DIXIE SERVICES INCORPORATED

POST OFFICE BOX 451
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CERTIFICATE OF ANALYSIS

Number: 93770 Final

Date: May 29, 1998

Client: The Adept Group, Inc.
1575 Westwood Boulebard, Suite 200
Los Angeles, California 90024

Attention: Alex Spataru

Sample: Liquified petroleum gas, submitted 4/15/98
Origin: Aeriform
Marks: Listed below

The complete analyses of the LPG Mixtures are tabulated on the following page.

Dixie Services Incorporated,

John C. Powers

JCP/ebw

The information contained herein is based on laboratory observations and tests performed on samples submitted and identified by the above-named client (which may be any company, organization or individual) and conducted in accordance with methodology which may be specified by the client. No representations or warranties either express or implied, of merchantability, fitness for any particular use, or of any other nature are made hereunder with respect to the information herein provided. Dixie Services disclaims any and all liability for damage or injury which results from the use of the information contained herein, and nothing contained herein shall constitute a guarantee, warranty or representation by Dixie Services with respect to the accuracy of the information, the sample, products or items described, or their suitability for use for any specific purpose. This document is intended for the sole use of the client and may not be reproduced except in full without the written approval of Dixie Services.

	Composition	Cyl #RC5193	Cyl #5600011	Cyl #5600902	Cyl #PHS2706	Cyl #5600066	Cyl #5600234
		19.99 % n-Butane	5.02 % n-Butane	1.913 % n-Butane	10.01 % n-Butane	5.006 % n-Butane	1.908 % n-Butan
		3.83 % Propylene	10.02 % Propylene	3.839 % Propylene	10.02 % Propylene	15.01 % Propylene	3.835 % Propyle
		76.18 % Propane	84.96 % Propane	94.248 % Propane	79.97 % Propane	79.984 % Propane	94.257 % Propa
D 2598	Vapor pressure, 100 °F, (calc.)	149 psig	172 psig	174 psig	165 psig	174 psig	174 psig
D 3246	Sulfur	<1 ppm	<1 ppm	<1 ppm	<1 ppm	<1 ppm	<1 ppm
		<0.1 grains/100 ft 3	<0.1 grains/100 ft 3	<0.1 grains/100 ft 3	<0.1 grains/100 ft 3	<0.1 grains/100 ft 3	<0.1 grains/100 f
UOP 619	Fluoride	0.1 ppm	0.6 ppm	<0.1 ppm	0.9 ppm	0.2 ppm	0.1 ppm
D 1837	Volatile residue,						
	Temperature @ 95 % evaporation	+19.3 °F	-29.0 °F	-38.9 °F	-6.7 °F	-30.0 °F	-38.2 °F
D 2158	Residual matter						
	Residue on evaporation	<0.05 mL	<0.05 mL	<0.05 mL	<0.05 mL	<0.05 mL	<0.05 mL
	Oil stain	Pass (0.3 mL)	Pass (0.3 mL)	Pass (0.3 mL)	Pass (0.3 mL)	Pass (0.3 mL)	Pass (0.3 mL)
D1838	Copper corrosion	1A	1A	1A	1A	1A	1A
D 2713	Moisture	Pass	Pass	Pass	Pass	Pass	Pass
D 2163	Ethane	0.04 vol %	0.05 vol %	0.02 vol %	0.04 vol %	0.05 vol %	0.02 vol %
	Propane	76.12 vol %	85.26 vol %	94.05 vol %	80.02 vol %	80.23 vol %	94.07 vol %
	Propylene	3.71 vol %	9.58 vol %	3.73 vol %	9.79 vol %	14.60 vol %	3.72 vol %
	Isobutane	0.18 vol %	0.24 vol %	0.29 vol %	0.17 vol %	0.15 vol %	0.29 vol %
	n-Butane	19.95 vol %	4.87 vol %	1.91 vol %	9.98 vol %	4.97 vol %	1.90 vol %
D 2623	Motor octane number	94.4	94.6	96.1	94.1	93.7	96.0
D 2623M	Research octane number	106.8	107.7	108.5	107.0	106.6	108.3

