia Limited, *LPG Ford Falcon*, Media Release, 4 March 2008.

⁹ Ford Motor Company of Australia Limited, Pers. Comm, 21 April 2009.

¹⁰ GM Holden, pers. comm.. 29 April 2009.

¹¹ *Vehicle Fuel Efficiency*, Public Discussion Paper, September 2008, p.27.

Note: This paper will not cover every parameter in the current standard, but will discuss only those parameters which have either been revised in EN 589, or where stakeholders have raised concern about the current specification. Individual parameters are discussed in section 5.4 below.

The fuel quality requirements of current and emerging LPG vehicle technology will be considered to determine where the standard may need to be tightened. Stakeholders are asked to comment on any other parameters not identified in this paper which may need to be amended. Any amendments to the current standard will also need to be considered with regard to potential impacts on the LPG industry.

Table 1: National fuel quality standard for autogas¹²

Parameter	Standard	Test method	Date of effect
Motor octane number (MON)	90.5 min	Composition by ISO 7941 Calculation by EN 589 Annex B	1 March 2004
Vapour pressure (gauge) at 40°C	800 kPa min 1530 kPa max	ISO 8973	1 March 2004
Volatile residue (C5s and higher)	2.0 max mol %	ISO 7941	1 March 2004
Residue on evaporation	100 mg/kg	JLPGA-S-03 by mass method at 105°C	1 March 2004
Corrosion, copper strip	Class 1	EN ISO 6251	1 March 2004
Hydrogen sulfide	Negative	EN ISO 8819	1 March 2004
Sulfur (after stenching)	100 mg/kg	ASTM D2784	1 March 2004
Dienes	0.3 mol % max	ISO 7941	1 March 2004
Moisture content	No free water at 0°C	EN 589	1 March 2004
Odour	20% lower flammability limit (LFL)	EN 589 Annex A	1 March 2004

The starting premise for the development of all fuel standards under the Act is harmonisation with international standards. The decision to harmonise Australian vehicle emission standards with UNECE emission standards (representing international standards – see box 5.1 below), effectively gives rise to a starting premise that Australian fuel specifications should be harmonised with UN ECE fuel specifications.

It is recognised, however, that the development of CEN (European Committee for Standardization) fuel specifications, while linked to the EC vehicle standards, have also been designed to address issues that are specific to European Union countries. The Australian Government has, therefore, applied a set of guiding principles for fuel standards development which include a general principle that fuel standards should address environmental or health issues based on Australian-specific requirements. In such instances, harmonisation with particular elements of the European specifications may be neither necessary nor desirable.

¹² Fuel Standard (Autogas) Determination 2003 under the *Fuel Quality Standards Act 2000*.

Box 5.1: International' standards

Australia is a signatory to the World Trade Organization which recognises only the regulations developed by the UNECE as international standards for vehicles. The UNECE vehicle emission standards were selected for adoption in Australia to harmonise with international vehicle emission standards. Most Asian countries, and indeed the majority of countries in the world (with the exception of North America and Japan), have adopted UN ECE regulations on emission standards. The terms 'Euro 2', 'Euro 3' and 'Euro 4' are common terminology used to describe the progressively more stringent versions of the UNECE standards.¹³

5.2 HARMONISATION WITH EU LPG AUTOMOTIVE FUEL STANDARD

As there was no European Union directive for LPG fuels, European member countries adopted the industry standard produced by CEN. EN 589 2000 has provided the basis for the development of an autogas fuel standard for Australia, however, when work commenced on developing the fuel standard, autogas supplied in Australia was meeting more stringent specifications than the European Standard. Since the implementation of the autogas standard in Australia in 2003, EN 589 has been tightened over time with the most recent amendments in 2008 – see table 2.

