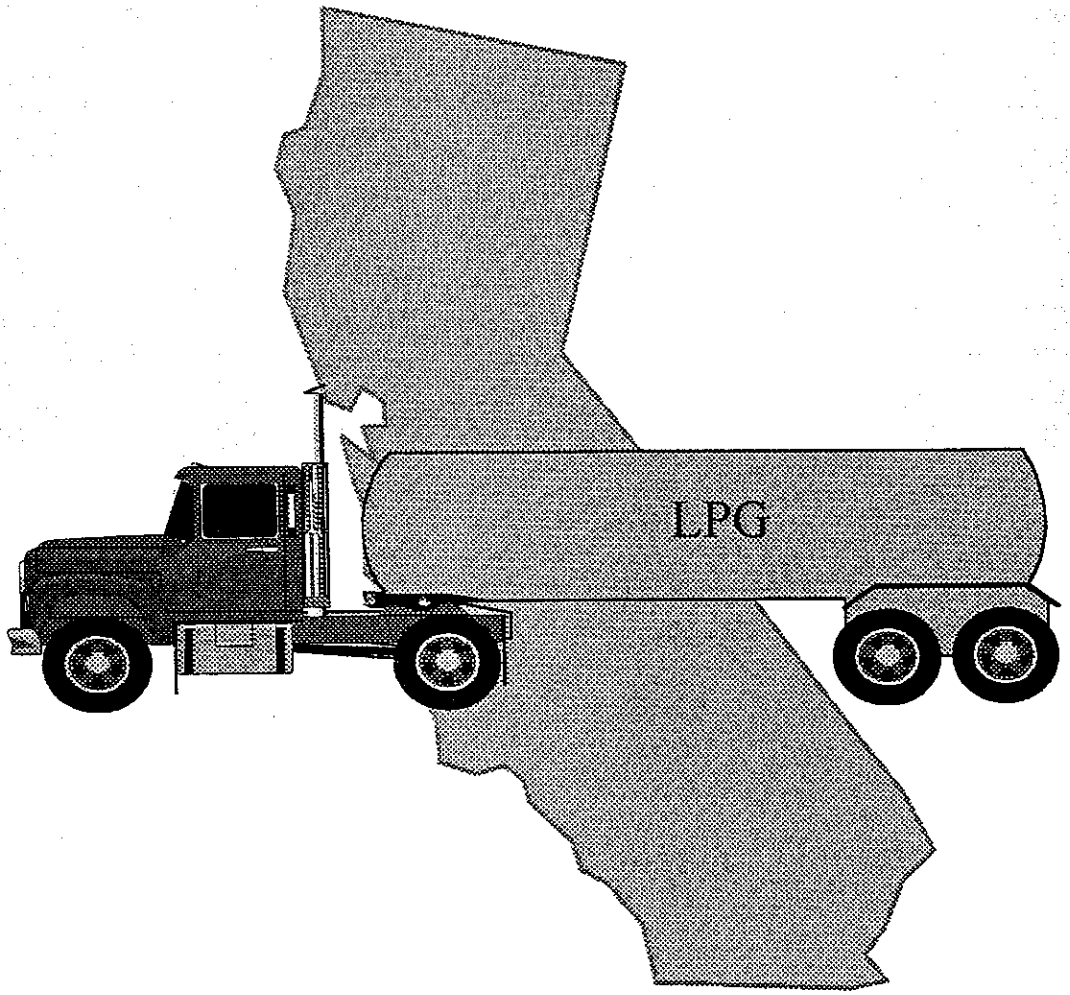
Proposed Amendment to the Limit on the Propene Content of Liquefied Petroleum Gas Intended for Use in Motor Vehicles

Release date: January 1997



California Environmental Protection Agency

Air Resources Board

State of California
AIR RESOURCES BOARD

PROPOSED AMENDMENT TO THE LIMIT ON THE PROPENE CONTENT OF LIQUEFIED PETROLEUM GAS INTENDED FOR USE IN MOTOR VEHICLES

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January 1997

State of California
AIR RESOURCES BOARD

INITIAL STATEMENT OF REASONS FOR PROPOSED RULEMAKING

Public Hearing to Consider a
PROPOSED AMENDMENT TO THE LIMIT ON THE PROPENE CONTENT OF LIQUEFIED PETROLEUM GAS INTENDED FOR USE IN MOTOR VEHICLES

To be considered by the Air Resources Board on March 27-28, 1997 at:

Air Resources Board
Board Hearing Room
Lower Level
2020 L Street
Sacramento, California

Air Resources Board
P.O. Box 2815
Sacramento, CA 95812

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ACKNOWLEDGMENTS

We acknowledge the assistance and cooperation received from several persons and groups. In particular, we thank the Western Propane Gas Association and its members.

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I.

INTRODUCTION, SUMMARY, AND RECOMMENDATION

A. Introduction

This report presents a proposal by the staff of the Air Resources Board ("ARB" or "Board") to delay a reduction of the limit on the propene content of liquefied petroleum gas (LPG) that is sold for motor vehicles. Currently, the propene limit is ten percent by volume, maximum. It is scheduled to decrease to five percent on January 1, 1997.

The report is the Initial Statement of Reasons for an amendment to section 2292.6, Title 13, California Code of Regulations. That section limits several properties of LPG, including the propene content. Section 2291 of the same code prohibits the sale or supply of LPG that is intended for use in motor vehicles in California if the LPG does not comply with the limits in section 2292.6. Both sections are in Appendix 1 of this report.

The staff is proposing to delay reducing the propene limit until January 1, 1999. Our proposal is in response to a petition on September 20, 1996, from the Western Propane Gas Association (WPGA, an association of LPG marketers). In the petition,

WPGA contends that if the limit on the propene content declines to five percent on January 1, 1997, there will be insufficient complying (motor-vehicle-grade) LPG for WPGA members to maintain an adequate supply to the vehicles that now use LPG. The petition is in Appendix 2.

Regulatory Background In March 1992, the Board adopted specifications for LPG. These included specifications for certification fuel for certifying new LPG vehicles and specifications for commercial (in-use) LPG for vehicles. The commercial specifications (which are the sole subject of the current proposal) define the fuel that is to be used by motor vehicles in California. They assure the vehicle and engine manufacturers about the properties of the in-use LPG that their vehicles will receive.

The Board included a maximum limit on the propene content because, as an olefin, propene is more reactive in the atmosphere than is propane, the main component of LPG. The initial propene limit was ten percent, and the limit was to have declined to five percent on January 1, 1995. However, in 1994, the Board amended the regulation to postpone until January 1, 1997, the effective date of the five-percent limit for in-use LPG. That action was taken after the WPGA raised issues similar to the issues raised in the current petition. There was no significant opposition in 1994 to the delay. There was no change to the specifications for the certification fuel used to test new LPG vehicles and engines to determine their compliance with their emission standards.

In 1994, the staff expected that during the delay of the five-percent propene limit, information would be developed on the emission and performance consequences of a higher limit. Also, it was thought in 1994 that changes in the operation of refineries, in response to the cleaner-burning gasoline regulations, could increase the amount of LPG that complies with the five-percent limit.

The LPG specifications are not part of the State Implementation Plan (SIP); no emission reductions are claimed in the SIP for the specifications. Thus, the delay in the more stringent propene limit from 1995 until 1997 had no effect on the SIP.

Interactions with the Public and Affected Parties In response to the petition from the WPGA, the staff held a public workshop, on December 3, 1996, to discuss issues concerning the propene limit and its possible delay. Also, we have surveyed the LPG production and marketing industries to evaluate the availability of complying LPG. The current proposal reflects the results of the staff's analysis of the information from those sources.

B. Summary

The information available to the staff indicates that if the propene limit for vehicular LPG declines to five percent in January 1997, a supply problem is likely in

northern California. One of the producers of LPG known to the staff in northern California does not meet the five-percent limit and will not change its operations to do so. As a result, the documented production of vehicle-grade LPG in northern California will decline by 56 percent if the propene limit becomes five percent.

If the supply of LPG with under five percent propene could be directed only to vehicular use, the supply should be adequate. However, only a few LPG marketers are able to handle vehicular-grade LPG as a product separate from commercial-grade LPG. This is because the vehicular demand for LPG constitutes only about 20 percent of the total LPG demand on marketers and does not justify the expenditure to install separate storage and delivery systems for a vehicle-only fuel. Therefore, if the reduced supply of vehicular-grade LPG is not enough to meet the total LPG demand, many marketers will carry only the commercial grade and will not sell fuel for vehicular use.

In the event of a supply problem, existing engines that have been converted to LPG might be re-converted to gasoline or diesel, at the cost of the emission reductions resulting from their initial conversions to LPG. Also, the lack of a reliable supply of vehicular-grade LPG could dissuade vehicle and engine manufacturers from developing LPG-fueled low-emission vehicles. This could forestall LPG as a practical alternative fuel, despite its attractive economics and emission properties.

The limited data on emissions indicate that LPG vehicles have greater emissions of ozone precursors and CO when using LPG with the propene content at ten percent than when using LPG with propene at five percent. The estimated differences are seven percent for hydrocarbons, one percent for NOx , and 34 percent for CO. However, the emissions remain lower than emissions from the same vehicles using gasoline. Because the population of such vehicles is small (at most 45,000 in the state), the effects of delaying the five-percent propene limit for commercial LPG are also small--estimated to be at most 0.07 ton of hydrocarbons per day, 0.03 tons of NOx per day, and 5 tons of CO per day, in the state. These delayed reductions are very small compared to the overall vehicular emission inventory.

Engine and vehicle manufacturers have concerns that commercial fuel with propene contents above five percent could harm performance or damage future low-emission engines. Technical work to elucidate the issues of emissions and performance may be forthcoming in the next two years. Organizations consulted by the staff appear interested in pursuing such work.

C. Recommendation

The staff recommends that the Board:

1. Postpone the five-percent propene limit for LPG intended for use in motor vehicles

until January 1, 1999, by adopting the amendment in Appendix 3.

2. Instruct the staff to work with the engine and vehicle manufacturers, oil refiners, and the Western Propane Gas Association to establish a consensus standard for LPG for motor vehicles, taking into account emissions, engine performance, fuel production issues, and fuel distribution issues.

3. Instruct the staff to work with the air pollution control districts to explore the potential to reduce emissions from the non-vehicular use of LPG.

II.

LPG AS A MOTOR VEHICE FUEL

A. About This Chapter

This chapter describes LPG and how LPG is produced, marketed, and used in California. It shows the available information about emissions from LPG motor vehicles versus the propene content of the LPG. It also discusses other factors related to the propene content.

B. Description and Uses of LPG

Description "LPG" (liquefied petroleum gas) refers to a mixture of light hydrocarbons, predominantly propane, that is pressurized into a liquid for use as a fuel. LPG has uses similar to those of natural gas. To the ordinary consumer, LPG is usually known as "propane". Propane sold at retail usually meets the industrial specifications for either "commercial propane" or "propane HD-5".* Table 1 shows the compositional elements of those specifications. Commercial propane is used in space heating (e.g., in rural buildings and recreational vehicles) and portable appliances (e.g., barbeques). HD-5 is intended for motor vehicles and other internal-combustion engines. Fuel meeting HD-5 is purer in propane than is commercial-grade propane.

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* Another grade of LPG, "Commercial B-P Mixture", is less common.

In California, fuel used in both on-road and off-road motor vehicles must meet the ARB specifications.* Table 1 also shows the ARB specifications in their current (1996) and scheduled future (1997) versions. The 1997 version is patterned after HD-5.

Table 1. **Specifications for LPGs**

Constituent	Grades			
	Commercial Propane	**Propane HD-5**	**ARB** 1996	1997+
Propane	"predominantly propane"	>90%	>80%	>85%
C_4+ (butane & heavier)	<2.5%	<2.5%	<2.5%	<2.5%
Olefins (e.g., propene)	(no limit)	<5.0%	<10%	<5.0%

The Division of Measurement Standards (DMS) in the Department of Food and Agriculture has a role in setting specifications for vehicular LPG. DMS adopts standards for motor vehicle fuels to ensure that they are adequate for the uses for which they are sold. DMS is required by state law to adopt standards set by a consensus organization, such as the American Society for Testing and Materials (ASTM) or the Society of Automotive Engineers, unless such standards are less stringent than the ARB's or other agency's standards.