Certificate of Analysis No. 93770

	Composition	Cyl #RC5193	Cyl #5600011	Cyl #5600902	Cyl #PHS2706	Cyl #5600066	Cyl #5600234
		19.99 % n-Butane	5.02 % n-Butane	1.913 % n-Butane	10.01 % n-Butane	5.006 % n-Butane	1.908 % n-Butan
		3.83 % Propylene	10.02 % Propylene	3.839 % Propylene	10.02 % Propylene	15.01 % Propylene	3.835 % Propyle
		76.18 % Propane	84.96 % Propane	94.248 % Propane	79.97 % Propane	79.984 % Propane	94.257 % Propa
D 2598	Vapor pressure, 100 °F, (calc.)	149 psig	172 psig	174 psig	165 psig	174 psig	174 psig
D 3246	Sulfur	<1 ppm	<1 ppm	<1 ppm	<1 ppm	<1 ppm	<1 ppm
		<0.1 grains/100 ft 3	<0.1 grains/100 ft 3	<0.1 grains/100 ft 3	<0.1 grains/100 ft 3	<0.1 grains/100 ft 3	<0.1 grains/100
UOP 619	Fluoride	0.1 ppm	0.6 ppm	<0.1 ppm	0.9 ppm	0.2 ppm	0.1 ppm
D 1837	Volatile residue,						
	Temperature @ 95 % evaporation	+19.3 °F	-29.0 °F	-38.9 °F	-6.7 °F	-30.0 °F	-38.2 °F
D 2158	Residual matter						
	Residue on evaporation	<0.05 mL	<0.05 mL	<0.05 mL	<0.05 mL	<0.05 mL	<0.05 mL
	Oil stain	Pass (0.3 mL)	Pass (0.3 mL)	Pass (0.3 mL)	Pass (0.3 mL)	Pass (0.3 mL)	Pass (0.3 mL)
D1838	Copper corrosion	1A	1A	1A	1A	1A	1A
D 2713	Moisture	Pass	Pass	Pass	Pass	Pass	Pass
D 2163	Ethane	0.04 vol %	0.05 vol %	0.02 vol %	0.04 vol %	0.05 vol %	0.02 vol %
	Propane	76.12 vol %	85.26 vol %	94.05 vol %	80.02 vol %	80.23 vol %	94.07 vol %
	Propylene	3.71 vol %	9.58 vol %	3.73 vol %	9.79 vol %	14.60 vol %	3.72 vol %
	Isobutane	0.18 vol %	0.24 vol %	0.29 vol %	0.17 vol %	0.15 vol %	0.29 vol %
	n-Butane	19.95 vol %	4.87 vol %	1.91 vol %	9.98 vol %	4.97 vol %	1.90 vol %
D 2623	Motor octane number	94.4	94.6	96.1	94.1	93.7	96.0
D 2623M	Research octane number	106.8	107.7	108.5	107.0	106.6	108.3

PROGRESS REPORT

Date: 5/5/98
Report: #7, Period: 98/04/27 to 98/05/01
ADEPT / Cummins B5.9 LPG **Attn: Mr. Alex Spataru / Ms. Alina Kulikowski-Tan**

To:	Mr. Alex Spataru Ms. Alina Kulikowski-Tan	**Estimated Testing Completion Date:**	To be determined
Client:	ADEPT Group Inc.	**Estimated Project Expenditure to 98/05/03:**	US$39,300
Project:	**ADEPT / Cummins B5.9 LPG**	**Estimated Expenditure for Last Week (Apr.27-May 03):**	US$900
Tel:	(310) 478-8448	**Estimated Cost at Completion:**	To be determined
Fax:	(310) 478-5658	**Initial Payment received:**	US$42,000
ADEPT P.O.:	Date: March 2,1998, Value: US$141,350	**Invoiced to date:** US$19,194.53	
ORTECH Ref:	Project No.: 1-05-01-01-11516 Proposal No.: 97-1-05-01-01-P8138-FI	**Invoice details:** #107761 (Apr.16,1998)	
		Received to date: NO	

Submitted by: Dr. Aurobindo Das
Telephone: (905) 822-4111 (X418)
Fax: (905)823-1446

Activities/Tasks Conducted Period: 98/04/27 to 98/05/03	Activities/Tasks Conducted (cont'd) Period: 98/04/27 to 98/05/03
1. LPG fuel was received on April 30. ADEPT was informed on the fuel receipt and fuel composition analysis results (form AERIFORM). It was noticed that the propane concentration of test fuel #2 was 81.15% versus the ADEPT request 80±1%. 2. During the telephone discussion on April 28, Mr. Spataru suggested to set the ECU voltage at 13.3±0.5 volt for all tests. 3. Test Protocol is attached for your review and comments. Please note that a baseline emission test (3 hot cycles) was suggested midway through the program after test fuel #2. AA#2 is attached (US$1,000).	4. Equipment issues on the GC speciation analyzer were identified. Replacement components were ordered, and expected early next week. Quality control checks, low limit of detection etc., will be repeated. Official emission tests will start on May 19 (Statuary holiday May 18). 5. No facility charges incurred this week.

Activities/Tasks Planed Period: 98/05/04 to 98/05/10	Activities/Tasks Planed (contend) Period: 98/05/04 to 98/05/10
• Repeat quality control setup on GC speciation analyzer: - lower limit of detection - Daily control charts - System linearity	• Run one cold and one hot cycles to collect engine exhaust samples for verifying new system component performance. • Repeat THC speciation peak identification.