Table 2: EN 589 2008

Property	Unit	Limits		Test method ^a
		Minimum	Maximum	
Motor octane number, MON		89.0		Annex B
Total dienes content (including 1.3 butadiene)	mole %		0.5	EN 27941
Hydrogen sulphide		negative		EN ISO 8819
Total sulfur content ^b (after stenching)	mg/kg		50	EN 24260 ASTM D 3246 ASTM D 6667
Copper strip corrosion (1 h at 40°C)	rating		class 1	EN ISO 6251
Evaporation residue	mg/kg		60	EN 15470 EN 15471
Vapour pressure, gauge at 40°C ^c	kPa		1 550	EN ISO 4256 EN ISO 8973 and Annex C
Vapour pressure, gauge, min. 150 kPa at a temperature of: ^{d,e} - for grade A - for grade B - for grade C - for grade D - for grade E	°C		-10 -5 0 +10 +20	EN ISO 8973 and Annex C
Water content ^f		No free water at 0°C		EN 15469
Odour		Unpleasant and distinctive at 20 % LFL		Annex A of EN 589 2008

Note: Table 2 refers to specifications only and does not include notes and annexes relating to test methods.

¹³ DoTRS, 1999, RIS – *New ADRs for Control of Vehicle Emissions*, p. 42.

Specifications that apply under EN 589 relating to residue on evaporation and sulfur levels are now tighter than the Australian autogas standard. In reviewing the Australian autogas standard, harmonisation with these tighter specifications needs to be considered.

Changes to the EU fuel specifications over time have been driven by vehicle emission standards and engine emissions control technologies, and new mandated quality and compositional requirements for petrol, diesel and LPG fuel. LPG fuel quality requirements for current and emerging LPG vehicle technology in the Australian fleet are discussed in section 5.3 below.

5.3 LPG VEHICLE TECHNOLOGY – FUEL QUALITY REQUIREMENTS

Australia is dependent on international vehicle technologies which in turn require fuel of an adequate quality to ensure their optimum performance in terms of emissions and fuel efficiency. The supply of new LPG vehicle technology to the Australian market is in part, dependent on whether appropriate fuel is available.¹⁴

At the time the autogas standard was developed, there were a number of existing and emerging fuel technologies that were considered necessary for vehicles to meet future emissions standards (i.e, Euro 3 and beyond). These include:

- gaseous and liquid fuel injection
- advanced catalyst formulations which offer support for the introduction of lean burn engine technologies, and
- on board diagnostic (OBD) systems.

In terms of the timing to introduce these technologies:

- LPG-specific catalyst formulations were expected to be introduced by 2007
- gaseous injection systems were expected to appear between 2005 and 2008, and
- liquid fuel injection and OBD systems were expected to be in Australian vehicles from 2010 to coincide with Euro 4 requirements.

The national standard for autogas that was introduced under the Act is almost identical to the industry standard that applied at that time. It provides for fuel that is compatible with the Euro 2 emissions standards that are incorporated into ADR79/00 which were implemented on 1 January 2003. However, questions were raised whether the standard would facilitate the introduction of ADR79/01 (Euro 3) and Euro 4 emission standards (adopted in ADR79/02), as some of the more sophisticated technologies can be sensitive to fuel parameters.

For the purposes of this review, it is useful to reiterate the discussion on vehicle technology that was included in the discussion paper released for public comment at the time the autogas standard was developed.¹⁵ This discussion sets the scene for consideration of developments with the technology since 2001 when the autogas standard was first considered.

¹⁴ *Regulation Impact Statement, Fuel Quality Standard Liquefied Petroleum Gas*, September 2003, p.8.

¹⁵ *Setting National Fuel Quality Standards, Paper 5, Proposed Standards for Liquefied Petroleum Gas ('Autogas')*, October 2001, Appendix A, p. 50.

At that time, it was recognised that LPG technology may undergo a similar change that has occurred in the delivery of petrol to engines. In petrol engine vehicles there was an increase in complexity level and cost – carburettors were replaced by throttle body injectors (TBI) for electronic fuel management. In some car models this step was omitted and manufacturers adopted the next level of complexity with port injection for each cylinder (MPFI¹⁶). Not all of these systems injected the fuel at the same time in the engine cycle, but almost all engines had sequential fuel injection (SFI) which achieves this. Spark ignition direct injection (SIDI) cars had not yet reached the Australian market as they have now.