To date, DMS has not adopted any standards for vehicular LPG. However, DMS has stated its tentative intent to adopt specifications set by the ASTM for a class of LPG called "Special-Duty Propane". The specifications for Special-Duty Propane are identical to HD-5. Special Duty Propane is regarded by the ASTM as a fuel appropriate for engines in severe service, which include some LPG motor vehicles.

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* Title 13, CCR, section 2291 prohibits the sale or supply of LPG intended for use in motor vehicles if the LPG does not meet the specifications in section 2292.6. LPG is deemed to be intended for motor vehicles if (1) it is stored at a facility used to dispense LPG to motor vehicles, (2) it is delivered or intended for delivery to such a facility, or (3) it is sold or supplied to a person engaged in distributing motor vehicle fuels to motor vehicle-fueling facilities, unless reasonable precautions have been taken to ensure that the LPG will not be used as a motor vehicle fuel.

Consumption Table 2 summarizes the available data on recent non-industrial consumption* of LPG in California. Data for several years are in Appendix 4. About 330 million gallons of LPG are used annually, of which about 28 million gallons are used in on-road vehicles. The on-road LPG is required to meet the ARB specifications. In addition, LPG used in farm vehicles and in other off-road motor vehicles must also meet the ARB specifications. Those uses fall under the categories "Farm (mobile and stationary)" and "other" in "Internal combustion, non-farm" in Table 2. However, the amounts used in vehicles cannot be disaggregated and quantified.

Table 2. **Typical Use Rates for LPG in California**

	Million Gallons/Year
Internal combustion, non-farm	
on-road vehicles*	28
other**	32
sub-total	*60*
Farm (mobile & stationary)**	25
Residential/commercial, non-farm	245
Total (rounded)	330

* All required to meet ARB specifications
** An unknown part is required to meet the ARB specifications.

Sources: See Appendix 4.

The vehicular use in the "Farm" category is probably very small because there are very few heavy-duty LPG engines (e.g., tractors). However, it is not known what portion of the 32 million gallons in "other" is used for off-road vehicles that are LPG-capable, such as fork-lifts and other service vehicles. Therefore, the amount of LPG that must meet the ARB specifications is between 28 and 60 million gallons per year, or between about 10 and percent 20 percent of the LPG that is sold at the consumer level.

* There is also industrial consumption of LPG as refinery fuel and as feed to chemical reactors, not shown in Table 2.

C. How LPG is Produced and Marketed

Production LPG is produced by oil refineries and by gas plants in oil and gas fields. In refineries, it is a by-product of processes that produce gasoline. At gas plants, LPG is separated from crude oil and from natural gas (methane and ethane).

Some refineries have substantial amounts of propene in their LPG. The propene content depends on whether or not the refinery has a fluidized catalytic cracker (FCC), which creates olefins (such as propene) in its by-product gas, and whether or not the refinery separates those olefins to feed to processes that make high-octane gasoline blending materials. Without such a process, a refiner has no in-house use for propene. Unless the price and demand for low-propene LPG become high enough, the refiner will probably blend the propene-rich FCC gas into its LPG.

LPG from gas plants has almost no propene if the LPG comes only from production fields. However, some gas plants receive gas by-products from refineries. LPG from such gas plants can contain substantial propene.

Table 3 shows, by propene content, the available data on the amounts of LPG produced in 1995/1996. The data were received in response to a recent survey by the staff of refiners and gas plants. The total LPG volume in the responses somewhat exceeds the estimated total LPG use in California, shown in Table 2. More data from the survey are in Appendix 5.

Table 3. **Results of Survey of Producers, by Producer Type**

	Refiners	Gas Plant Operators	Total
Number surveyed	13	7	20
Number of responses	13	5	18
Annual production, million gallons *			
<5% propene**	150	20	170
5% to 10% propene**	50	25	75
other (>10% propene)	145	0	145
Total (rounded)	345	45	390

* Volumes shown are commercial propane or HD-5. In addition, one respondent produces B-P mixture (not a propane product).

** currently legal for vehicles

Although the amount produced of LPG with less than five percent propene is more than adequate to satisfy the vehicular demand, the practicalities of marketing (discussed later) preclude segregating that LPG just for use in vehicles.

Table 4 shows by production region the production survey results for the LPG with propene less than five percent and LPG between five and ten percent propene. In southern Califonia, all the documented production typically meets that limit, so the staff's proposal would have no effect there. (However, as discussed later, most producers will not guarantee that their LPG will meet the five-percent limit.) There is more analysis of LPG supply in Chapter III.

Table 4. Results of Producers' Survey, by Region of Production

Production Region:	Northern Calif.	Southern Calif.	San Joaquin Valley	State *
Number surveyed	5	10	9	20
Number of responses	5	9	8	18
Number of Producers				
<5% propene	1	6	2	6
5% to 10% propene	1	0	1	2
>10% propene, B-P mix, or no LPG	3	2	5	9
Annual Production, million gallons **				
<5% propene	40	115	15	170
5% to 10% propene	50	0	25	75

* Less than sum over regions because some companies produce in more than one region.

** 3rd quarter, 1995 to 2nd quarter, 1996

Marketing Most LPG that is sold at retail is handled in one of three ways:

- A marketer picks up the fuel by tank truck from a supplier's loading rack and delivers it in bulk to the customer's storage tank.

- A marketer picks up the fuel and transfers it into his own storage tank, to which the customer brings his LPG vessel or vehicle for filling.

- o A marketer picks up the fuel and stores it in his own tank, from which he later fills a tank truck that is dispatched to various customers' sites.

Most LPG is delivered from the marketers' own storage tanks. At most storage sites, a marketer has only one tank/dispensing system for LPG. More information on marketing is in Chapter III.

D. Effects of the Propene Content on Emissions

Recent data on emissions from LPG vehicles versus the propene content of the LPG are available from only one published study, summarized below, which was sponsored by the WPGA in support of its petition. Appendix 6 describes the study and its results in more detail.

Three 1995 vehicles were converted to dual-fuel (LPG and gasoline) operation and then tested on Indolene (federal certification gasoline) and on three LPGs that resembled vehicular LPG. The propene contents of the test LPGs were five, ten, and twenty percent. The organic gas emissions were speciated for determining the reactivities of emissions.

Figures 1 to 3 show the results for NMHC, NOx, and CO emissions. In general, emissions when the propene content was 10 or 20 percent exceeded emissions when propene was five percent, although this is not true for some combinations of pollutant, vehicle, and LPG. Comparing the LPG with 10% propene against the LPG with 5% propene, the average emission increases were:

NMHC -- 7 percent NOx -- 1 percent CO -- 34 percent.

In addition, the specific reactivity of the NMHC emissions increased by about ten percent; so that the NMHC emissions on a reactivity-adjusted basis increased by 19 percent between the LPGs with five and ten percent propene.

Despite the emission increases with increasing propene in the LPG, emissions of NMHC were less when the vehicles were tested on the LPG with 10% propene than when they were tested on the gasoline (Indolene). The same is true of NOx from two of the three vehicles. In particular, the reactivity-adjusted NMHC (not shown in the figures) from the 10% propene LPG, which averaged .32 gram/mile over three vehicles, was only about one-third of the emissions from the gasoline, 0.92 gram/mile.

Figure 1

NMHC Emission Results

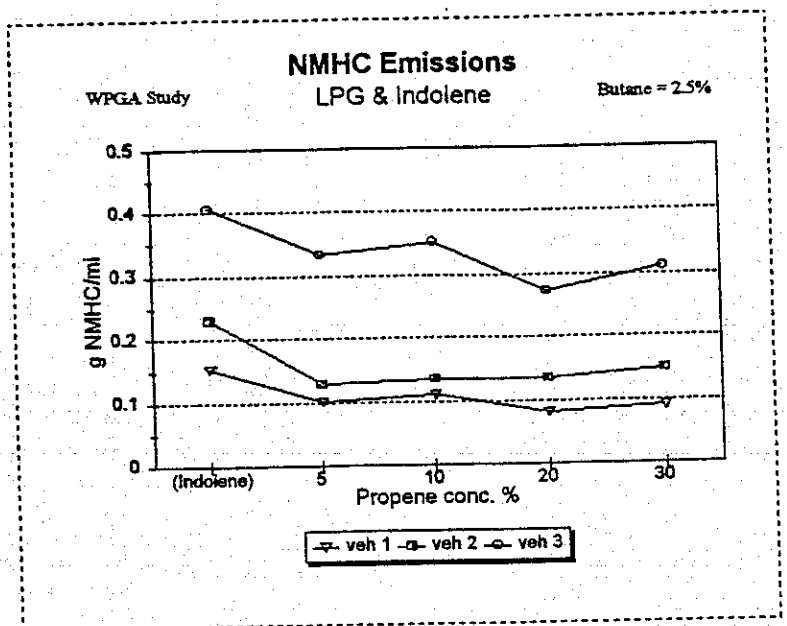


Figure 2

NOx Emission Results

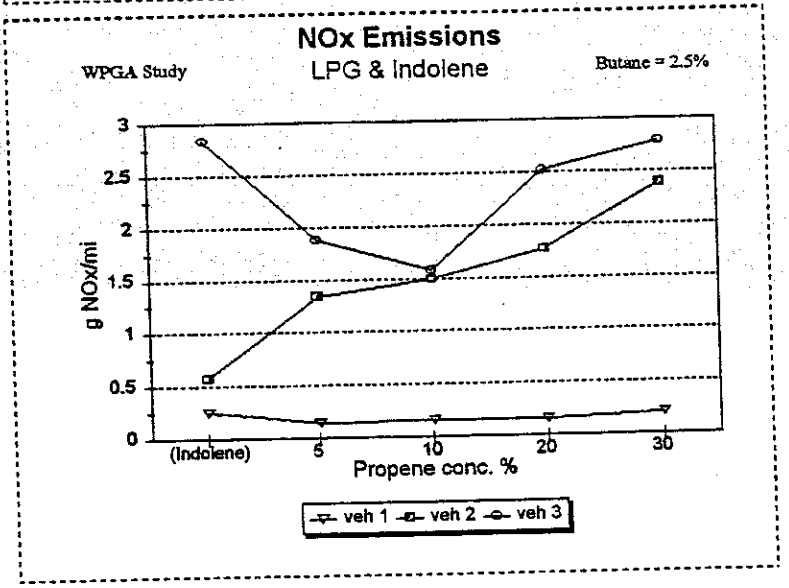
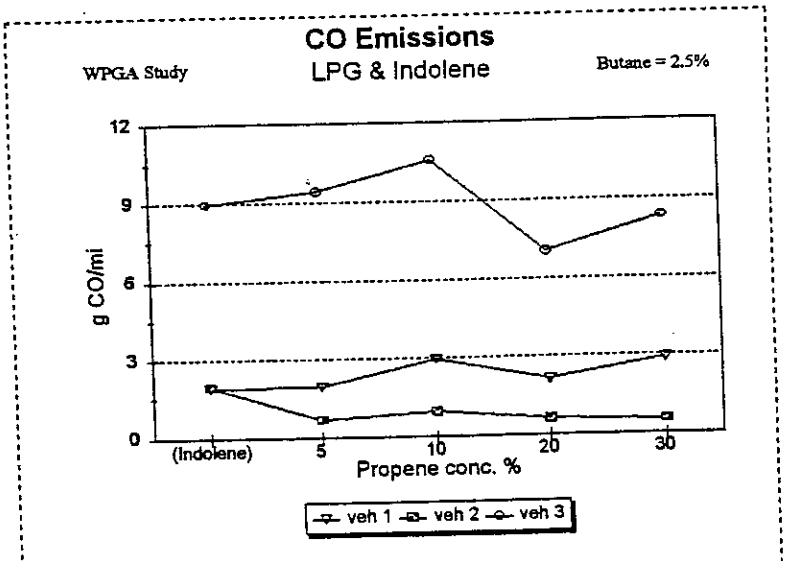


Figure 3

CO Emission Results



The WPGA has estimated that there are at most 45,000 on-road LPG vehicles in California, almost all conversions dedicated to LPG. Most are light-duty trucks. This is consistent with published estimates of the number of LPG vehicles in the U.S. Using this value, the ARB's vehicular emission inventory for California, and the mean percent increases just cited, we estimate in Table 5 the emissions in the state from the LPG vehicle population. (The numbers are calculated as if all vehicular LPG were at either five percent propene or ten percent propene.)