PROGRESS REPORT

Date: 5/11/98
Report: #8, Period: 98/05/04 to 98/05/10
ADEPT / Cummins B5.9 LPG

Attn: Mr. Alex Spataru / Ms. Alina Kulikowski-Tan

To:	Mr. Alex Spataru Ms. Alina Kulikowski-Tan
Client:	ADEPT Group Inc.
Project:	**ADEPT / Cummins B5.9 LPG**
Tel:	(310) 478-8448
Fax:	(310) 478-5658
ADEPT P.O.:	Date: March 2,1998, Value: US$141,350
ORTECH Ref:	Project No.: 1-05-01-01-11516 Proposal No.: 97-1-05-01-01-P8138-FI

Estimated Testing Completion Date:		To be determined
Estimated Project Expenditure to 98/05/10:		US$42,500
Estimated Expenditure for Last Week (May 04-May 10):		US$3,200
Estimated Cost at Completion:		To be determined
Initial Payment received:		US$42,000
Invoiced to date:	US$19,194.53	US$18,454.23
Invoice details:	#107761 (Apr.16,1998)	#108228 (May 8, 1998)
Received to date:	NO	NO

Submitted by: Dr. Aurobindo Das
Telephone: (905) 822-4111 (X418)
Fax: (905) 823-1446

Activities/Tasks Conducted Period: 98/05/04 to 98/05/10	Activities/Tasks Conducted (cont'd) Period: 98/05/04 to 98/05/10
1. Equipment issues on the GC speciation analyzer were resolved. Failed components were replaced, and system performance was verified using engine exhaust samples collected from recent transient cycle runs. 2. Both quality control setup and THC speciation peak identification on GC speciation analyzer were commenced (repeat).	4. Official emission tests are still scheduled to start on May 19 (Statutory holiday May 18). 5. No facility charges incurred this week.

Activities/Tasks Planed Period: 98/05/11 to 98/05/17	Activities/Tasks Planed (contend) Period: 98/05/11 to 98/05/17
• Complete quality control setup on GC speciation analyzer: - lower limit of detection - Daily control charts - System linearity	• Complete THC speciation peak identification. • Complete monthly calibration of all emission equipment (EPA emission certification test requirements).

ORTECH

PROGRESS REPORT

Date: 5/20/98
Report: #9, Period: 98/05/11 to 98/05/17
ADEPT / Cummins B5.9 LPG Page 1 **Attn: Mr. Alex Spataru / Ms. Alina Kulikowski-Tan**

To:	Mr. Alex Spataru Ms. Alina Kulikowski-Tan
Client:	ADEPT Group Inc.
Project:	**ADEPT / Cummins B5.9 LPG**
Tel:	(310) 478-8448
Fax:	(310) 478-5658
ADEPT P.O.:	Date: March 2,1998, Value: US$141,350
ORTECH Ref:	Project No.: 1-05-01-01-11516 Proposal No.: 97-1-05-01-01-P8138-FI

Estimated Testing Completion Date:		July 3, 1998
Estimated Date for Issuing Final Report:		July 17, 1998
Estimated Project Expenditure to 98/05/17:		US$45,300
Estimated Expenditure for Last Week (May 11-May 17):		US$2,800
Estimated Cost at Completion:		To be determined
Initial Payment received:		US$42,000
Invoiced to date:	US$19,194.53	US$18,454.23
Invoice details:	#107761 (Apr.16,1998)	#108228 (May 8, 1998)
Received to date:	NO	NO

Submitted by:	Dr. Aurobindo Das
Telephone:	(905) 822-4111 (X418)
Fax:	(905) 823-1446

Activities/Tasks Conducted Period: 98/05/11 to 98/05/17	Activities/Tasks Conducted (cont'd) Period: 98/05/11 to 98/05/17
1. Monthly calibration of all emission equipment (EPA emission certification test requirements) was completed. 2. With fixed ECU supply voltage (13.3 volts) and fixed throttle controller setting, engine gaseous emission repeatability was checked on ORTECH's certification fuel. Results were documented in the following page for your review.	3. Quality control setup on GC speciation analyzer was 90% completed. 4. THC speciation peak identification was continued. 5. Technical Committee approved Amendment Authorization #1 (US$10,000) on May 15, 1998.

Activities/Tasks Planed Period: 98/05/18 to 98/05/24	Activities/Tasks Planed (contend) Period: 98/05/18 to 98/05/24
• Following items will be completed: - Quality control setup on GC speciation analyzer; - THC speciation peak identification.; - Baseline emission tests on certification LPG fuel from AERIFORM.	

Engine Gaseous Emission Repeatability Results:

Date	Test #	Description	Work bhp-hr	Ref. Work bhp-hr	THC g/bhp-hr	CO g/bhp-hr	NOx - corr. g/bhp-hr	CO2 g/bhp-hr
1998/05/07	0507-1	Cold (run 938)	12.02	13.01	1.465	1.520	3.37	704
	0507-2	Hot (run 939)	12.11	13.01	0.677	0.172	2.94	672
	0507-3	Hot (run 940)	12.05	13.01	0.723	0.142	2.77	673
Composite			12.07	13.01	0.809	0.352	2.93	677
1998/05/12	0512-1	Cold (run 941)	11.97	13.01	1.428	1.738	3.62	708
	0512-2	Hot (run 942)	12.03	13.01	0.646	0.295	3.06	675
	0512-3	Hot (run 943)	12.04	13.01	0.694	0.132	2.98	673
	0512-4	Hot (run 944)	12.12	13.01	0.794	0.253	2.96	670
Composite			12.05	13.01	0.814	0.475	3.09	678
1998/05/13	0513-1	Cold (run 945)	12.08	13.01	1.452	1.232	3.43	699
	0513-2	Hot (run 946)	12.09	13.01	0.710	0.326	2.86	671
	0513-3	Hot (run 947)	12.12	13.01	0.634	0.193	2.84	671
Composite			12.10	13.01	0.783	0.398	2.93	675

Notes:
1. ECU supply voltage was fixed at 13.3 volts.
2. Dynamometer and throttle settings were fixed.
3. Fuel used was ORTECH's certification LPG fuel.