LPG systems were expected to follow a similar path in fuel supply complexity with the additional option to supply as gas or liquid. LPG can potentially reduce emissions because it can be provided to the engine inlet manifold as a gas when passed through a pressure regulator and vaporiser. This avoids the substantial problem of ‘liquid fuel handling’ which occurs with petrol engines. This problem has diminished in petrol engines with improvements in petrol engine technology, but is only avoided with SIDI.

During transient driving manoeuvres (accelerating or decelerating) the existence of uncontrolled quantities of liquid fuel in the manifold prevents the accurate control of the air to fuel ratios ideal for the engine’s operation (stoichiometric), which is needed to maximise the conversion of HC, CO and NO_x to CO₂ and water in the three-way exhaust catalyst. Technology emerging in the market at the time the autogas standard was developed included LPG systems which inject liquid LPG in a similar way to petrol, while others inject vaporised LPG in a similar way to CNG (compressed natural gas) systems.

5.3.1 LPG vehicle technology ‘generations’

The advancements in LPG vehicle technology are categorised as Generations 1 to 4:

- **Generation 1** – Basic LPG systems which supply vaporised LPG via a converter but with no exhaust oxygen feedback control.
- **Generation 2** – Systems which supply vaporised LPG via a converter and have electronic feedback control to the converter (usually controlling the supply pressure). The supply of fuel to the engine can be by a venturi mixer or a gas carburettor.
- **Generation 3** – Systems which supply LPG to individual intake ports via valves or injectors. These systems utilise single- or multi-port fuel injection of either dry gas or liquefied fuel and have a faster closed loop response time and more precise delivery of the LPG to the engine.
- **Generation 4** – Systems which inject LPG in either liquid or gaseous form directly into the combustion chamber after the valves have closed. The system provides full timed sequential injection. These will be compatible only with the new wave of direct injection spark ignition engines (comparable to MPFI petrol systems).

¹⁶ Multi Port Fuel Injection systems.

The technology and fuel delivery requirements in moving from Generation 2 (which do not rely on liquid injection) and Generation 3 and 4 systems (which might rely on liquid injection) may necessitate changes to certain fuel parameters to ensure optimal performance of the vehicle.

For some Generation 3 and 4 systems, it is desirable to keep the fuel liquid at all times, which may be difficult due to high fuel temperatures experienced in Australian outback conditions (hot fuel handling). As a result of flow system pressure drops, the fuel must not boil in the injectors before injection into the manifold air, or afterwards in the fuel return line, as re-liquefying the fuel could cause problems in the fuel tank due to the rising fuel temperature. Hot fuel handling is known to be an implementation issue for Generation 3 and 4 systems. Another is presence of transient petrol like fuel pools in the manifold. In Generation 2 and 3 systems (which do not rely on liquid injection) the reverse is true. Within fuel tank temperature and pressure storage limitations, it is desirable to have a fuel that vaporises readily to ensure that there is no liquid fuel carry over.

5.3.2 Relationship between technology generation and EU emission standards

While the linkages between LPG system technologies and different stages of emission control standards are not absolute, some general observations can be made. Generation 2 technology was the minimum requirement to enable compliance with the Euro 2 standards which applied to new vehicles until the end of 2003. Some Generation 2 and most Generation 3 technologies may also enable compliance with Euro 3 standards, although some manufacturers meeting Euro 3 standards in Europe have opted for Generation 3 technology as a minimum. In principle, the on board diagnostic (OBD) requirements of Euro 3 can be met with Generation 2 and 3 technologies.

In 2001, when the autogas standard was developed, Euro 4 standards had been determined and agreed in Europe, but were not implemented until 2005. In 2001, LPG single or multi-port fuel injection using dry gas or liquid fuel (Generation 3) technologies were being utilised in Europe. This technology was also emerging in other regions.¹⁷ At the time, the technology applied in Australia was Generation 2 technology comprising a carburettor or venturi mixer for vaporised gas and closed loop air to fuel ratio control. This technology regulated the control of fuel from closed looped oxygen sensor readings and is not as sophisticated as the Generation 3 single or multi-port fuel injection technology.