Table 5. **Estimated Emissions from 45,000 LPG Vehicles**
(and total on-road inventory in California)
(tons/day)

	NMHC	NOx	CO
Gasoline*	1.4	1.9	19
LPG @10% propene	0.5**	2.4	20
LPG @ 5% propene	0.4**	2.4	15
(on-road inventory)	(1,200)	(1,500)	(9,000)

* from annual-average planning inventory for 1995

** reactivity-adjusted to gasoline basis

If <u>all</u> LPG used in vehicles were at 10% propene, the increases in emissions over the same LPG containing 5% propene would be:

NMHC (reactivity-adjusted) -- 0.07 tpd NOx -- .03 tpd CO -- 5 tpd

These values are very small compared to the emission inventory for the on-road vehicle population. Moreover, since about 70 percent of the LPG that is now usable in vehicles already has less than five percent propene, the actual emission reductions that would be delayed by the staff's proposal are only about:

NMHC (reactivity-adjusted) -- 0.02 tpd NOx -- .01 tpd CO -- 2 tpd

The value for the delayed decrease in NMHC is smaller than the emission increase that the converted vehicles would produce if they ran on gasoline instead of LPG (about one ton per day).

In addition, a change in the propene content could affect emissions from non-road vehicles that use vehicular LPG (e.g., forklifts). However, there are no emission-rate data or vehicle-population data by which to estimate such an effect.

The rate of certifications of new LPG conversion kits has fallen to near zero. Few new conversions are being done. Thus, we expect that the emission effect of postponing the five-percent propene limit will not exceed the above numbers.

E. Other Effects of the Propene Content on Vehicles

Octane Number Increasing the propene content of LPG from five to ten percent would reduce slightly the fuel's octane number, because propene has a lesser octane value than does propane. Too low an octane value of a fuel leads to engine knock, which is destructive.

Since there have been no complaints by vehicle owners who use the current LPG, the lower octane of the ten-percent fuel is apparently adequate for the existing vehicles. However, a potential problem for new vehicles was brought up at the workshop on December 3. One heavy-duty engine manufacturer has stated its intent to sell LPG-fueled ULEV heavy-duty engines in California in the near future. These engines will use the "lean-burn" design, which (it is claimed) is sensitive to the octane of the fuel. While no data to determine the minimum required octane value have been offered, the manufacturer has stated that it will require the use of HD-5 propane to maintain the validity of the mechanical warranty on a heavy-duty LPG engine. This requirement would conflict with the ten-percent limit on propene if the proposed postponement of the five-percent standard would extend past the date when the lean-burn engines would first be in use.

It was also stated at the workshop that achieving ULEV emissions with LPG engines requires a high degree of control of air:fuel ratio. The propene content of LPG affects the stoichiometric ratio of air to fuel. It was suggested that too great an allowed range of the propene content among commercial LPGs could overwhelm the air/fuel control and cause in-use emissions to exceed certification emissions (which are measured with a narrowly specified certification fuel).

These concerns about the potential effects of the propene content of LPG indicate that a delay in implementing the five-percent limit should not extend much past the time when engine manufacturers plan to first sell new LPG engines in California. Also, the concerns indicate a potential conflict between the perceived needs of engine manufacturers and the properties of the fuels that refiners can economically produce.

Reactivity of Emissions Increasing the propene content of LPG increases the reactivity of exhaust emissions. Therefore, meeting LEV standards in new engines and vehicles could become more difficult if the propene limit of commercial fuel were to remain permanently at 10% and the specification for LPG certification fuel were changed.

Fuel-Injector Gumming The American Automobile Manufacturers Association has indicated that propene at ten percent of LPG could accelerate the deposition of gums in fuel injectors. Since few current LPG vehicles (conversions) are fuel-injected, this concern does not apply to a short delay in the five-percent propene limit. However, it raises another issue that needs consideration in evaluating the propene limit for the future.

F. Other Issues about the LPG Specifications

One LPG producer has expressed interest in substantially raising the ARB limit on the butane content of vehicular LPG, to as high as 50 percent. This would allow the use of butanes that are now in excess in the summer because of the limit on the volatility of gasoline. It is possible that such a change would have only a small effect on emissions or on reactivity. However, more emission data are needed to evaluate this concept. Also, the effect of a higher allowed butane content on engine manufacturers' designs for future engines needs evaluation.

III.

PROPOSED REGULATORY AMENDMENT

A. About This Chapter

In this chapter, the staff describes the recommended amendment of section 2296.2 and the rationale for the amendment. The chapter presents information on the availability of complying LPG if the propene limit declines to five percent on January 1, 1997, including the results of the staff's surveys on availability at production points and from marketers. This chapter presents the arguments for and against the delay, as expressed in the workshop and other communications with concerned parties.

B. Supply of Complying LPG

Table 6 summarizes responses of a survey of the companies in California that supply LPG at wholesale in California. (Sources of imported LPG are not included in the survey. At the workshop on December 3, it was suggested that imports might account for as much as 25 percent of the LPG supply.) Among the 17 respondents to the survey, eight are current suppliers of vehicular LPG (<10% propene), of which six sell LPG that meets the five-percent propene limit (and will continue to offer it in 1997). The respondent in the north that sells LPG with propene between five and ten percent is the largest producer and one of only two in northern California now providing LPG for vehicles. This respondent and one in the San Joaquin Valley will not produce complying LPG if the propene limit declines to five percent.

Table 6. **Summary of Producers' Survey Responses**

Production Region:	Northern Calif.	Southern Calif.	San Joaquin Valley	State **
No. surveyed	5	10	9	20
No. responded	5	9	8	18
No. selling vehicular LPG in 1996	2	6	3	8
No. with LPG @ <5% propene in '97*	1	6	2	6
No. to guarantee consistent availability of LPG with <5% propene	0	0	0	0
Supply of vehic. LPG, mill. gal/yr: -- current (<10 % propene)	90	115	40	245
-- in 1997 (<5% propene)	40	115	15	170

* excluding B-P mixtures
** May not equal the sum over regions because some companies market in multiple regions.

None of the respondents who typically provide LPG with propene less than five percent will guarantee constant availability of that product in 1997. No refiner plans capital improvements to augment its ability to supply vehicle-grade LPG. However, two suppliers indicated potentials to increase production by a total of 43 million gallons per year. One is in the north and one is in the south.

The documented supply rate of vehicular LPG will fall from 245 to 170 million gallons per year if the propene limit declines to five percent and if each supplier's production rate remains at the 1996 value. Both numbers exceed the estimated on-road use rate for LPG. However, since most marketers of vehicular-grade LPG sell it to all their customers, the 170 million gallons of five-percent fuel may not suffice. (This is discussed more below.) In particular, there could be a supply problem in northern California.

In the survey responses, among the LPGs with propene contents less than 10 percent, the average propene content was 4.2 percent. Two of the respondents offer LPG with essentially zero propene from a total of four facilities.

Table 7 summarizes the results of a survey of LPG marketers (retailers). Among the 28 respondents (of 100 surveyed), 22 companies now sell LPG to vehicular accounts

from a total of 104 sites. Those sites now dispense an estimated 165 million gallons of LPG per year (presumably, vehicle-grade) for all uses, of which an estimated 21 percent goes to on-road or off-road vehicles. Only 13 of those sites have segregated storage to allow the handling of more than one grade of LPG.

Of the 22 marketers who currently sell LPG for vehicles, only 14 plan to sell it in 1997 if the propene limit declines to five percent; and of those, only three are certain of a supply of the complying LPG. Of the 104 sites (among the respondents) where LPG is now sold to vehicles, only 73 are owned by marketers who expect to continue sales to vehicles under the five-percent limit, and only 38 are expected to actually be vehicular sales sites in 1997. The estimated current sales of LPG from those 38 sites (for all uses) are 69 million gallons per year. That volume is only 42 percent of the LPG sales volume of all the respondents who now sell to vehicular accounts. Thus, the currently assured availability of LPG to vehicles under the five-percent limit is poor.

Table7. **Summary of Marketers' Survey Responses**

Distribution Region:	No. Calif.	So. Calif.	S. Joaquin Valley	State *
Number of marketers surveyed				100
No. of responses; *(no. of sites operated)*	16	9	11	28 *(123)*
Respondents now selling to vehicles :				
-- no. of marketers; *(no. of sites)*	12	8	10	22 *(104)*
-- no. with segr'ted storage; *(no. sites)*	3	3	4	6 *(13)*
-- current sales of LPG (all uses**), million gal/yr				165
-- of sales, % that goes to vehicles**				21%
Respondents who plan to sell to vehicles in 1997 if the propene limit is 5% :				
-- no. of marketers; *(no. vehic. sites)*	(no regional data)			14 *(38)*
-- no. with certain supply for 1997				3
-- estimated current total sales at the 38 vehic. sites for 1997, million gal/yr				69^

* Does not equal the sum over regions because some companies market in multiple regions.
** Includes marketers' use in own LPG vehicles.
^ 132 mil. gal current sales by 14 respondents * 38 vehic. sites in '97 / 73 current vehic. sites

The decline in the expected number of sites for sales to vehicles and the low number of marketers who are confident of a supply in 1997 appear disproportionate to the documention of only two producers who will no longer supply complying LPG.

Although the marketers' survey response rate was not high, the data from both surveys tend to corroborate WPGA's concern that complying vehicular LPG will not be universally available in 1997 if the propene limit declines to five percent. Since most of the existing LPG vehicles are conversions dedicated to LPG, some may be left without practical access to fuel. Also, poor availability of fuel could discourage vehicle and engine manufacturers from designing and certifying new low-emission vehicles (LEVs) for LPG.

The potential problem in availability may not be one of inadequate statewide production of complying LPG. Rather, the problem may be inadequate regional production or inadequate facilities at refineries or marketing sites for handling vehicular LPG as a separate product. A refiner or marketer could have adequate volumes of LPG meeting the five-percent limit to satisfy vehicular demand but not enough to satisfy all LPG demand. If a refiner or marketer in that situation lacks segregated storage, it would usually choose to carry only the grade that will satisfy most of its customers: commercial propane.

The sales to vehicles comprise only about 20 percent of the total LPG sales at sites that now sell to vehicles. Therefore, the estimated 28+ million gallons per year demand by vehicles translates to about 140+ million gallons total demand for vehicular-grade LPG, as long as marketers do not have segregated storage. While that potential total demand may be less than the historical supply documented by the survey responses (165 million gallons), it is substantially greater than the estimated sales volume of the marketers and sites that expect to sell LPG to vehicles under the five-percent limit (69 million gallons).

Although segregated storage could always be added at a refinery or a marketing site, the current demand for vehicular LPG appears insufficient to support the expense of such additions. A refiner who has propene in its LPG could extract it for some use or convert it to propane, but the small market for low-propene LPG now provides no economic incentive to do so.

C. Action Proposed by WPGA

In its petition, the Western Propane Gas Association requests that the term of the ten-percent propene limit be extended past January 1, 1997. The petition does not recommend a new date of effect for the five-percent limit nor any action to alleviate the forecast inadequacy in LPG supply.

D. Arguments Against a Delay

Engine and vehicle manufacturers have expressed opposition to delaying the five-percent propene limit because of a perceived potential for performance problems in future engines and vehicles. Since the staff proposal is for only a two-year delay and because no engines or vehicles have been certified for LPG for 1997 or later years, the staff believes that any problems in this regard will be minimal. Ascertaining the true sensitivity of future LPG engines to the propene content will be a subject for the working group described in the next section.

E. Staff's Recommendation

The staff recommends that the five-percent propene limit be postponed for another two years, until January 1, 1999. This will enable the existing population of LPG vehicles to maintain the current supply of fuel.

The staff believes that the technical issues of emissions, fuel requirements of future LPG vehicles and engines, and the economics of production and marketing need to be addressed in a multi-industry dialogue. Accordingly, the staff will convene a working group of interested parties to discuss these issues and to develop a consensus standard for the propene content of vehicular LPG. Since the utility of such a standard would be enhanced if it were a national standard, the staff will invite the US EPA to participate in the working group.

If a propene limit less than ten percent is finally set, high-propene LPG could be diverted from vehicular use to stationary source use. Therefore, it would be logical to investigate the potential for air pollution control districts to control the propene content of stationary source LPG. The staff will raise this matter with the district staffs.