PROGRESS REPORT

Date: 27/05/98
Report: #10, Period: 98/05/18 to 98/05/24
ADEPT / Cummins B5.9 LPG **Attn: Mr. Alex Spataru / Ms. Alina Kulikowski-Tan**

To:	Mr. Alex Spataru Ms. Alina Kulikowski-Tan	**Estimated Testing Completion Date:**		July 3, 1998
		Estimated Date for Issuing Final Report:		July 17, 1998
		Estimated Project Expenditure to 98/05/24:		US$59,300
Client:	ADEPT Group Inc.	**Estimated Expenditure for Last Week (May 18-May 24):**		US$14,000
Project:	**ADEPT / Cummins B5.9 LPG**	**Estimated Cost at Completion:**		To be determined
Tel:	(310) 478-8448	**Initial Payment received:**		US$42,000
Fax:	(310) 478-5658	**Invoiced to date:**	US$19,194.53	US$18,454.23
ADEPT P.O.:	Date: March 2,1998, Value: US$141,350	**Invoice details:**	#107761 (Apr.16,1998)	#108228 (May 8, 1998)
ORTECH Ref:	Project No.: 1-05-01-01-11516 Proposal No.: 97-1-05-01-01-P8138-FI	**Received to date:**	NO	NO

Submitted by: Dr. Aurobindo Das
Telephone: (905) 822-4111 (X418)
Fax: (905) 823-1446

Activities/Tasks Conducted Period: 98/05/18 to 98/05/24	Activities/Tasks Conducted (cont'd) Period: 98/05/18 to 98/05/24
1. Following items were completed: - Quality control setup on GC speciation analyzer; - THC speciation peak identification.; - Baseline emission tests on the certification LPG fuel from AERIFORM (results are attached). - Manual torque map on the certification LPG fuel. 2. A manual torque map has been run on the test fuel #1 from AERIFORM. No audible knock has been identified. Proper fuel switching procedure was followed.	3. Based on 3 runs, the baseline emission results on the certification fuel are as follows: NMHC, THC, CO, NOx, PM Xr (g/bhp-hr): 0.902, 0.938, 0.372, 2.822, 0.006 S.D. (g/bhp-hr): 0.126, 0.127, 0.045, 0.086, 0.001 δ (%): 13.95, 13.53, 12.00, 3.05, 8.99 Note: Xr is the average composition emission with the certification fuel; S.D. is the standard deviation; δ is the coefficient of variation.

Activities/Tasks Planed Period: 98/05/25 to 98/05/31	Activities/Tasks Planed (contend) Period: 98/05/25 to 98/05/31
• Following items will be completed: - THC speciation and NMOG analysis on baseline samples; - Emission tests on the test fuel #1; - Manual torque maps on the test fuel #1 and possible on fuel #2.	• Pending for the decision on testing fuel #1. • Pending for the Amendment Authorization #1 (US$10,000) to be signed.

ADEPT LPG FUEL STUDY

EPA HDE TRANSIENT CYCLE EMISSIONS SUMMARY

					MASS EMISSIONS							SPECIATION		NMOG	
DATE	TEST #	BRIEF TEST DESCRIPTION	WORK** hp-hr	BSFC lb/hp-hr	NMHC g/bhp-hr	THC g/bhp-hr	CO g/bhp-hr	NOx g/bhp-hr	Particulate g/bhp-hr	CO2 g/bhp-hr	Carbonyls g/bhp-hr	C2-C4 g/bhp-hr	C5-C12 g/bhp-hr	GC g/bhp-hr	HFID g/bhp-hr
		Baseline, Cert. Fuel*, Set #1													
98-05-20	0520-1	Cold (run 957)	11.84	0.519	1.540	1.594	1.236	3.158	0.007	696					
	0520-2	Hot #1(run 958)	11.86	0.519	0.881	0.913	0.320	2.797	0.007	670					
	0520-3	Hot #2 (run 959)	11.89	0.517	0.651	0.683	0.277	2.666	0.004	663					
	0520-4	Hot #3 (run 960)	11.88	0.518	0.668	0.700	0.247	2.686	0.007	663					
		Weighted Average	**11.87**	**0.518**	**0.849**	**0.884**	**0.418**	**2.779**	**0.006**	**670**					
		Baseline, Cert. Fuel*, Set #2													
98-05-21	0521-1	Cold (run 961)	11.83	0.533	1.549	1.592	0.612	3.018	0.011	703					
	0521-2	Hot #1 (run 962)	11.89	0.509	0.641	0.679	0.278	2.739	0.007	674					
	0521-3	Hot #2 (run 963)	11.89	0.521	0.761	0.793	0.288	2.777	0.004	677					
	0521-4	Hot #3 (run 964)	11.93	0.528	0.663	0.695	0.278	2.653	0.006	676					
		Weighted Average	**11.89**	**0.521**	**0.811**	**0.847**	**0.329**	**2.765**	**0.006**	**680**					
		Baseline, Cert. Fuel*, Set #3													
98-05-22	0522-1	Cold (run 966)	11.86	0.528	1.632	1.676	0.604	3.322	0.011	699					
	0522-2	Hot #1(run 967)	11.88	0.522	0.948	0.981	0.414	2.839	0.007	673					
	0522-3	Hot #2 (run 968)	11.92	0.516	0.918	0.956	0.299	2.829	0.006	669					
	0522-4	Hot #3 (run 969)	11.93	0.520	0.977	1.014	0.278	2.894	0.007	670					
		Weighted Average	**11.90**	**0.521**	**1.045**	**1.083**	**0.369**	**2.921**	**0.007**	**675**					
		Standard Deviation	0.016	0.002	0.126	0.127	0.045	0.086	0.001	5.01					
		Mean of Weighted Averages	11.89	0.520	0.902	0.938	0.372	2.822	0.007	675					
		Coefficient of Variation	0.14%	0.32%	13.95%	13.53%	12.00%	3.05%	8.99%	0.74%					