5.3.3 Current Original Equipment Manufacturer (OEM) technology

Current OEM LPG technology used in Australia incorporates both Generation 2 and 3 vapour delivery systems, with carburettor closed loop and port fuel injection (PFI) injectors respectively. There is some penetration of liquid injection systems (LPI) in aftermarket retrofits and several OEMs overseas, who utilise LPI technology, have stated they are investigating introducing this technology into the Australian marketplace. Changes to the LPG fuel standard may be required to facilitate the introduction of this type of technology.¹⁸

¹⁷ Setting National Fuel Quality Standards, Paper 5, *Proposed Standards for Liquefied Petroleum Gas ('Autogas')*, October 2001, p. 6.

¹⁸ GM – Asia Pacific, pers. comm.. 3 April 2009.

While there is no knowledge of any OEMs with Generation 4 direct injection LPG systems in production, there are several companies worldwide developing this system. It is envisaged this technology could enter the marketplace in around three to four years, so this review of the LPG fuel standard should also consider the likely minimum fuel requirements to support this technology. Dedicated LPG engines can offer additional CO₂ benefits by optimising (increasing) the compression ratio for LPG operation. This requires strict control of the alkenes and dienes to avoid lowering the octane of the fuel to the point where destructive knock could occur.

According to GM Asia Pacific, various technical papers suggest that very lean operation with LPG is also possible. This technology however, requires NO_x traps in the exhaust and the efficiency of these devices is adversely impacted by sulfur in the fuel. Information obtained by GM indicates that at 10 mg/kg sulfur the NO_x traps need to be purged (run rich and at higher temperature for a period of time) after around 2500km under normal driving conditions.

GM advises that the current standard might need to be amended to provide for stricter autogas composition directly limiting olefin content (see the note above about high compression ratio engines). GM suggests that propene could be limited to 10 per cent, with minimum propane limits of 50 per cent, and the tightening of the sulfur limit to 50 mg/kg to bring the standard in line with Euro 4. GM claims that for Euro 5 fuel sulfur levels might need to be reduced to 10 mg/kg which could require a new odorant, instead of the sulfur-based ethyl mercaptan which is currently used by the LPG industry. (This is discussed further in section 5.4.1 below.)

Discussions to date with vehicle manufacturers have indicated they are still in the early stages of investigating the introduction of the more advanced LPG vehicle technology utilising direct liquid injection systems. Amendment of some of the parameters in the autogas standard may need to be delayed until the LPG vehicle manufacturers have had sufficient time to consider what is required in terms of fuel quality to ensure the optimum performance of these vehicles.

Comment: Stakeholders are asked to provide information on developments with LPG vehicle technology since 2001, and current and potential fuel quality requirements. In particular, OEMs and equipment suppliers are also asked to provide views on the expected uptake of specific technologies in the near term (five years), particularly those technologies where performance is strongly linked to fuel parameters such as sulfur.

Comment: OEM's and vehicle manufacturers are also asked to indicate when they will be in a position to comment confidently on the fuel quality requirements for the more advanced LPG vehicle technologies.

5.4 REVIEW OF INDIVIDUAL PARAMETERS IN AUTOGAS STANDARD

With amendments to EN 589 and advancements in vehicle technology to meet tighter emission standards, it is now appropriate to consider the merits of amending the autogas standard to reflect these developments. In particular, if there is a significant shift by manufacturers to adopt technology requiring liquid injection (Generation 3 or Generation 4), tighter LPG fuel specifications may be required.

The LPG fuel parameters discussed below have either been revised in the European standard EN 589, or have been raised by stakeholders as potentially needing revision to facilitate current and emerging LPG vehicle technology. They include:

- sulfur
- residue on evaporation
- test method for water content
- propane and butane composition
- vapour pressure, and
- olefins.