IV.

ECONOMIC AND ENVIRONMENTAL EFFECTS

A. Economic Effects

The proposed amendment would not create a new regulation; nor would it impose a new cost on any party.

The staff has identified the following economic effects that could result from the proposed amendment.

Consumers of Vehicular LPG The proposed amendment would enable consumers of vehicular LPG avoid the adverse consequences of a potential supply shortage of vehicular LPG in northern California and the San Joaquin Valley. These avoided (or delayed) adverse economic impacts could include price increases for vehicular LPG meeting the 5 percent propene standards and a need to reduce the use of LPG vehicles.

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* California Government Code section 11346.3(a) requires that in proposing to adopt or amend administrative regulations, state agencies shall assess the potential for adverse economic impacts on California business enterprises and individuals. The assessment shall include the impact of the proposed or amended regulation on the ability of California businesses to compete with businesses in other states. In addition, section 11346.3(b) requires state agencies to assess the potential impact of their regulations on the creation or elimination of jobs in Califonia, the creation of new businesses or their elimination, and the expansion of businesses in California.

Most of the up to 45,000 LPG-fueled on-road motor vehicles in the state are in commercial fleets. In the event of a price increase (if the proposed amendment is not adopted), the vehicle owners could reduce their use of LPG by converting LPG vehicles to run on gasoline again, by replacing them with new gasoline or diesel vehicles, or by increasing the use of non-LPG vehicles already owned.

The staff has not identified any adverse economic impacts on consumers of vehicular LPG that would result from adopting the proposed amendment.

Producers and Marketers of Vehicular LPG For producers and marketers of vehicular LPG that currently has a propene content between five and ten percent, the proposed amendment would prevent (or delay) the costs associated with the immediate need to find other markets for this product, install segregated distribution facilities, or reduce the propene content of the LPG.

Since the supply of complying LPG would at least initially be less if the propene limit were to decline to 5 percent, the price of complying LPG might rise. Producers of LPG having a propene content of five percent or less would have to forego the revenue increase associated with higher prices for vehicular LPG. Thus the proposal could delay an increase in revenues that producers of complying LPG could experience in connection with a price increase.

The impact of suppliers' price increases on marketers of complying LPG (if he proposal is not adopted) would depend on the marketers' ability to pass the increases on to consumers. Such an ability could depend on the ability to segregate vehicular LPG as a separate product. However, the staff is not aware of any LPG producers or marketers who have altered their facilities or operations to reduce the propene content of their LPG, or to allow segregation of vehicular LPG, in reliance on the implementation of the five-percent propene content standard on January 1, 1997.

The proposed amendment would not affect employment or the number or competitiveness of businesses in California.

B. Environmental Effects

The staff has analyzed the potential environmental effects of the proposed amendment. The amendment would merely postpone emissions benefits from the decline of the propene limit to 5 percent for two years, until 1999, rather than relax a standard that has already been in effect for a significant period.

As noted above, the only available data on the emission effect of changing the propene content of vehicular LPG comes from the WPGA-sponsored three-car study conducted in 1996. The numbers below are based on those data. However, in addition

to the propene content, a number of other fuel-to-fuel and vehicle-to-vehicle variables affect emissions but were not examined in the WPGA study. A more robust data set would provide more reliable data.

If the three-car test results are extrapolated to the (at most) 45,000-vehicle LPG fleet with worst-case assumptions, the proposed amendment would delay for two years the following reductions in emissions from on-road vehicles that use LPG in California:

NMHC (reactivity-adjusted) -- 0.07 tpd NOx -- 0.03 tpd CO -- 5 tpd

However, about 70 percent of the LPG available for vehicular use already has a propene content less than five percent, and there is no reason to expect that such LPG would change if the propane limit would decline to five percent. Therefore, we would expect the propene content of fuel for 70 percent of all LPG vehicles to not decline. When this factor is accounted for, the emissions reductions that would be delayed by the staff proposal are projected at about:

NMHC (reactivity-adjusted) -- 0.02 tpd NOx -- 0.01 tpd CO -- 2 tpd

There could be like emissions effects up to about the same magnitude from non-road vehicles that use LPG, although there are no emission-rate or vehicle-population data by which to reliably estimate such effects.

If the proposed amendment is not adopted, some LPG vehicles could have to be converted to operate on gasoline or diesel fuel. In the three-car study sponsored by WPGA, the per-vehicle increase in reactivity-adjusted NMHC emissions associated with a switch from LPG to gasoline was almost 10 times as great as the per-vehicle increase in reactivity-adjusted NMHC emissions associated with an increase in propene content from 5 percent to 10 percent. This indicates that a modest number of conversions to gasoline could fully offset the NMHC emission decline from the change in propene content. Instead of converting LPG vehicles that no longer have fuel, the owners could substitute other vehicles. New gasoline vehicles would likely have lower emissions of all pollutants than would the abondonned LPG vehicles, older gasoline vehicles might have equivalent or greater emissions, and diesel vehicles would emit more particulate matter.

If LPG is displaced by gasoline, there could be a difference in reactivity-adjusted marketing emissions of NMOG when the subject vehicles are fueled. This potential difference has not been evaluated, but it would be a very minor change to the marketing emission inventory.

If the proposed amendment is not adopted, LPG with a propene content between five and ten percent, which is now burned in vehicles, may be used in other combustion

devices. If such fuel displaces LPG with a lower propene content, the reactivity of emissions from those devices would probably increase.

The staff has considered alternatives to the proposal to lessen the small delay in emission reductions that would result from the amendment. One alternative would be to delay implementing the five-percent propene limit only in northern California (north of the Tehachapis), which is the area where supply shortages of LPG meeting that limit are expected on the basis of production data. However, we believe that such a geographically limited approach would not have emission effects significantly different from the proposal, because LPG in southern California already meets the five-percent propene limit. Furthermore, while production of vehicular LPG with more than five percent propene apparently does not occur in the southern part of the state, some such LPG may be marketed there. The potential for this circumstance to disrupt supply, if the five-percent limit were enforced in the south, should not be dismissed.

None of the above emission effects would affect the State Implementation Plan. No other significant environmental impacts have been identified.

Appendix 1

Current Regulations

Title 13, California Code of Regulations

Section 2292.6 **Specifications for Liquefied Petroleum Gas**

The following standards apply to liquefied petroleum gas (the identified methods are incorporated herein by reference):

Specifications for Liquefied Petroleum Gas

Specification	Value	Test Method
Propane	85.0 vol. % (min.) a/	ASTM D 2163-87
Vapor Press. at 100° F	208 psig (max.)	ASTM D 1267-89 ASTM D 2598-88 b/
Volatility residue: evaporated temp., 95% or butane and heavier	-37° F (max.) 2.5 vol. % (max.)	ASTM D 1837-86 ASTM D 2163-87
Propene	5.0 vol. % (max.) c/	ASTM D 2163-87
Residual matter: residue on evap. of 100 ml oil stain observed.	 0.05 ml (max.) pass d/	 ASTM D 2158-89 ASTM D 2158-89
Corrosion, copper strip	No. 1 (max.)	ASTM D 1838-89
Sulfur	120 ppmw (max.)	ASTM D 2784-89
Moisture content	pass	ASTM D 2713-86
Odorant	e/	

a/ Propane shall be required to be a minimum of 80.0 volume percent starting on January 1, 1993. Starting on January 1, 1997, the minimum propane content shall be 85.0 volume percent.

b/ In case of dispute about the vapor pressure of a product, the value actually determined by Test Method ASTM D 1267-89 shall prevail over the value calculated by Practice ASTM D 2598-88.

c/ The propene shall be limited to 10.0 volume percent starting January 1, 1993. Starting January 1, 1997, the propene limit shall be 5.0 volume percent.

d/ An acceptable product shall not yield a persistent oil ring when 0.3 ml of solvent residue mixture is added to a filter paper, in 0.1 ml increments and examined in daylight after 2 min. as described in Test Method ASTM 2158-89.

e/ The liquefied petroleum gas upon vaporization at ambient conditions must have a distinctive odor potent enough for its presence to be detected down to a concentration in air of not over 1/5 (one-fifth) of the lower limit of flammability.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Assn. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal. Rptr. 249 (1975). Reference: Sections 39000, 39001, 39002, 39003, 39010, 39500, 40000, 43000, 43016, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Assn. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal. Rptr. 249 (1975).

Title 13, California Code of Regulations

§ 2291. Basic Prohibitions.

(a) Starting January 1, 1993, no person shall sell, offer for sale or supply an alternative fuel intended for use in motor vehicles in California unless it conforms with the applicable specifications set forth in this article 3.

(b) An alternative fuel shall be deemed to be intended for use in motor vehicles in California if it is:

(1) stored at a facility which is equipped and used to dispense that type of alternative fuel to motor vehicles, or

(2) delivered or intended for delivery to a facility which is equipped and used to dispense that type of alternative fuel to motor vehicles, or

(3) sold, offered for sale or supplied to a person engaged in the distribution of motor vehicle fuels to motor vehicle fueling facilities, unless the person selling, offering or supplying the fuel demonstrates that he or she has taken reasonably prudent precautions to assure that the fuel will not be used as a motor vehicle fuel in California.

(c) For the purposes of this section, each retail sale of alternative fuel for use in a motor vehicle, and each supply of alternative fuel into a motor vehicle fuel tank, shall also be deemed a sale or supply by any person who previously sold or supplied such alternative fuel in violation of this section.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Assn. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal. Rptr. 249 (1975). Reference: Sections 39000, 39001, 39002, 39003, 39010, 39500, 40000, 43000, 43016, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Assn. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal. Rptr. 249 (1975).

Appendix 2

Petition from Western Propane Gas Asssociation

Western Propane Gas Association

OFFICERS AND MEMBERS OF EXECUTIVE COMMITTEE

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9/20/96

Mr. Michael Kinney
Executive Officer
California Air Resources Board
2020 L Street
Sacramento, CA

RE: A Petition by the Western Propane Gas Association to Extend the Current Interim Transportation Fuel Specification for Liquified Petroleum Gas (LPG) beyond January 1, 1997.

Dear Mr. Kinney:

The Western Propane Gas Association (WPGA) hereby requests an extension of the current LPG Transportation Fuel Specification which would allow a propylene constituent of up to 10% beyond the scheduled cut off date of January 1, 1997. This request is made in order for CARB staff to review and report the results of fuel emission testing conducted by WPGA and ARCO/Southwest Research to the board.

BACKGROUND

At a hearing conducted March 12, 1992, the Board adopted specifications for LPG transportation fuel as part of its Alternative Fuels Regulations. These specifications were based upon the Gas Processors Association's (GPA) Standard 2140 commonly referred to as HD-5, as well as ASTM Designation D 1835-89 Special Duty Propane, a parallel specification to HD-5. The ASTM/GPA specifications call for the LPG composition to be not less than 90% liquid volume propane, no more than 5% liquid volume propylene, no more than 2.5% liquid volume butane, and includes limitations on various levels of residual compounds. ASTM/GPA adopted these specifications in 1962 because engine technology at the time called for higher octane fuels in heavy duty (i.e. farm equipment) applications. LPG at the time contained high levels of propylene which tended to lower octane (R + M)/2 into the upper 80s. An HD-5 specification requires LPG to contain a predominance of propane thereby lifting the octane level well above 100.

During the comment process preceding the adoption of the fuel specification, WPGA testified to staff that establishing a specification paralleling an HD-5 standard as opposed to a commercial grade propane standard would preclude refinery based propane supply for transportation uses, subject marketers to develop a segregated distribution system, and eliminate the possibility of using butane in the transportation fuel sector. Staff reasoning at the time was that no emission test results for other LPG fuels were available for consideration and HD-5 was the only

published specification apart from commercial grade propane and butane. Raw propylene emissions were considered to be up to 19 times more reactive than raw propane emissions and it wasn't perceived that propylene would be destroyed in the combustion process. Engine manufacturers were claiming that propylene *may* cause gumming of the fuel injection system and deposits in the fuel metering system and were clamoring for a tight specification to design their engines. Consequently, despite strenuous opposition by WPGA, staff unilaterally refuted all comments we submitted, proposing a fuel specification limiting propylene content to 10% through 12/31/94 and reducing to 5% after that.