Note: *Table of Fuel Compositions

	Propane	Propylene	N-Butane
Certification Fuel (cyl. # NA18973)	94.42%	3.68%	1.90%
Test Fuel #1 (cyl. # 73977)	85.28%	9.86%	4.86%
Test Fuel #2 (cyl. # 8490J)	81.15%	14.15%	4.70%
Test Fuel #3 (cyl. # 73991)	80.07%	9.97%	9.96%
Test Fuel #4 (cyl. # 8493J)	76.34%	3.78%	19.88%

** Reference Work = 12.74 hp-hr

ORTECH

PROGRESS REPORT

Date: 01/06/98
Report: #11, Period: 98/05/25 to 98/05/31
ADEPT / Cummins B5.9 LPG Page 1 **Attn: Mr. Alex Spataru / Ms. Alina Kulikowski-Tan**

To:	Mr. Alex Spataru Ms. Alina Kulikowski-Tan	**Estimated Testing Completion Date:**		July 3, 1998
		Estimated Date for Issuing Final Report:		July 17, 1998
		Estimated Project Expenditure to 98/05/31:		US$73,300
Client:	ADEPT Group Inc.	**Estimated Expenditure for Last Week (May 25-May 31):**		US$14,000
Project:	**ADEPT / Cummins B5.9 LPG**	**Estimated Cost at Completion:**		To be determined
Tel:	(310) 478-8448	**Initial Payment received:**		US$42,000
Fax:	(310) 478-5658	**Invoiced to date:**	US$19,194.53	US$18,454.23
ADEPT P.O.:	Date: March 2,1998, Value: US$141,350	**Invoice details:**	#107761 (Apr.16,1998)	#108228 (May 8, 1998)
ORTECH Ref:	Project No.: 1-05-01-01-11516 Proposal No.: 97-1-05-01-01-P8138-FI	**Received to date:**	NO	NO

Submitted by: Dr. Aurobindo Das
Telephone: (905) 822-4111 (X418)
Fax: (905) 823-1446

Activities/Tasks Conducted
Period: 98/05/25 to 98/05/31

1. Emission tests on the test fuel #1* were completed. The results are summarized as follows:

	NMHC	THC	CO	NOx	PM
1st set (98/05/28)	0.694	0.726	0.409	3.067	0.009
2nd set (98/05/29)	0.730	0.762	0.451	3.157	0.007
Mean	**0.712**	**0.744**	**0.430**	**3.112**	**0.008**

Activities/Tasks Conducted (cont'd)
Period: 98/05/25 to 98/05/31

*Note: Composition of fuel #1 is:
Propane: 85.28%
Propylene: 9.86%
N-butane: 4.86%

2. ORTECH received AA#1 on June 1, 1998.

Activities/Tasks Planed
Period: 98/06/01 to 98/07/07

- Following items will be completed:
  - THC speciation and NMOG analysis on baseline samples;
  - Emission tests on the test fuel #2;
  - Manual torque maps on the test fuel #2.

Activities/Tasks Planed (contend)
Period: 98/06/01 to 98/07/07

- Pending for the decision on testing fuel #2.