It is proposed to amend the autogas standard to bring it into line with the 2008 amendments to EN 589, and to work with the vehicle manufacturers on amending other parameters in the standard as more information emerges about fuel quality requirements for the more advanced LPG vehicle technology.

Proposal:

1. That the levels specified for sulfur and residue on evaporation, and the test methods for residue on evaporation and water content be amended, as specified in section 5.4.1 below, to bring the autogas standard in line with EN 589 2008.
2. That amendment of any of the other parameters in the autogas standard be delayed until vehicle manufacturers can comment confidently on what amendments are required to facilitate the more advanced LPG vehicle technology.

5.4.1 Issues in relation to individual parameters in the current autogas standard

Alignment with EN 589 2008:

Sulfur

Limiting sulfur levels is important for the efficient function of vehicle technologies necessary for compliance with emission standards – particularly hydrocarbon emissions. The sulfur limit minimises sulfur oxide emissions and limits potential corrosion by exhaust gases from combustion of LPG.

OEM advice suggests that the effectiveness of NOx traps for new lean burn technology is adversely impacted by sulfur in the fuel. It appears that there may even be issues with sulfur at levels as low as 10 mg/kg, however, the number of vehicles currently utilising this technology is minimal.

The 2008 amendments to EN 589 reduced sulfur levels in LPG supplied in Europe from 100 mg/kg to 50 mg/kg. The Australian autogas standard sets the maximum sulfur limit at 100 mg/kg. At the time the autogas standard was developed, LPG had one of the lowest sulfur contents of any petroleum-derived fuel. However, since the autogas standard was introduced, sulfur levels in petrol and diesel have been reduced, with the diesel standard now specifying a limit of 10 mg/kg, and sulfur levels in unleaded petrol and premium unleaded petrol reduced to a maximum of 150 mg/kg and 50 mg/kg respectively.

In Australia and Europe the limit is set after odorant is added. In Australia the odorant used is ethyl mercaptan which is a sulfur compound and therefore contributes to the sulfur content of LPG. The LPG industry in Australia is investigating alternative odorants such as Vigileak and work is continuing to find a suitable alternative odorant. Ethyl mercaptan is also the odorant used in Europe. Various non-sulfur odorants are also being trialled there, such as Gasodor[™]S-free[™].¹⁹

Reducing sulfur levels to 10 mg/kg would require LPG producers to find an alternative to ethyl mercaptan. The cost benefit analysis (CBA) of the proposed national LPG fuel standard, undertaken by The Allen Consulting Group in January 2003, reported that an alternative odorant had not yet been identified by the industry. The CBA reported that obtaining levels of 50 mg/kg sulfur in LPG would require that pre-odorant fuel contain low sulfur levels, probably no more than around 20 mg/kg, and this would result in a cost to some LPG producers.

While the cost to achieve a 50 mg/kg limit was not expected to be significant, achieving even lower sulfur levels (i.e. 10 mg/kg sought by some manufacturers to enable highly sulfur-sensitive technologies) would require an alternative odorant, and it was not known at the time the cost of an alternative odorant, or what the potential cost of investments in sulfur reduction would be. At the time this paper was prepared, advice from the industry was that an alternative odorant had still not been identified.

Recommendation: It is proposed that, from 1 June 2010, the current specification for sulfur in the autogas standard be reduced from 100 mg/kg to 50 mg/kg, to align with EN 589. If evidence suggests that a significant proportion of emerging LPG vehicle technology requires lower levels, further reduction to 10 mg/kg will be considered. Any move to lower sulfur levels to 10 mg/kg, however, would need to assess whether the industry can use an alternative odorant to ethyl mercaptan.

Comment: Stakeholders are asked to comment on the proposal to amend the sulfur specification in the autogas standard to 50 mg/kg and the proposed implementation date.

Comment: Stakeholders are also asked to comment on the potential for the industry to adopt an alternative odorant if sulfur levels were further reduced to 10 mg/kg in the future, a possible timeframe, and potential costs to industry.