In March of 1994, WPGA petitioned the Board for an extension of the 10% fuel specification in order to conduct emissions testing of various LPG fuel blends. Further study of California propane supply both within and from outside the state confirmed that commercial grade propane continued to dominate supply, and consistent supply of California specification propane would not be available within the target implementation date. Marketers of LPG could not control the composition of the fuel they sold, nor would fuel segregation be an economically viable option. WPGA argued that in theory LPG did not need to meet California specifications in order to be a clean alternative transportation fuel but needed additional time to demonstrate it. In addition, it was hoped by June of 1996 that excess propylene would be alkylated into reformulated gasoline thus rendering the future question of propylene content moot.

In its September 1994 meeting, the Board extended interim LPG specifications limiting propylene content to 10% liquid volume while maintaining a 2.5% butane level and lower levels of residual compounds. This interim standard is now due to expire 1/1/97 whereupon the fuel specification reverts to a 5% propylene limit.

TEST RESULTS

At a meeting held September 10, 1996, WPGA presented its findings regarding emissions testing conducted at Automotive Testing Labs of East Liberty Ohio (ATL) to members of CARB staff. Test results from various studies conducted at Southwest Research Institute (SwRI) for ARCO were also presented. In all tests, vehicles of varying weight classes were retrofitted to operate on LPG fuels utilizing commercially available retrofit kits having a CARB Executive Order. Each vehicle was pre-and post-tested using either Indolene, RF-A, and/or CF-2 in order to set baseline emissions results for the given vehicle and to prove the effectiveness of the emissions equipment available on the vehicle.

In WPGA's testing, three separate vehicles operating on seven different blends of LPG were evaluated in comparison to Indolene. ATL performed FTP-75 emissions tests and fully speciated results were provided. Except for the initial adjustment for propane, no additional adjustments of the retrofit kit were made to compensate for the varying LPG blends. The results of those tests showed very little difference among the various blends in their Ozone Forming Potential (OFP). With the exception of some of the more extreme blends, all results show substantially less OFP than the baseline Indolene. Similar results were achieved with substantially different blends in the ARCO/SwRI tests. A chart depicting WPGA's results are provided at the end of this letter.

Of major interest in the study results is the use of butane. As noted, California specifications limit the use of butane to 2.5%, following the GPA/ASTM standard. Again, butane was seen in 1962 to have a lower octane level which could compromise potential engine performance-yet butane's octane level is substantially higher than today's gasoline.

WPGA test results show the use of butane in LPG blends to contribute to the lowering of NOx levels in many instances. In addition, butane contains a higher heating value per gallon than propane, thus contributing to vehicle economy. Due to the lowering of RVP levels in gasoline, butane is now in surplus in California much of the year. It not only is exported out of the state, but also out of the country. It makes greater sense to allow higher volumes of butane in LPG transportation fuel specifications than to export this clean fuel out of the country.

REASONS FOR EXTENDING THE INTERIM FUEL SPECIFICATION

1) The GPA specification was developed over 30 years ago to accommodate an entirely different set of conditions than exist today: different engine designs, different fuel system strategies, severe engine usage, no emission concerns. It is inappropriate to use such a standard for today's conditions.

2) The original specification as adopted by CARB was urged by the vehicle manufacturers. The OEMs claim that LPG other than HD-5 *may* harm their engines but have not been forthcoming with data to support the contention. Meanwhile, LPG marketers over the years have experienced extended engine life in their fleets utilizing commercial grade propane-sometimes containing high levels of propylene and or butane-with retrofitted engines designed to operate on gasoline. WPGA is not aware of any warranty claims on record that cite the cause of engine failure as being LPG related.

The OEMs currently offer only one model vehicle-a medium duty Ford truck-designed to operate on propane. Production of this truck is scheduled to cease 12/31/97 and Ford has NO PLANS to replace it. Aside from a few engine proposals from heavy duty engine manufacturers, no OEM has plans to produce a propane engine in the near future. So what we have is a fuel specification created to accommodate engine manufacturers who have shown no commitment to produce vehicles that operate on LPG.

3) The number of vehicles powered by LPG in California (estimated at 45,000-50,000) continues to decline even without the added burden of the California fuel specification. The onerous cost of securing CARB certification for retrofit systems, adapting to OBD II specifications, and the lack of OEM produced LPG vehicles means LPG vehicles being retired from their useful life are being replaced with gasoline and diesel powered vehicles. Rather than run the risk of fines for not using California specification LPG, some vehicle operators may elect to convert their vehicles back to gasoline. Based upon WPGA's test results, this could cause an immediate increase in overall emissions, be cost prohibitive to deconvert, and create greater dependancy on imported oil-a phenomena directly opposite of what the alternative fuels strategy was supposed to be about and diametrically opposed to EPACT.

4) Specification grade LPG supply continues to be relatively unavailable. The interim specification was originally proposed as a bridge allowing the producers time to upgrade refineries and gas plants to make California specification propane. For many plants, the cost of required upgrades in order to produce California spec LPG far exceeds the economic returns available-even to have propylene available for alkylation into gasoline. Propylene continues to be a component of commercial grade propane both within the state as well as from out of state supply points, and there doesn't appear any chance of changing this reality. The specification for transportation grade LPG needs to parallel the real world supply situation.

5) Marketers cannot afford the upgrades in distribution infrastructure in order to segregate supply. Nor is it economically feasible to absorb the additional costs of bringing spec grade LPG from points farther away than local supply points. California specification LPG is only required for the automotive market-a market segment equal to about 10% of overall LPG sales in the state. Commercial grade LPG is perfectly acceptable for all other propane markets. Even if it were possible to segregate transportation and distribution infrastructure, LPG supply to traditional home heating markets in wintertime could be compromised.

CONCLUSION

We have provided staff with copies of the test results from both WPGA's and ARCO's studies. We have also provided staff with a report discussing those results and where we propose to go from here. In order to give both CARB and the LPG industry time to sort out these issues, WPGA respectfully requests an extension of the current transportation fuel specification, allowing a propylene content of 10% by volume.

There are additional issues affecting the retrofit industry which we have addressed in a separate letter. We would welcome the opportunity to open a dialog with you in order to address WPGA's concerns regarding the use of LPG as an alternative fuel. Please let us know your thoughts.

Sincerely yours,
WESTERN PROPANE GAS ASSOCIATION

William Platz
Chairman; Clean Fuels Committee

cc: John D. Courtis; ARB
Gary Yee; ARB
Robert Myers; PVC
Mary Reynolds; WPGA

Western Propane Gas Association

Fuel Specification Test Results

DODGE CARAVAN

FUEL BLEND DESIGNATION	Propane %	Propylene %	Butane %	NMHC g/ml	THC g/ml	CO g/ml	NOx g/ml	NMOG g/ml	Total ROG g/ml	Specific Reactivity g/g NMOG	RAF (CALC'D)	OFP g O3/ml.	FUEL ECON MPG
INDOLENE (Avg)				0.154	0.184	1.890	0.252	0.143	0.169	3.502	1.000	0.500	19.67
HD 5-2.5	92.5	5.0	2.5	0.101	0.124	1.959	0.144	0.099	0.121	1.161	0.332	0.115	14.60
HD 10-2.5	87.5	10.0	2.5	0.111	0.142	2.971	0.154	0.117	0.157	1.275	0.364	0.148	14.12
HD 20-2.5	77.5	20.0	2.5	0.081	0.104	2.130	0.155	0.078	0.103	1.699	0.405	0.132	14.74
HD 30-2.5	67.5	30.0	2.5	0.091	0.119	2.901	0.201	0.090	0.120	2.080	0.594	0.188	14.65
HD 5-20	75.0	5.0	20.0	0.100	0.124	2.780	0.109	0.098	0.125	1.274	0.364	0.125	14.93
HD 5-40	55.0	5.0	40.0	0.109	0.135	3.107	0.109	0.104	0.131	1.468	0.419	0.153	15.47
HD 10-40	50.0	10.0	40.0	1.046	1.152	14.662	0.087	1.107	1.218	1.156	0.330	1.279	14.84

CHEVROLET C1500 2X4

FUEL BLEND DESIGNATION	Propane %	Propylene %	Butane %	NMHC g/ml	THC g/ml	CO g/ml	NOx g/ml	NMOG g/ml	Total ROG g/ml	Specific Reactivity g/g NMOG	RAF (CALC'D)	OFP g O3/ml.	FUEL ECON MPG
INDOLENE (Avg)				0.230	0.260	1.950	0.575	0.229	0.261	3.226	1.000	0.737	16.26
HD 5-2.5	92.5	5.0	2.5	0.129	0.166	0.671	1.344	0.132	0.170	1.523	0.472	0.201	12.05
HD 10-2.5	87.5	10.0	2.5	0.135	0.173	0.921	1.491	0.137	0.172	1.689	0.524	0.232	12.09
HD 20-2.5	77.5	20.0	2.5	0.135	0.171	0.591	1.772	0.135	0.171	1.996	0.619	0.270	12.22
HD 30-2.5	67.5	30.0	2.5	0.150	0.185	0.518	2.390	0.149	0.183	2.308	0.715	0.344	12.20
HD 5-20	75.0	5.0	20.0	0.119	0.153	0.964	1.005	0.120	0.154	1.599	0.496	0.193	12.50
HD 5-40	55.0	5.0	40.0	0.138	0.173	1.395	0.796	0.142	0.177	1.778	0.551	0.251	12.63
HD 10-40	50.0	10.0	40.0	0.135	0.168	1.469	0.847	0.134	0.167	1.968	0.610	0.263	12.69

CHEVROLET K2500 4X4

FUEL BLEND DESIGNATION	Propane %	Propylene %	Butane %	NMHC g/ml	THC g/ml	CO g/ml	NOx g/ml	NMOG g/ml	Total ROG g/ml	Specific Reactivity g/g NMOG	RAF (CALC'D)	OFP g O3/ml.	FUEL ECON MPG
INDOLENE (Avg)				0.406	0.484	8.950	2.840	0.445	0.523	3.380	1.000	1.505	11.42
HD 5-2.5	92.5	5.0	2.5	0.333	0.409	9.410	1.880	0.332	0.407	1.582	0.468	0.525	8.46
HD 10-2.5	87.5	10.0	2.5	0.352	0.428	10.568	1.578	0.329	0.402	1.790	0.530	0.589	8.47
HD 20-2.5	77.5	20.0	2.5	0.273	0.341	7.011	2.521	0.279	0.349	2.154	0.637	0.601	8.51
HD 30-2.5	67.5	30.0	2.5	0.310	0.380	3.320	2.790	0.316	0.305	2.726	0.807	0.861	8.49
HD 5-20	75.0	5.0	20.0	0.409	0.495	14.849	1.045	0.398	0.484	1.673	0.495	0.666	8.68
HD 5-40	55.0	5.0	40.0	0.655	0.786	30.380	0.781	0.625	0.754	1.883	0.557	1.177	8.63
HD 10-40	50.0	10.0	40.0	0.470	0.563	20.639	0.814	0.454	0.547	2.083	0.616	0.946	8.80

Appendix 3

Proposed Revision of Section 2296.2

(Proposed deletions are shown in ~~strike-out type~~. Proposed additions are underlined.)

Amend section 2292.6, Title 13, California code of Regulations, to read as follows:

Section 2292.6 **Specifications for Liquefied Petroleum Gas**

The following standards apply to liquefied petroleum gas (the identified methods are incorporated herein by reference):

Specifications for Liquefied Petroleum Gas

Specification	Value	Test Method
Propane	85.0 vol. % (min.) a/	ASTM D 2163-87
Vapor Press. at 100° F	208 psig (max.)	ASTM D 1267-89 ASTM D 2598-88 b/
Volatility residue: evaporated temp., 95% or butane and heavier	 -37° F (max.) 2.5 vol. % (max.)	 ASTM D 1837-86 ASTM D 2163-87
Propene	5.0 vol. % (max.) c/	ASTM D 2163-87
Residual matter: residue on evap. of 100 ml oil stain observed.	 0.05 ml (max.) pass d/	 ASTM D 2158-89 ASTM D 2158-89
Corrosion, copper strip	No. 1 (max.)	ASTM D 1838-89
Sulfur	120 ppmw (max.)	ASTM D 2784-89
Moisture content	pass	ASTM D 2713-86
Odorant	e/	

a/ Propane shall be required to be a minimum of 80.0 volume percent starting on January 1, 1993. Starting on January 1, 1997, the minimum propane content shall be 85.0 volume percent.

b/ In case of dispute about the vapor pressure of a product, the value actually determined by Test Method ASTM D 1267-89 shall prevail over the value calculated by Practice ASTM D 2598-88.

c/ The propene shall be limited to 10.0 volume percent starting January 1, 1993. Starting January 1, ~~1997~~ 1999 , the propene limit shall be 5.0 volume percent.

d/ An acceptable product shall not yield a persistent oil ring when 0.3 ml of solvent residue mixture is added to a filter paper, in 0.1 ml increments and examined in daylight after 2 min. as described in Test Method ASTM 2158-89.

e/ The liquefied petroleum gas upon vaporization at ambient conditions must have a distinctive odor potent enough for its presence to be detected down to a concentration in air of not over 1/5 (one-fifth) of the lower limit of flammability.

