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## **ARB LPG Fuel Blends Evaluation Project February 1999 Progress Report**

submitted to:

### **LPG Fuel Blends Evaluation Project Task Group and Co-Sponsors**

*American Automobile Manufacturers Association, ARCO Products Co., California Air Resources Board, Cummins Engine Co., Engine Manufacturers Association, Equilon, Ford Motor Co., GFI, IMPCO, National Propane Gas Association, National Renewable Energy Laboratory, Natural Resources Canada, Propane Education and Research Council, Railroad Commission of Texas Alternative Fuels Research & Education Division, South Coast Air Quality Management District, Tosco Refining Co., and Western Propane Gas Association*

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### **I. Executive Summary**

Medium and Light-duty emissions tests were completed in 1998. Statistical analysis of the Light-duty results continues. Composition test results were received for Medium-duty emissions fuel and Performance/Combustion fuel. Southwest Research Institute's (SwRI) draft Final Report for Performance/Combustion tests was sent to the Task Group. The ADEPT Group, Inc. (ADEPT) and Bodycote ORTECH (ORTECH) continued to negotiate the Durability test agreement. ADEPT continued review of the durability test cycle with input from Cummins Engine Co. (Cummins), Ford Motor Co. (Ford), SwRI, ORTECH and other industry experts. ADEPT investigated oil analysis to evaluate engine wear during the Durability tests. Project fundraising and management continued.

### **II. Test Program Work Performed**

#### **A. Fuel Properties and Octane Tests**

Composition tests for Certification Fuel and Fuel #1 used at SwRI were completed (see appendices for results). Table 1 compares Dixie Services Inc.'s (Dixie) test results with Air Liquide's initial analysis. The test fuels were within acceptable limits (see appendices for complete fuel blend comparison). SwRI returned all sixteen (16) Air Liquide cylinders (since no further tests were needed).

**Table 1: Dixie Results of Blend Composition Analysis after Performance/  
Combustion Tests at SwRI (Air Liquide Cylinders)**

Type	Cylinder #	Component	Air Liquide (vol. %)	Dixie (vol. %)	Difference (vol. %)
<b>Cert. Fuel</b>	5114AX	Propane	93.97	93.81	0.16
		n-Butane	1.91	2.04	-0.13
		Propylene	3.82	3.78	0.04
		Isobutane	0.30	0.34	-0.04
<b>Fuel #1</b>	5074AX	Propane	84.83	84.58	0.25
		n-Butane	5.00	5.23	-0.23
		Propylene	9.87	9.88	-0.01
		Isobutane	0.30	0.30	0.00

Three cylinders from ORTECH were returned to Phillips 66 for fuel composition tests in January. Test results are not yet available.

***B. Medium-Duty Engine (Cummins B5.9LPG) Emissions Tests at Bodycote ORTECH.***

Tests were completed in August 1998. Final Report was submitted on November 18, 1998. Prior monthly reports and the Final Report can be accessed on ARB's website: <http://www.arb.ca.gov/altfuels/lpg/mvlpge/mvlpge.htm>.

Statistical analyses performed by ADEPT and Dr. Ne-Zheng Sun of UCLA concluded that the results of completed Emissions Tests are not sufficient to develop a model for fuel blends with emissions "equivalent" to those of Certification Fuel. The model would define an envelope in three dimensions, %-propane, %-propylene, and %-n-butane for fuel blends that would yield emissions equivalent to Certification Fuel. Data from the five candidate fuels is the first step to develop this optimization model. Emissions tests on more blends will yield enough data points to create the model.

***C. Light-Duty Truck (F150 Bi-Fuel) Emissions Tests at ARB Haagen Smit Laboratory.***

Tests ended in September 1998. ARB's final report is not yet available.

**D. Performance/Combustion Tests at Southwest Research Institute.**

Tests were completed in January. Table 2 shows the average composition for fuels tested.

**Table 2: Average Fuel Compositions, by Percent Volume, at SwRI.**

<b>Fuel</b>	<b>Propylene (C<sub>3</sub>H<sub>6</sub>)</b>	<b>Propane (C<sub>3</sub>H<sub>8</sub>)</b>	<b>i-Butane (C<sub>4</sub>H<sub>10</sub>)</b>	<b>n-Butane (C<sub>4</sub>H<sub>10</sub>)</b>
<b>Certification Fuel</b> Air Liquide	4.04	93.85	0.30	1.81
<b>Fuel #1</b> Air Liquide	9.89	84.83	0.30	4.99

In general, engine performance was unaffected by fuel blend. The engine was able to produce full power (145 kW) at each engine speed with both blends. No detonation was encountered (audibly or visually with an oscilloscope) with either blend.<sup>1</sup>

SwRI's draft Final Report was distributed to the Task Group.

Test program protocol and previous reports can be accessed at ARB's website:  
<http://www.arb.ca.gov/altfuels/lpg/mvlpge/mvlpge.htm>.

**E. Durability Tests at Bodycote ORTECH.**

Project Agreement negotiations continued. ORTECH submitted a draft proposal. Cummins, Ford, ADEPT and ORTECH continued to refine the durability test cycle and test conditions with feedback from Task Group members. The goal is to get as close to Cummins' Durability Test cycle as possible without Cummins full disclosure.