Residue on evaporation

Excessive residues in autogas cause operability problems in LPG vehicles. Autogas with excessive levels of contaminants can cause:

- residue build up in regulators and vaporisers, which can cause engines to stop
- increased maintenance costs (e.g. more regular cleaning of LPG fuel systems and converters), and
- in extreme cases, converters to become unserviceable requiring their replacement.

¹⁹ BP Australia, pers. comm.. 24 August 2009.

At the time the autogas standard was developed, controlling residue levels was considered to be one of the most important issues for LPG fuel quality. Applying the residue limits in the standard throughout the supply chain was seen as a significant challenge for the industry. The EN 589 specification of 100 mg/kg, that applied at the time, was adopted. The latest revision of EN 589 reduced the standard for evaporation residue from 100 mg/kg to 60 mg/kg to improve the durability of automotive LPG equipment. Reducing the limit was dependent on an appropriate test method being defined.

The test method that was specified in EN 589 for evaporation residue (previously ISO 13757) has been replaced with two test methods – EN 15470 and EN 15471. While the intent is to harmonise as much as possible with the European standard, The department prefers the approach of specifying only one test method for each parameter listed in a fuel standard. This approach provides transparency for the industry on which test method is used by the department to determine compliance.

The department therefore needs to determine, if the autogas standard is revised to limit residue on evaporation to 60 mg/kg, whether there is a need to specify both test methods now applying in EN 589, or whether the industry has a preference for only one of the methods to be specified in the autogas standard.

Recommendation: That from 1 June 2010, the specification for residue on evaporation in the autogas standard be revised to 60 mg/kg to align with EN 589, and that only one of the test methods specified in the revised EN 589 be adopted i.e. EN 15470 or EN 15471.

Comment: Stakeholders are asked to comment on the proposal to harmonise with the revised specification for evaporation residue in EN 589, and the implications for industry of adopting one or both of the revised test methods.

Test method for water content

Both the autogas standard and EN 589 specify that there must be no free water at 0°C. The test method specified in the autogas standard simply refers to EN 589. To determine compliance with the standard, the same testing procedure specified in EN 589 must be used.

When the autogas standard was introduced, the test method in EN 589 was specified as ‘Propane rich=EN ISO 13758, EN ISO 3993’. With the revision to EN 589 in 2008, the test method for water content is now EN 15469 and the standard specifies:

Liquefied petroleum gases for automotive purposes shall not contain free water at 0°C and at the saturated vapour pressure on visual inspection.

NOTE 1 For propane rich mixtures with a minimum of 60 per cent propane, compliance with EN ISO 13758 [1] equally satisfies this requirement.

For operational purposes it is allowed to add up to 2 000 mg/kg methanol. No other antifreeze agents shall be added.

Comment: Stakeholders, and particularly LPG producers and suppliers, are asked to comment on whether there would be any issues from adopting the revised approach in EN 589 for testing water content.

Other parameters:

Propane and butane

There are significant differences in the propane content of autogas across Australia, and particularly between autogas supplied in city centres and that are available in regional areas. To reduce transport costs, the same delivery of LPG will need to supply the fuel for both vehicle and household use. The LPG supplied in these circumstances will, therefore, need to contain propane only.

The autogas standard does not specify the hydrocarbon makeup of LPG, however, the proportions of propane and butane are indirectly limited through the vapour pressure and MON parameters.

Future vehicle technologies such as liquid injection (Generations 3 and 4), require low vapour pressure or a reduced vapour pressure range, which in turn could necessitate a deviation from the current propane to butane range. Butane levels are indirectly set at around 60 per cent through the vapour pressure limits and MON specification. Previous research suggests that, in terms of environmental performance, the optimal propane to butane ratio is 50:50.