Appendix 4

Use and Production Data

California Data

Source:	EIA State Energy Data Report (1)		EIA Prime Supplier Report (2)		CEC: Refinery & Nat. Gas Plants (3)		API: 1994 Sales of NGLS & LRGs (4)		API: 1994 Sales of NGLS & LRGs (4)		API: 1994 Sales of NGLS & LRGs (4)		EIA State Energy Data Report (5)	
Type of Data:	Energy Consumption in Calif.		Prime Supplier Sales Volumes" in Calif.		Retail & Wholesale		Residential & Commercial		Int'l Combust. Fuel (excludes farm use)		Farm		Transportation Energy Consumption in Calif.	
Product:	"LPG"		"Propane"		"Commer'l Grd. Prop."		"Propane"		"Propane"		"Propane"		"LPG"	
Comment:	all NGLs & LRGs; incl. industrial consumption		end-user consump.; includes industrial fuel		from EIA 782A forms; includes HD-5		comm. LPG, HD-5 & propane in mixes		comm. LPG, HD-5 & propane in mixes		comm. LPG, HD-5 & propane in mixes		on-road use, only	
	KBbls	BPD	KGal	BPD	KGal	BPD	KGal	BPD	KGal	BPD	KGal	BPD	KBbls	BPD
Year														
1985	20,497	56,156											1,225	3,356
1986	20,119	55,121											931	2,551
1987	22,328	61,173											837	2,293
1988	22,798	62,460											902	2,471
1989	24,697	67,663											885	2,425
1990	19,992	54,773											931	2,551
1991	18,596	50,948			338,166	22,059	343,455	22,404	74,625	4,868	38,764	2,529	760	2,082
1992	21,088	57,775			325,428	21,228	236,175	15,406	64,227	4,190	24,677	1,610	651	1,784
1993	16,655	45,630			325,000	21,200	248,027	16,179	62,361	4,068	25,507	1,664	655	1,795
1994							244,739	15,965	56,675	3,697	24,955	1,628		
1995														
Jan-Jul, '96			328,418	36,711										

PADD V Data

Source:	EIA (6)		EIA (6)	
Type of Data:	"Year-to-Date Supply" "Field Production"		"Year-to-Date Supply" "Products Supplied"	
Product:	"Propane/Propene"		"Propane/Propene"	
Comment:				
	KBbls	BPD	KBbls	BPD
Jan-Aug, '96	2,553	10,550	10,998	45,446

1. U.S.DOE Energy Information Agency, "State Data Report", 1993, Table 41, p. 53
2. U.S.DOE Energy Information Agency, "Prime Supplier Report", July 1996, p. 31
3. California Energy Commission, not published
4. American Petroleum Institute, National Propane Gas Association, and Gas Processors Assoc.; "1994, Sales of Natural Gas Liquids and Liquified Refinery Gases, Table 4, pp. 6, 7
5. U.S.DOE Energy Information Agency, "State Data Report", 1993, Table 45, p. 57

Appendix 5

Results of Surveys of Producers and Marketers

Summary of Responses to Producers' Survey

Production Type *	Product Grade Label	Typical Propene <10% now?	Typical Propene <5% in 1997?	Segregated storage?	Guarantee availability?	LPG from Oct 95 - Sep 96 avg. BPD	avg. propene	Expected prod. @ < 5% in '97, BPD
gas plant	(no LPG)							
refinery	(no LPG)							
refinery	(no LPG)							
refinery	commercial	yes	no	no	no	3,288	8%	0
refinery	commercial	no	no	no	no	4,500		0
refinery	(no LPG)							
refinery	HD-5	yes	yes	no	no	2,356	< 5%	4,125
refinery	(LPG is C4's)							
gas plant	commercial	yes	yes	no	no	614	0%	550
gas plant	commercial	yes	yes	no	no	274	0%	350
refinery	commercial	no	no	no	no	5,123	21%	0
refinery	commercial	yes	yes	no	no	693	0.1%	1,000
refinery	commercial	yes	yes	no	no	247	0.1%	300
gas plant	HD-5	yes	yes		no	370	< 2%	400
refinery	commercial	yes	yes	no	no	2,589	< 3%	3,625
refinery	commercial	yes	yes	no	no	2,219	< 3%	2,000
refinery	no LPG) ,							
refinery	(no LPG)							
gas plant	commercial	yes	no	no	no	1,671	> 5%	0
gas plant	(no LPG)							
refinery	commercial	yes	yes	no	no	1,800	3%	2,000
refinery	B-P mix	yes	yes	no	no	2,192	0%	2,192
					Sum:	27,936		16,542
					Sum @ <10% propene:	16,121	(excl. B-P mix)	
					Sum @ <5% propene:	11,162	"	

* For refining companies with two refineries, each refinery is tabulated separately. One gas plant operator provided separate data for two plants, which also are tabulated separately.

Liquefied Petroleum Gas Marketer's Survey Results

#	Retail Site Distribution			Sales Delivery Mode			Supply Sources			Miles from Supply	MV Sales		Planned Sites in '97	Add Fueling Equipment	Source of HD5 for '97	Can Test Fuel
	North	South	SJV	Bobtail	Truck	Rail	Refinery	Plant	Import		Onroad	Offroad				
Plan to supply in 1997																
1	y	n	y	97%	3%	0%	82%	8%	11%	158	0.6%	4.7%	12	n	Uncertain	n
2	y	y	y	97%	3%	0%	60%	0%	40%	45	8.0%	12.0%	5	y	None	n
3	y	n	n	0%	100%	0%	85%	0%	15%	70	15.0%	10.0%	3	n	Uncertain	n
4	n	n	y	100%	0%	0%	?	?	?	150	10.0%	10.0%	3	n	Uncertain	n
5	n	y	n	78%	17%	5%	94%	1%	5%	50	30.0%	40.0%	3	n	Uncertain	n
6	y	n	n	99%	1%	0%	100%	0%	0%	150	2.9%	0.1%	2	n	Certain	n
7	n	n	y	92%	8%	0%	0%	100%	0%	110	5.0%	14.0%	2	n	Uncertain	n
8	y	n	y	75%	25%	0%	80%	5%	15%	100	0.4%	2.0%	2	n	Uncertain	n
9	y	n	n	100%	0%	0%	100%	0%	0%	100	0.0%	0.5%	1	n	Uncertain	n
10	y	n	n	100%	0%	0%	100%	0%	0%	0	0.6%	3.0%	1	n	Uncertain	n
11	n	n	y	99%	0%	0%	100%	0%	0%	15	1.0%	1.0%	1	n	Certain	y
12	n	n	y	100%	1%	0%	3%	95%	2%	120	1.0%	1.0%	1	n	Uncertain	n
13	n	y	n	100%	0%	0%	?	?	?	225	0.5%	0.0%	1	n	Certain	n
14	n	y	n	100%	0%	0%	100%	0%	0%	100	6.0%	2.0%	1	n	None	n
Do not plan to supply in 1997											0.0%	0.0%				
											0.0%	0.0%				
15	y	n	n	100%	0%	0%	100%	0%	0%	130	0.0%	0.0%	0	n	Uncertain	n
16	y	n	n	0%	100%	0%	1%	0%	0%	30	0.0%	0.0%	0	n	Uncertain	n
17	y	n	n	100%	0%	0%	20%	80%	0%	200	0.0%	0.0%	0	n	Uncertain	n
18	y	n	n	100%	0%	0%	100%	0%	0%	100	0.0%	1.0%	0	n	Uncertain	n
19	y	n	n	100%	0%	0%	100%	0%	0%	119	0.5%	0.0%	0	n	Uncertain	n
20	y	n	n	90%	10%	0%	100%	0%	0%	150	1.0%	1.0%	0	n	Uncertain	n
21	y	n	n	100%	0%	0%	100%	0%	0%	125	2.0%	0.0%	0	n	Uncertain	n
22	n	n	y	100%	0%	0%	100%	0%	0%	150	4.0%	0.0%	0	n	Uncertain	n
23	n	n	y	60%	40%	0%	70%	30%	0%	140	10.0%	5.0%	0	n	Uncertain	n
24	n	y	n	100%	0%	0%	?	?		75	0.0%	1.0%	0	n	None	n
25	n	y	n	90%	10%	0%	15%	70%	15%	110	4.0%	5.0%	0	n	Uncertain	n
26	n	y	n	100%	0%	0%	90%	10%	0%	160	5.0%	20.0%	0	n	Uncertain	n
27	y	y	y	84%	16%	0%	75%	20%	5%	100	2.0%	0.5%	0	n	Uncertain	n
28	y	y	y	95%	5%	0%	80%	20%	2%	150	5.0%	25.0%	0	n	None	n

Note: One survey respondent did not provide complete information; therefore, those results are not included.

Liquefied Petroleum Gas Marketer's Survey Results

Aggregated Totals		
Retail sites	123	Sites
Motor vehicle grade retail sites	104	Sites
Storage for bobtail delivery	141	Sites
Storage for direct transport	48	Sites
Segregated storage sites	13	Sites
Segregated storage sites used in 96	2	Sites
Total typical sales volume	169	Million gal/year
Volume used in own fleet	20	Million gal/year
Planned HD5 grade sites for '97	38	Sites

Cal/EPA

California Environmental Protection Agency

Air Resources Board

P.O. Box 2815
2020 L Street
Sacramento, CA
95812-2815

Pete Wilson
Governor

James M. Strock
Secretary for Environmental Protection

November 15, 1996

Dear Sir or Madam:

I am writing to request your cooperation in completing the enclosed survey form, "LPG Producers' Survey". This survey is being sent by the Air Resources Board (ARB) to all liquified petroleum gas (LPG) producers in California. Our purpose is to estimate the amount of LPG available for use in motor vehicles in California and to understand factors that may limit that amount.

Section 2292.6 of the California Code of Regulations (enclosed) currently limits the propene content of motor vehicle LPG to ten percent. On January 1, 1997, the limit will drop to five percent. Members of the Western Petroleum Gas Association have expressed concern that under the lower propene limit, there will be an insufficient supply of compliant LPG, particularly if distributors are unable to carry separate vehicular and commercial products. In such a case, distributors could forgo supplying vehicular fuel.

The survey asks for information that characterizes the quality and production process for your LPG. Also, it asks for recent historical production volumes. The survey should be completed separately for each facility that produces finished LPG. If your company is both a refiner and an oil/gas producer, we may have sent this letter to both parts of your company. The entire mailing list is enclosed so that you can see who else in your company (or an affiliate) has received this letter.

You may claim trade-secret status for your information in the survey. California law provides substantial protection for trade secrets (except trade secrets that are emission data). For information which you deem to be a trade secret, you have the option of either: (1) submitting detailed written justification with the completed survey form in accordance with section 91022© of the California Code of Regulations, or (2) providing written justification at a later date, if a request for release of the information is received by the ARB.

We do not plan to release any data from individual companies. However, in accordance with ARB regulations (Title 17, CCR, sections 91000 to 91022), and the California Public Records Act (Government Code Sections 6250 et seq.), the information which you provide may be released to the United States Environmental Protection Agency, which protects trade secrets as provided in federal regulations and in section 114© of the federal Clean Air Act and amendments thereto (42 U.S.C. 7401 et seq.). Also, if information does not qualify as trade secret, it could be released to the public, upon request.

We would appreciate your return of the completed survey form by November 30, 1996.