Without Cummins' Certification Fuel durability test data, ADEPT and ARB further explored the possibility of running durability tests on two fuels: Cert. Fuel and Fuel #1.

ADEPT also explored the possibility of using only Fuel #1 and conducting tribological oil analysis. Oil analysis would provide early warning of engine failure as well as insure that there will be a reliable and impartial scientific evaluation of engine wear. ADEPT discussed engine wear issues with Hertz Mechanical Engineering (Hertz) in Saskatoon, Canada and with SwRI. ADEPT received a proposal and cost estimate for tribological work from Hertz.

**III. Project Management Support and Administrative Work Performed**

**A. Project Fundraising**

The Propane Education and Research Council (PERC) funding was received. ADEPT is

<sup>1</sup> Testing of a Cummins B5.9-195LPG Engine – Draft Final Report” SwRI Project No. 03-2369, Feb. 1999.

waiting for a reply from the California Energy Commission (CEC). AFRED/TAFC notified ADEPT that a funding approval meeting was scheduled for March 19. August and September 1998 Progress Reports were submitted.

**B. Project Expenditures**

Table 3 shows February expenditures and total expenditures to date.<sup>2</sup>

**Table 3: February Expenditures and Total Expenditures to Date**

Item	Funds Expended In February	Funds Expended to Date
Fuel (Air Liquide, Phillips)	\$9,696.39	\$23,627.99
Emissions Tests (ORTECH)	\$0.00	\$176,351.07 <sup>3</sup>
Perf./Comb. Tests (SwRI)	\$7,500.00	\$22,500.00
Fuel Properties (Dixie)	\$335.00	\$11,618.46
Engine	\$0.00	\$17,063.47
Project Management	\$626.74	\$54,447.25
Attorney Fees	\$0.00	\$2,250.00
Subcontractor	\$0.00	\$2,273.29
Miscellaneous	\$0.00	\$687.66
<b>Total</b>	<b>\$18,158.13</b>	<b>\$310,819.19</b>

Project Account Balance at month's end: **\$2,902.16**

Table 4 shows total funds received to date, by respective funder.

<sup>2</sup> All outlays above \$1,000 are pre-approved by the LPG Task Group and/or the TAC.

<sup>3</sup> Total includes \$23,422.55 (CAN\$35,931.02), paid directly to ORTECH by PGAC.

**Table 4: Total Funds Received to Date**

<b>Funder</b>	<b>Amount</b>
ARCO	\$45,000.00
EMA	\$1,000.00
NPGA	\$8,920.00
NRCan	\$119,500.95 <sup>4</sup>
PERC	\$25,000.00 <sup>5</sup>
SCAQMD	\$45,000.00
Shell/Equilon	\$36,000.00
Tosco	\$22,500.00
WPGA	\$10,800.00
<b>Total</b>	<b>\$313,721.35<sup>6</sup></b>

**C. Project Contracts and Other Documents**

The ARB completed the contract and approval of \$85,000 for the project. ADEPT held a contract update meeting with SCAQMD staff.

**Travel associated with effort described:**

No travel was conducted.

**IV. Work planned for the next reporting period (March 1 - 31, 1999)**

**Project Management-ADEPT**

1. Continue general project management.
2. Prepare and complete funding contracts for co-sponsors.
3. Continue fundraising.
4. Distribute to Task Group SwRI Final Report for Performance/Combustion tests.
5. Prepare for Durability tests.

**Test Program**

1. ARB-EI Monte will finalize results and submit a draft Final Report.
2. ORTECH will prepare for Durability tests.

**V. Attachments:**

Dixie Certificates of Analysis

Complete comparison of fuel speciation at SwRI (Air Liquide vs. Dixie)

<sup>4</sup> Total of three payments: one at US\$61,356.48 (conversion ratio of 0.6817), one at US\$34,721.92 (conversion ratio of 0.6518), and one at US\$23,422.55 (conversion ratio of 0.6519). Please note that this figure was incorrectly reported in prior monthly reports due to an ADEPT accounting error.

<sup>5</sup> The total PERC award was for \$30,000. Five thousand was directly allotted to PVC for their costs associated with the project.

## VI. Disclaimer

This report was prepared by ADEPT as result of work co-sponsored by the SCAQMD and Task Group members. Opinions, findings, conclusions, and recommendations within are those of the author and do not necessarily represent SCAQMD's views. SCAQMD, their officers, employees, contractors, and subcontractors make no warranty, expressed or implied, and assumes no legal liability for the information in this report. SCAQMD has not approved or disapproved this report, nor have they passed upon the accuracy or adequacy of the information contained herein.

## VII. Glossary of Acronyms

AFRED	Alternative Fuels Research and Education Division
ARB	California Air Resources Board
ARB-El Monte	ARB Haagen Smit Laboratory in El Monte, CA
CEC	California Energy Commission
EMA	Engine Manufacturers Association
F°	Fahrenheit
kW	kilowatts
LPG	liquefied petroleum gases
NPGA	National Propane Gas Association
NRCan	Natural Resources Canada
PERC	Propane Education and Research Council
PGAC	Propane Gas Association of Canada
PVC	Propane Vehicle Council
rpm	revolutions per minute
SCAQMD	South Coast Air Quality Management District
SwRI	Southwest Research Institute
TAFC	Texas Alternative Fuels Council
UCLA	University of California, Los Angeles
WPGA	Western Propane Gas Association