ADEPT LPG FUEL STUDY

EPA HDE TRANSIENT CYCLE EMISSIONS SUMMARY

					MASS EMISSIONS							SPECIATION		NMOG	
DATE	TEST #	BRIEF TEST DESCRIPTION	WORK** hp-hr	BSFC lb/hp-hr	NMHC g/bhp-hr	THC g/bhp-hr	CO g/bhp-hr	NOx g/bhp-hr	Particulate g/bhp-hr	CO2 g/bhp-hr	Carbonyls g/bhp-hr	C2-C4 g/bhp-hr	C5-C12 g/bhp-hr	GC g/bhp-hr	HFID g/bhp-hr
		Baseline, Cert. Fuel*, Set #1													
98-05-20	0520-1	Cold (run 957)	11.84	0.519	1.540	1.594	1.236	3.158	0.007	696					
	0520-2	Hot #1(run 958)	11.86	0.519	0.881	0.913	0.320	2.797	0.006	670					
	0520-3	Hot #2 (run 959)	11.89	0.517	0.651	0.683	0.277	2.666	0.004	663					
	0520-4	Hot #3 (run 960)	11.88	0.518	0.668	0.700	0.247	2.686	0.007	663					
		Weighted Average	**11.87**	**0.518**	**0.849**	**0.884**	**0.418**	**2.779**	**0.006**	**670**					
		Baseline, Cert. Fuel*, Set #2													
98-05-21	0521-1	Cold (run 961)	11.83	0.533	1.549	1.592	0.612	3.018	0.011	703					
	0521-2	Hot #1 (run 962)	11.89	0.509	0.641	0.679	0.278	2.739	0.007	674					
	0521-3	Hot #2 (run 963)	11.89	0.521	0.761	0.793	0.288	2.777	0.004	677					
	0521-4	Hot #3 (run 964)	11.93	0.528	0.663	0.695	0.278	2.653	0.006	676					
		Weighted Average	**11.89**	**0.521**	**0.811**	**0.847**	**0.329**	**2.765**	**0.006**	**680**					
		Baseline, Cert. Fuel*, Set #3													
98-05-22	0522-1	Cold (run 966)	11.86	0.528	1.632	1.676	0.604	3.322	0.011	699					
	0522-2	Hot #1(run 967)	11.88	0.522	0.948	0.981	0.414	2.839	0.006	673					
	0522-3	Hot #2 (run 968)	11.92	0.516	0.918	0.956	0.299	2.829	0.006	669					
	0522-4	Hot #3 (run 969)	11.93	0.520	0.977	1.014	0.278	2.894	0.007	670					
		Weighted Average	**11.90**	**0.521**	**1.045**	**1.083**	**0.369**	**2.921**	**0.007**	**675**					
		Test Fuel #1*, Set #1													
98-05-28	0528-1	Cold (run 976)	12.04	0.503	1.399	1.442	0.931	3.479	0.011	690					
	0528-2	Hot #1 (run 977)	12.06	0.498	0.647	0.679	0.366	3.072	0.011	664					
	0528-4	Hot #3 (run 979)	12.11	0.500	0.535	0.561	0.314	2.964	0.008	660					
	0528-5	Hot #4 (run 980)	12.08	0.501	0.547	0.579	0.285	2.960	0.008	661					
		Weighted Average	**12.08**	**0.500**	**0.694**	**0.726**	**0.409**	**3.067**	**0.009**	**666**					
		Test Fuel #1*, Set #2													
98-05-29	0529-1	Cold (run 981)	12.01	0.512	1.403	1.446	0.919	3.593	0.009	692					
		Hot #1 (run 982)	12.07	0.497	0.744	0.776	0.414	3.238	0.006	661					
		Hot #2(run 983)	12.12	0.495	0.505	0.531	0.413	3.011	0.007	655					
		Hot #3(run 984)	12.08	0.509	0.606	0.638	0.293	3.003	0.008	656					
		Weighted Average	**12.08**	**0.502**	**0.730**	**0.762**	**0.451**	**3.157**	**0.007**	**662**					

Note: *Table of Fuel Compositions

** Reference Work = 12.74 hp-hr

	Propane	Propylene	N-Butane
Certification Fuel (cyl. # NA18973)	94.42%	3.68%	1.90%
Test Fuel #1 (cyl. # 73977)	85.28%	9.86%	4.86%
Test Fuel #2 (cyl. # 8490J)	81.15%	14.15%	4.70%
Test Fuel #3 (cyl. # 73991)	80.07%	9.97%	9.96%
Test Fuel #4 (cyl. # 8493J)	76.34%	3.78%	19.88%

Figur 1a: Measure CO Emission For Test 0520-1 (Cold Cycle)

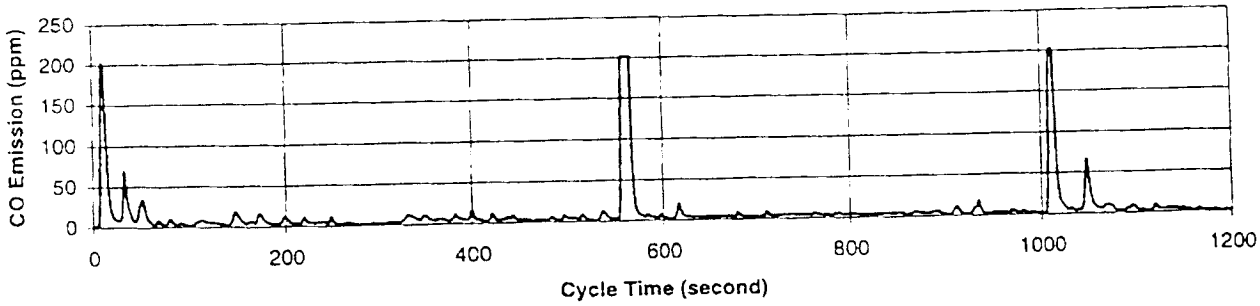

Figure 1b: Actual Speed for Test 0520-1 (Cold Cylce)