If you have any questions regarding the purpose for this survey, please call Mr. John Courtis, Manager of the Fuels Section, at (916) 322-6019. If you have any questions regarding how to complete the survey form, please call Mr. Richard Vincent at (916) 327-5977.

Sincerely,

Dean C. Simeroth, Chief
Criteria Pollutants Branch
Stationary Source Division

Enclosures (3)

LPG PRODUCER'S SURVEY
November 1996

Please complete a copy of this survey for each of your sites (refining, gas production, or importation) where LPG (predominantly propane) is released for sale in California (excluding inter-refinery). *Italic type* indicates that one option should be checked. Otherwise, please fill all pertinent blanks.

1. Company:_____ Contact: _____
   Address:_____ Title:_____
   _____ Phone:_____
   _____ Site Location:_____

2. Please check the geographic region(s) where your propane is distributed:
   S.F. Bay area ____ North Coast ____ Sacramento Valley ____ San Joaquin Valley ____
   Central Coast ____ LA Basin ____ San Diego ____ High Desert ____ Low Desert ____

3. Currently, how do you label (guarantee specification of) propane sold from this location?
   _____
   Do you deliver propane with a maximum propene content of 10% consistently *Yes*____ *No*____

4. For total propane distributed from this location in 1997, what percentage of propane could meet:
   -- the ARB spec. (5% olefin)? _____% -- commercial grade spec. (but not ARB)? _____%

5. What is the typical daily amount of propane meeting the ARB standard that this location could produce in 1997? 1st quarter _____BPD 2nd quarter _____BPD
   3rd quarter _____BPD 4th quarter _____BPD
   Please explain any seasonal variation: _____
   _____

6. If you will provide ARB propane in 1997, do you plan to make any guarantee that some ARB propane will be available on any given day at this location? *Yes* ____ *No* ____

7. Can you now segregate HD-5 propane from other grades at this location? *Yes* ____ *No* ____
   If so, do you plan to market propane under a variety of grades in 1997? *Yes* ____ *No* ____
   If so, do you plan to charge a premium price for ARB? *Yes* ____ *No* ___

8. In 1997, if propane that is expected to be ARB grade is determined to not be ARB grade, how long in advance of scheduled deliveries will shippers be notified? _____
   Will shippers be allowed to not take scheduled propane in this circumstance? *Yes* ____ *No* ____
   Under what terms? _____

LPG PRODUCER'S SURVEY (Con't)
November 1996

9. What is the typical batch size tested to determine propane specification at this location?____bbls

10. Please provide the indicated data for sales of propane during the past four quarters (excluding inter-refinery sales).

Quarter/ Year	Fuel Grade	Typical Composition			Volume (million bbls)
		% propane	%C4+	% olefins	
4 / 1995	HD-5 ARB (10% olefin) Commercial B-P mix				
1 / 1996	HD-5 ARB (10% olefin) Commercial B-P mix				
2 / 1996	HD-5 ARB (10% olefin) Commercial B-P mix				
3 / 1996	HD-5 ARB (10% olefin) Commercial B-P mix				

Cal/EPA
California Environmental Protection Agency

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P.O. Box 2815
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Pete Wilson
Governor

James M. Strock
Secretary for Environmental Protection

November 15, 1996

Dear Sir or Madam:

I am writing to request your cooperation by completing the enclosed survey form, "LPG Marketers' Survey". This survey is being sent by the Air Resources Board (ARB) to LPG marketers in California. Our purpose is to understand the capability of LPG distribution system to provide complying LPG to motor vehicles.

Section 2292.6 of the California Code of Regulations (enclosed) currently limits the propene content of motor vehicle LPG to 10 percent. On January 1, 1997, the limit will drop to 5 percent. Members of the Western Petroleum Gas Association have expressed concern that under the lower propene limit, there will be an insufficient supply of compliant LPG, particularly if distributors are unable to carry separate vehicular and commercial products. In such a case, distributors could forgo sales to vehicles.

You may claim trade-secret status for your information in the survey. California law provides substantial protection for trade secrets (except trade secrets that are emission data). For information which you deem to be a trade secret, you have the option of either: (1) submitting detailed written justification with the completed survey form in accordance with section 91022© of the California Code of Regulations, or (2) providing written justification at a later date, if a request for release of the information is received by the ARB.

We do not plan to release any data from individual companies. However, in accordance with ARB regulations (Title 17, CCR, sections 91000 to 91022), and the California Public Records Act (Government Code Sections 6250 et seq.), the information which you provide may be released to the United States Environmental Protection Agency, which protects trade secrets as provided in federal regulations and in section 114© of the federal Clean Air Act and amendments thereto (42 U.S.C. 7401 et seq.). Also, if information does not qualify as trade secret, it could be released to the public, upon request.

We would appreciate your return of the completed survey form by November 30, 1996.

If you have any questions regarding the purpose for this survey, please call Mr. John Courtis, Manager of the Fuels Section, at (916) 322-6019. If you have any questions regarding how to complete the survey form, please call Mr. Richard Vincent at (916) 327-5977.

Sincerely,

Dean C. Simeroth, Chief
Criteria Pollutants Branch
Stationary Source Division

Enclosures (2)

LPG MARKETERS SURVEY

November 1996

Please complete this survey for the propane your company sells at retail in California. *Italic type* indicates that one option should be checked. Otherwise, please fill all pertinent blanks.

1. Company: _____ Contact: _____

   Address: _____ Title: _____

   _____ Phone: _____

   _____

2. From how many retail sites does your company sell propane? _____

   How many of the sites offer propane for use in motor vehicles? _____

   Please check the geographic region(s) where you sell : S.F. Bay area ____ North Coast ____

   Sacramento Valley ____ San Joaquin Valley ____ Central Coast ____ LA Basin ____

   San Diego ____ High Desert ____ Lower Desert ____

3. At how many sites does your company:

   -- Receive and store propane for later bobtail delivery? _____

   -- Sell transport quantities directly to the end-user? _____

   What percents of your total sales volumes are: Bobtail? ____ Transport/truck? _____

   Transport/rail? _____

4. What percent of your annual propane supply for California sales comes from:

   Refineries?_____ Gas Plants?_____ Imports from out of state?_____

5. Please list your major FOB supply points:_____

   _____

   What is the typical distance from your supply point to your storage?_____miles

6. At how many sites can now segregate storage of more than one specification of propane? _____

   At how many sites do you now segregate and deliver more than one specification? _____

7. What is your typical annual California sales volume for all categories? _____gallons

   What percentage is sold to: over-the-road transportation uses? ____%

   non-road vehicles (e.g, forklifts)? ____%

8. In addition to the sales, how many gallons are used by your own fleet? _____ gal/yr

LPG MARKETERS SURVEY
(cont.)

9. At how many sites do you plan to sell or use propane for vehicular use in 1997 if the limit on propene (propylene) declines to 5% on January 1, 1997? _____

   Do you plan to install separate equipment to enable sales of vehicular propane? *Yes*___ *No*___

10. What is your understanding of your supplier's ability to sell you vehicular grade propanein 1997?

    Will supply ____ *Will not supply*____ *Uncertain* ____

11. Do you test or have the capacity to test the specification of the propane you receive against the supplier's statement of grade? *Yes*___ *No* ___

Appendix 6

Summary of Emission Data

ARB Staff's Summary of Data in
"Effect of Selected LPG Fuel Components on Speciated Exhaust Emissions"

Sponsored by: Western Propane Gas Association, Project 304
Conducted by: Automotive Testing Laboratories
Chief investigator: Wendy Clark

The investigators tested each of the LPGs listed in the following table in each of the listed vehicles. For each vehicle, one of the LPGs was tested in triplicate runs. No other replicates were run on LPG. Each vehicle was also tested at the beginning of the project and at the end on Indolene (federal certification fuel).

The vehicles were converted from gasoline for the purpose of the project, using conversion hardware from IMPCO Technologies.

Fuels and Vehicles Tested

Vehicles	LPGs			
		% Propane	% Propene	% Butanes
1. '95 Dodge Caravan	1.	92.5	5	2.5
2. '95 Chev. C1500	2.	87.5	10	2.5
3. '95 Chev. K2500	3.	77.5	20	2.5
	4.	67.5	30	2.5
	5.	75	5	20
	6.	55	5	40
	7.	50	10	40

All tests were done with the Federal Test Procedure (FTP), without evaporative measurements. The organic gas emissions were speciated by GC/MS. Aldehydes and ketones were collected in impingers containing acidifed DNPH and analyzed with high-performance liquid chromatography. Reactivities of the organic gas emissions were calculated according to the "Carter MIR" procedure.

The FTP-composite results for the Indolene tests are:

FTP-Composite Results on Indolene

	NMHC, g/mi	g Ozone/mi	NOx, g/mi	CO, g/mi
Veh 1, start	.146	.500	.238	1.41
Veh 1, end	.161		.265	2.37
Veh 2, start	.238	.737	.547	1.90
Veh 2, end	.222		.576	16.43
Veh 3, start	.456	1.505	2.72	11.13
Veh 3, end	.356		2.98	11.67

Tthe FTP-composite results for all LPG tests, including means of triplicates, are:

FTP-Composite Results for LPGs

LPG	Vehicle	NMHC	gO/mi	NOx	CO
1	1	0.101	0.115	0.144	1.959
1	2	0.129	0.201	1.344	0.671
1	3	0.333	0.525	1.88	9.41
2	1	0.111	0.148	0.154	2.971
2	2	0.135	0.232	1.491	0.921
2	3	0.352	0.589	1.578	10.568
3	1	0.081	0.132	0.155	2.13
3	2	0.135	0.27	1.772	0.591
3	3	0.273	0.601	2.521	7.011
4	1	0.091	0.188	0.201	2.901
4	2	0.15	0.344	2.39	0.518
4	3	0.310	0.861	2.790	8.320
5	1	0.1	0.125	0.109	2.78
5	2	0.119	0.193	1.005	0.964
5	3	0.409	0.666	1.045	14.849
6	1	0.109	0.153	0.109	3.107
6	2	0.138	0.251	0.796	1.395
6	3	0.655	1.177	0.781	30.38
7	1	1.046	1.279	0.087	14.66
7	2	0.135	0.263	0.847	1.469
7	3	0.47	0.946	0.814	20.639

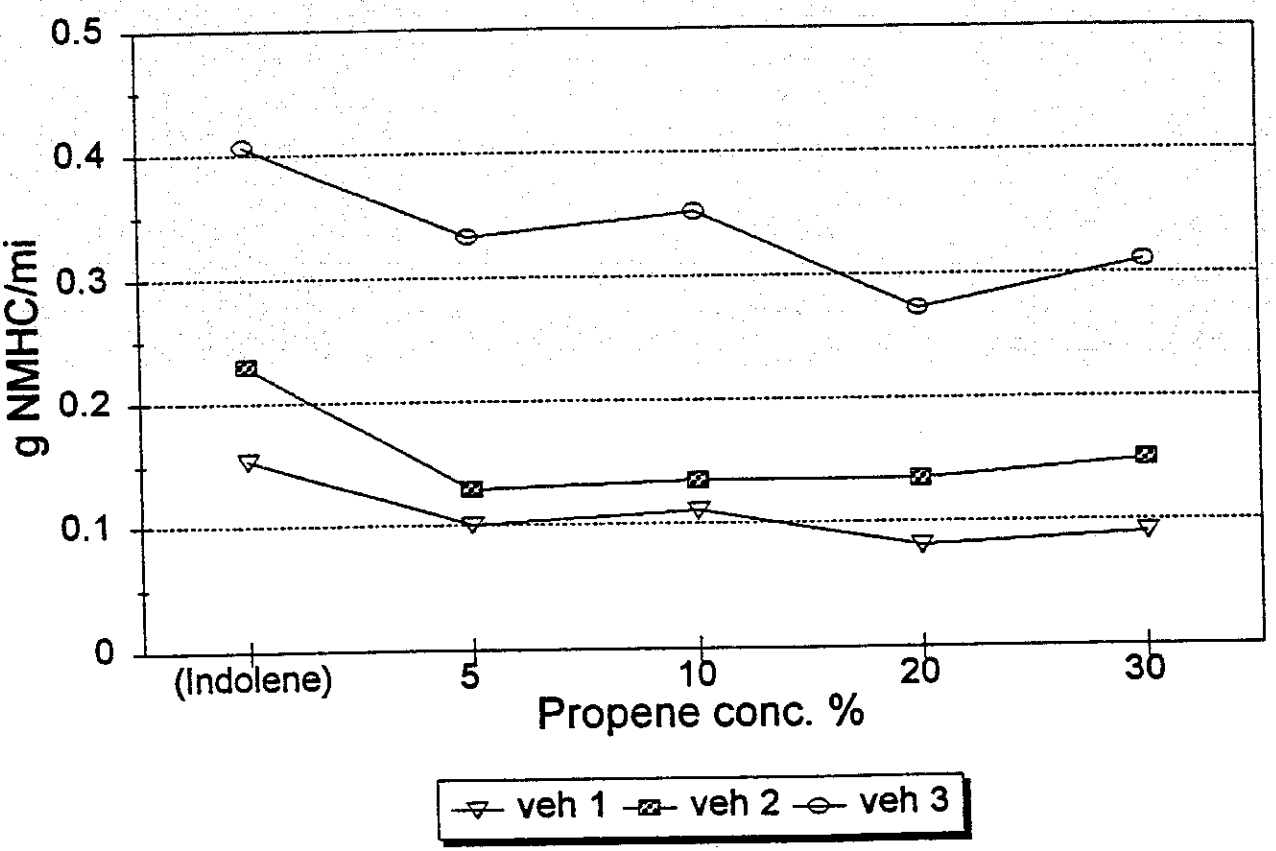
The following graphs compare emissions on Indolene and LPGs 1 to 4.