The CSIRO study *Lifecycle Emissions Analysis of Alternative Fuels for Heavy Vehicles*, commissioned by the Australian Greenhouse Office in 2001, reported that the addition of butane slows down combustion speed in an engine, so that it reduces NO_x emissions while it increases emissions of THC and CO (page 294). The report also stated that in some overseas countries automotive LPG (HD-5 specification) must contain a minimum of 95 per cent propane, the balance being butane and propylene (page 297) and the main benefit of propane is that the compression ratio can be altered to suit the higher octane fuel (page 321). However, restricting supply to such blends could significantly impact on widespread availability of LPG in Australia.

The performance of LPG engines is optimised for the current LPG fuel blends (i.e. up to 60 per cent butane). Altering current blends, by increasing the butane content, will result in wider fluctuations in butane to propane ratios, which vehicles are not optimised/calibrated against. It has been suggested that there should be stricter control of autogas composition with propane levels set at a minimum of 50 per cent. The ADR test procedures, however, require engines to demonstrate adaptability to different blends by requiring compliance on two extreme blends of test fuel. This should, therefore, only be an issue for aftermarket applications.²⁰

Harmonisation of the Australian autogas standard with EN 589, which does not directly control butane to propane ratios, has had a positive impact on the LPG production industry. This mainly arises through the ability to put more butane in autogas. In the case of refinery producers, this helps absorb excess butane arising from tighter summer Reid Vapour Pressure (RVP) limits for petrol, resulting in a higher value use for the excess butane. In

²⁰ Department of Infrastructure, Transport, Regional Development and Local Government, pers. comm. 4 September 2009.

the case of natural LPG producers, there is a benefit from being able to substitute lower cost butane for higher priced propane in mixed autogas.

Butane is, therefore, blended at higher ratios into autogas in summer. Higher ambient summer temperatures produce a higher pressure in the LPG vehicle fuel tank, which will allow more butane to be included while maintaining an adequate supply pressure. The only limiting factor to the amount of butane that can be blended is its relatively low Research Octane Number (RON) and MON value.

Capping the level of butane in the autogas standard would significantly limit the capacity of the LPG market to absorb excess butane arising from changes to petrol specifications. This could result in the need for refineries to flare butane, which is an undesirable environmental outcome. If other markets can absorb the excess butane, capping butane levels may be the preferred option given the potential emission outcome benefits.

Comment: Stakeholders are asked to comment on the current approach in the autogas standard which does not directly set limits for the propane to butane ratios and indirectly controlling these through the vapour pressure limits and the MON specification. Advice is particularly sought on requirements for future LPG vehicle technology if this is available.

Vapour pressure

Vapour pressure limits are related to climatic conditions. The specifications in the autogas standard applying in Australia differ to those that apply in EN 589 due to the colder climatic conditions in Europe.

When the autogas standard was developed, the industry standard of 800 kPa to 1530 kPa at 40°C was adopted. At the time, it was suggested that technology requiring liquid injection (Generation 3 and Generation 4), may require lower vapour pressures, whereas Generation 2, and some Generation 3 technology performs better with higher vapour pressure fuels.

As mentioned previously, many deliveries to regional centres need to supply LPG for both household use as well as vehicles, and LPG supplies are mainly propane. Due to the higher propane content, these supplies will comply with the vapour pressure range in the current autogas standard. A concern has been raised, however, that this may not always be the case with supplies of LPG that contain a mixture of both propane and butane. If this is the case, and the butane content results in the vapour pressure falling outside the specified range in the standard, the performance of Generation 3 and 4 vehicle systems, which rely on liquid injection, may be adversely affected.

Comment: Stakeholders are asked to comment on whether the current specification for vapour pressure in the autogas standard is adequate for existing LPG vehicle technology, and whether vapour pressure would need to be lowered to facilitate future vehicle technology (liquid injection).

Comment: State and territory environment agencies are asked to comment on potential vapour pressure requirements in their jurisdictions.

Olefins

Olefin levels need to be controlled to limit combustion chamber deposits. The olefin content of LPG is not directly controlled in either the European or Australian autogas standards, however, olefin content is indirectly controlled to around 40 per cent through the MON specification.