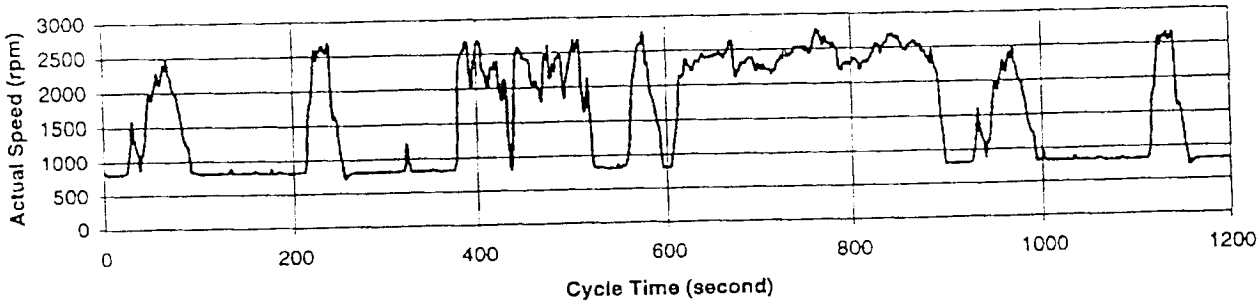

Figure 1c: Actual Torque for Test 0520-1 (Cold Cylce)

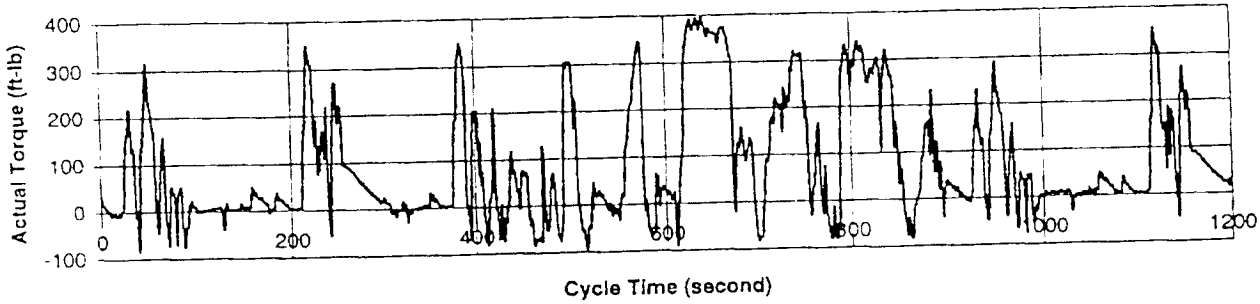

Figure 1d: Actual Lambda for Test 0520-1 (Cold Cylce)

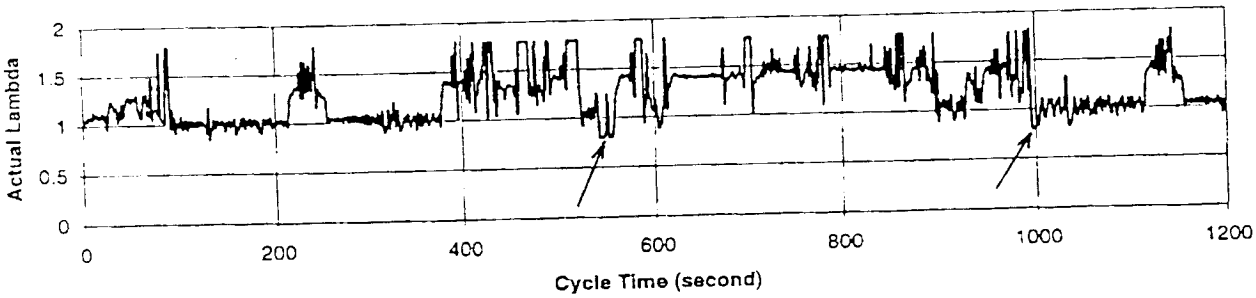

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Figure 3a: Measured CO Emission for Test 0522-1 (Cold Cycle)

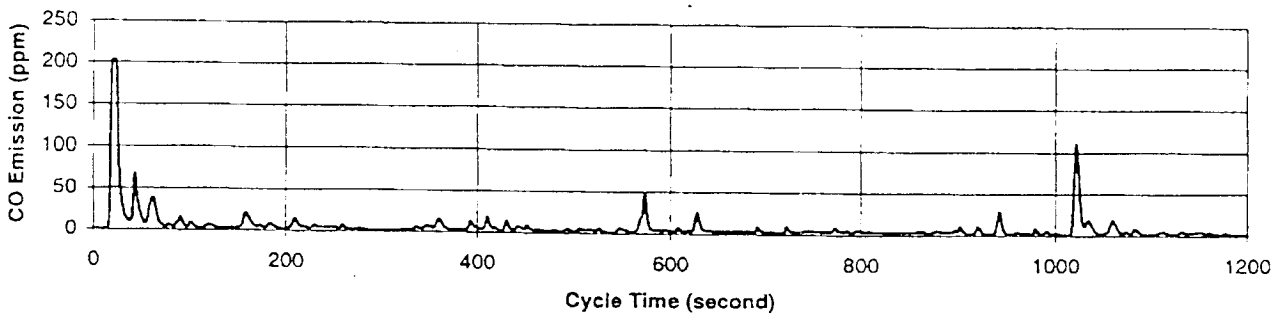


Figure 3b: Actual Speed for Test 0522-1 (Cold Cycle)