NMHC Emissions

WPGA Study

LPG & Indolene

Butane = 2.5%

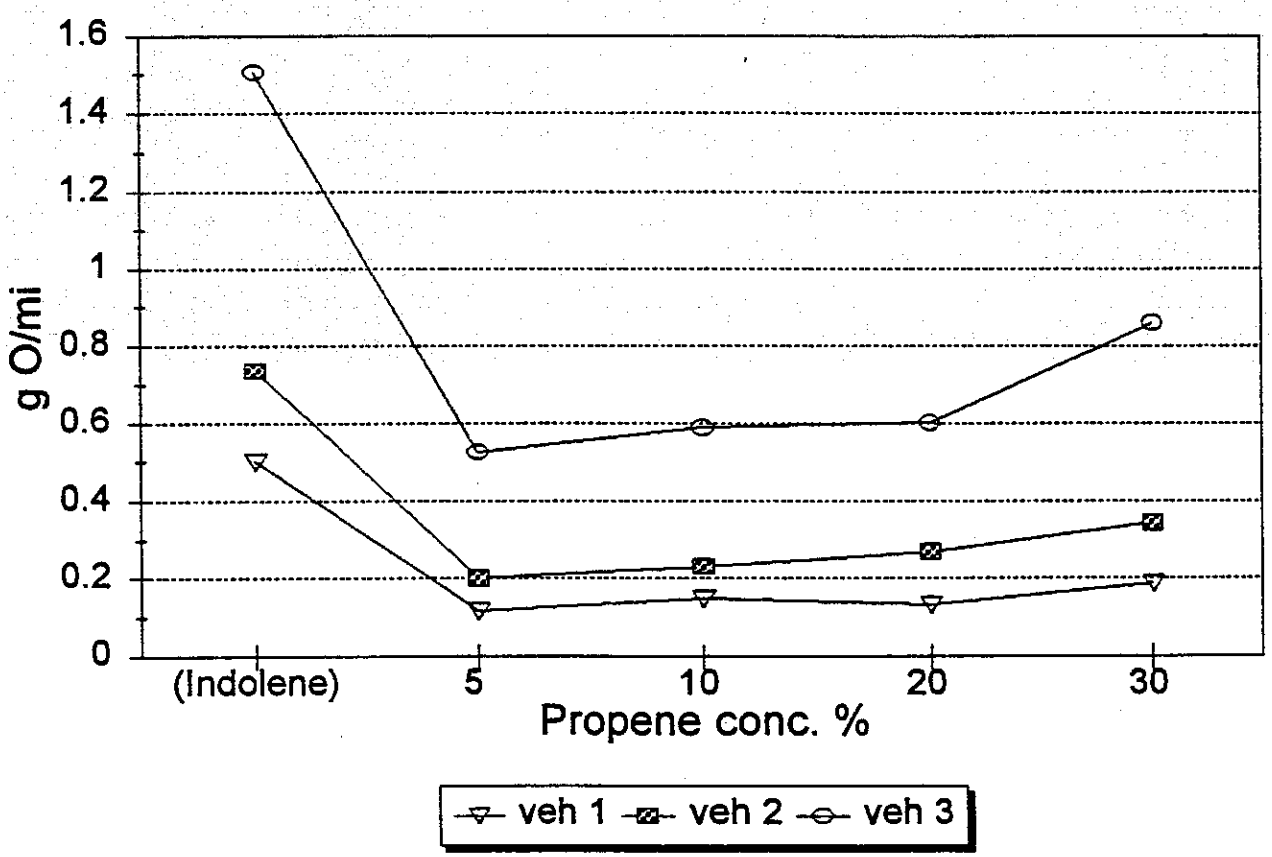


Ozone Formation

WPGA Study

LPG & Indolene

Butane = 2.5%

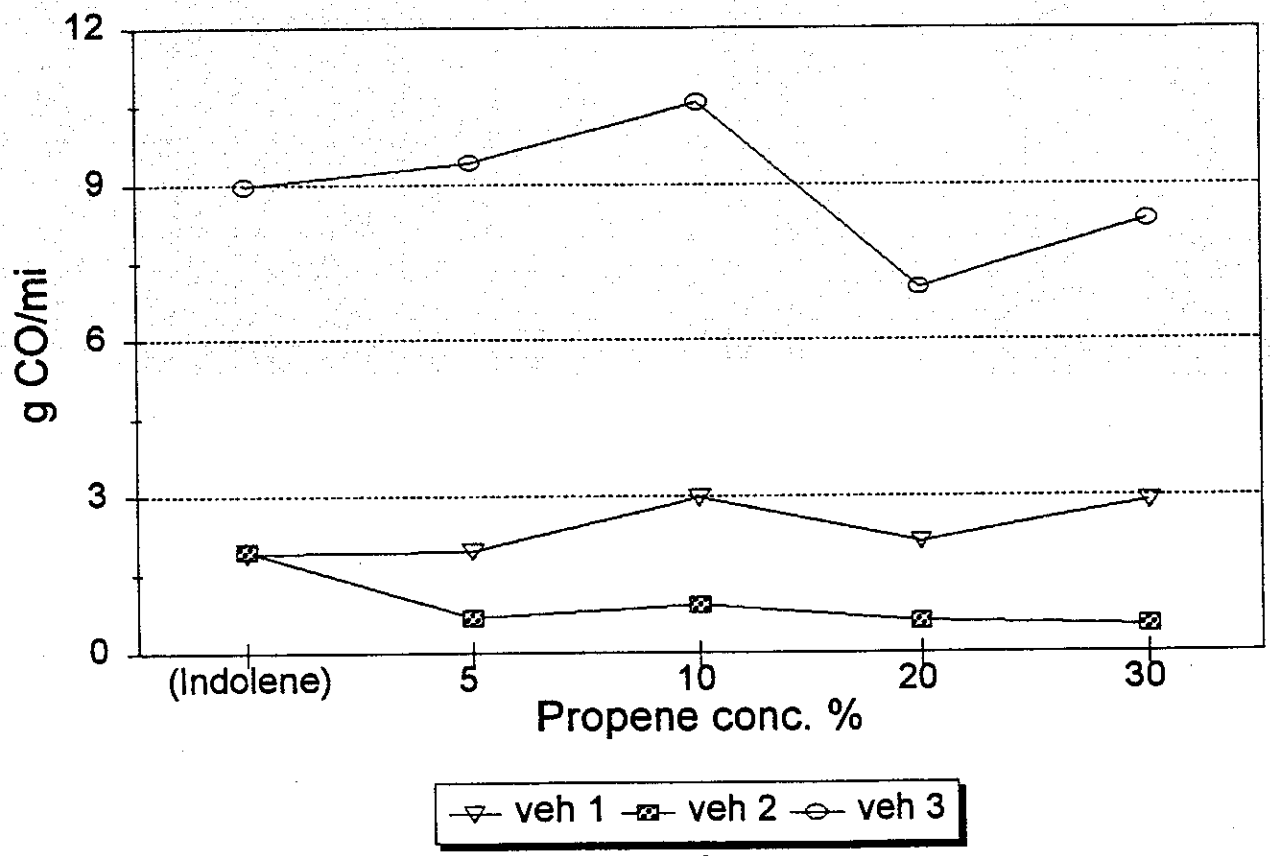


CO Emissions

WPGA Study

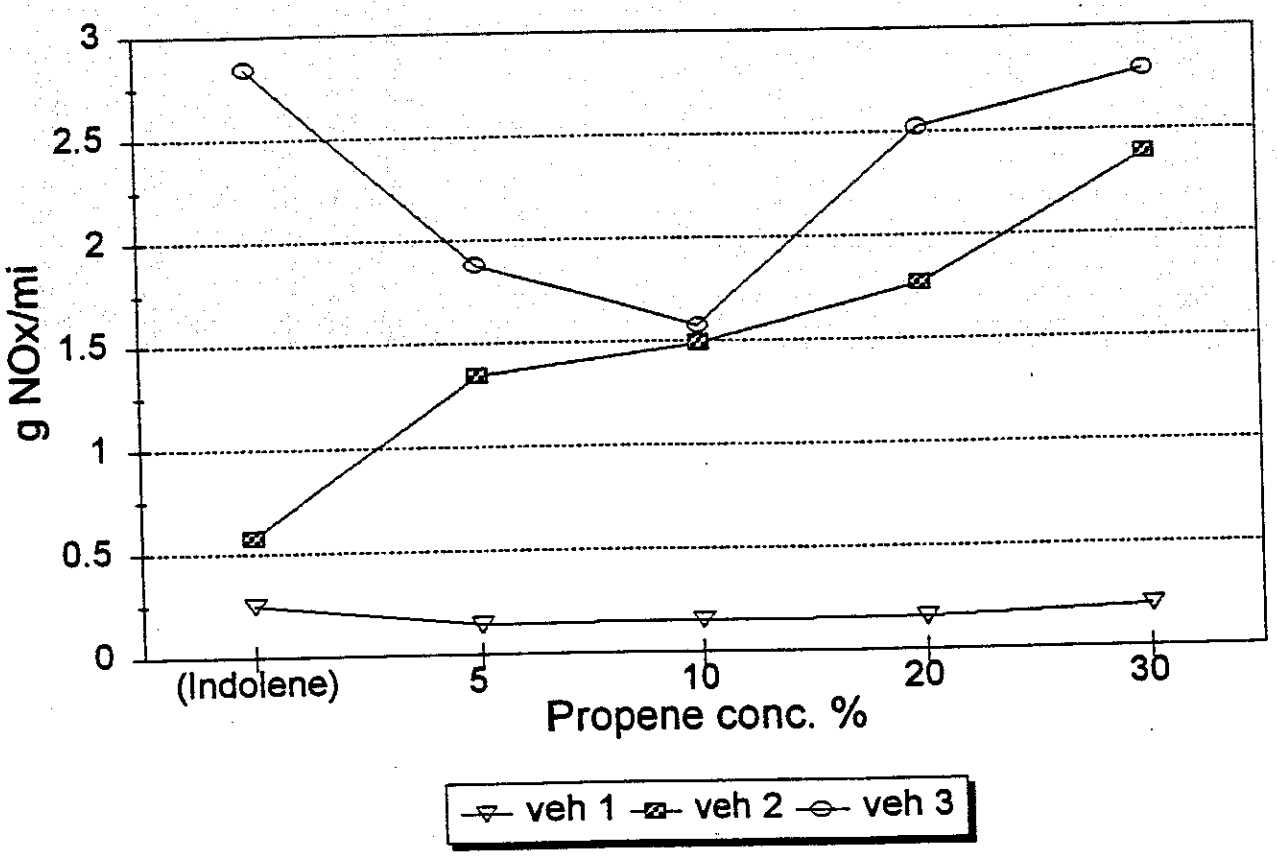
LPG & Indolene

Butane = 2.5%



NOx Emissions

WPGA Study

LPG & Indolene

Butane = 2.5%