At the time the autogas standard was developed, it was decided that the difference in ambient temperatures in Australia compared to Europe, warranted setting a minimum MON of 90.5 as opposed to the European level of 89.0. At that time it was recommended that consideration of setting a separate level for olefins be deferred. It was also suggested that further work may need to determine the fuel specifications suitable for Generation 3 and 4 LPG systems, as additives may be required to prevent injector clogging. There were proposals in Europe to lower the level of olefins to prevent such clogging.²¹ The European standard, however, does not currently set a limit for olefin levels

Recent OEM advice indicates it would be beneficial to directly limit olefin content in autogas to enable the compression ratio of dedicated LPG engines to be optimised for autogas. Achieving an increased compression ratio would require strict control of olefins and dienes so that the RON and MON of the fuel are not lowered to the point where destructive knock could occur²². Dienes are already controlled through the autogas standard where the specification of 0.3 mol per cent is stricter than the European standard of 0.5. GM has suggested that in order to achieve optimal compression ratios, propene (olefin) levels in autogas might need to be limited to 10 per cent.

Comment: Stakeholders are asked to comment on whether olefin levels in autogas should be directly controlled in the autogas standard and, if so, at what levels?

The parameters discussed in section 5.4 have either been amended in the European standard or raised by stakeholders in light of recent developments with LPG vehicle technology. However, stakeholders may consider that other parameters or test methods also require review.

Comment: Stakeholders are asked to comment on whether any other parameters or test methods in the autogas fuel quality standard should be amended.

Particulates

It has been suggested the autogas standard may need to include a minimum level for particulates due to the sensitivity of vehicle injector systems and particularly to particles around 25 microns from sources such as corrosion and scaling in tanks.

Comment: Stakeholders are asked to comment on the merits of including a minimum level for particulates in the autogas standard, or whether it is more appropriate to control this issue through fuel dispenser filters?

²¹ *Setting National Fuel Quality Standards, Paper 5, p.6.*

²² GM – Asia Pacific, pers. comm.. 3 April 2009.

6. SUMMARY

It is important to consider whether the current fuel quality standard for autogas is adequate to facilitate the optimum performance of emerging LPG vehicle technology in terms of emissions and fuel efficiency. Recent amendments to the European LPG automotive fuel standard have also prompted the need to review sulfur levels in autogas supplied in Australia, as well as other parameters that might need to be amended to bring the Australian autogas standard into line with EN 589 applying in Europe.

It is proposed to amend the autogas standard to align with EN 589 from June 2010. It will be important, however, to ensure that any amendments facilitate the more advanced LPG engine technology. This will require close consultation with vehicle manufacturers who may not, at this stage, have sufficient information about fuel quality requirements for emerging technology. Amending any other parameters, apart from those amended in EN 589 on 2008, may need to be delayed until information from vehicle manufacturers is available.

The review of the autogas standard may, therefore, involve two tranches: amending those parameters that have been amended in EN 589 by June 2010 to bring the autogas standard into line with the European standard; and other parameters amended at a later date as required. Any amendments to the standard will need to be made after close consultation with stakeholders, particularly LPG producers and OEMs. The LPG industry will need to consider the issues discussed in this paper to determine the technical implications and potential costs of complying with a revised autogas standard.

7. NEXT STEPS

At the end of the public consultation period, all submissions received from stakeholders will be considered to determine what parameters and test methods, if any, need to be amended in the autogas standard.

Any technical issues arising from the consultation period may require the department to engage an independent technical expert to determine the best approach to revising the current standard. If a technical consultancy is required, this could significantly delay any action to finalise the revision of the standard. It is, however, envisaged that a revised determination could be signed by the minister before June 2010, to incorporate the 2008 amendments to the European Standard.

The department, in consultation with relevant government agencies, will develop a proposed government position which will be discussed with key stakeholders before any amendment to the autogas determination is made.

Comment: Stakeholders are asked to comment on the proposed approach and timeframe for implementation of amendments to the autogas standard and on any issues that would warrant urgent action in terms of when the amendments need to be in place.

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