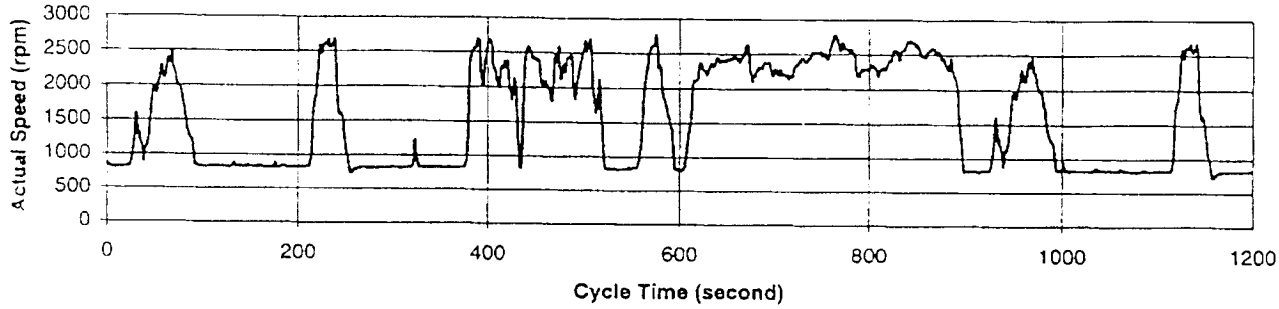


Figure 3c: Actual Torque for Test 0522-1 (Cold Cycle)

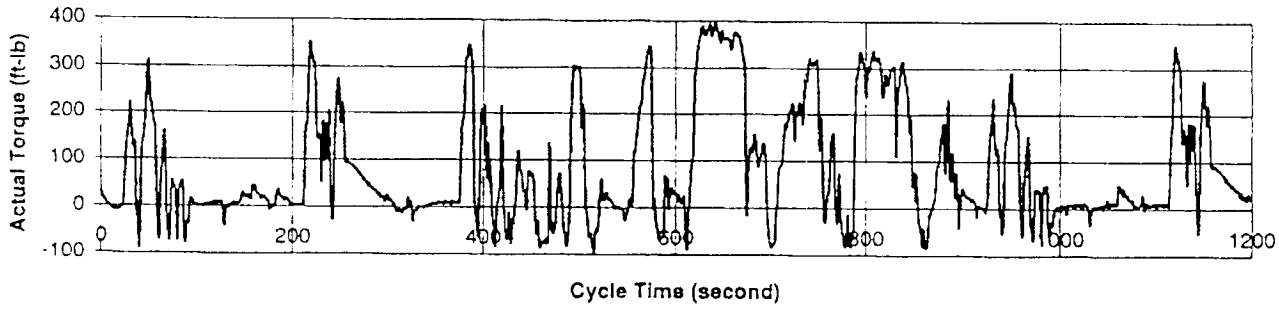
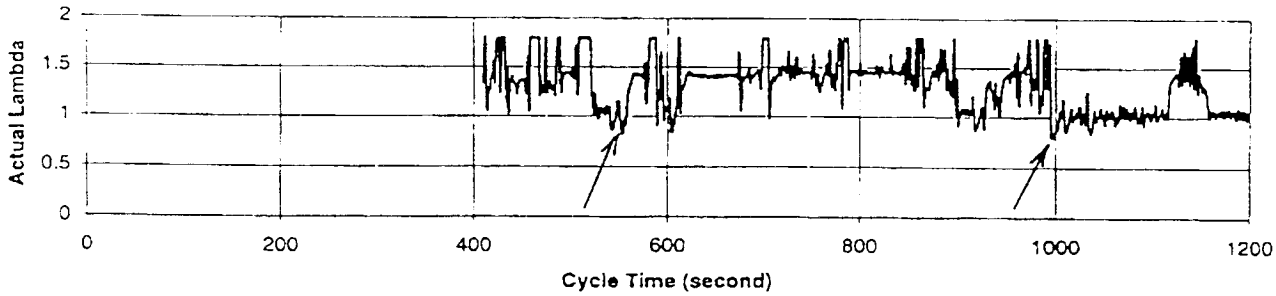


Figure 3d: Actual Lambda for Test 0522-1 (Cold Cycle)



Test Protocol

1. General

- Speed, torque, and gaseous analyzers will be calibrated following Code of Federal Regulations, Title 40, Part 86, Subpart N
- All other sensors will be calibrated following ORTECH Standard Operation Procedures (ISO 9002).
- The transient test procedures will be EPA certification procedures for Heavy-Duty Engines documented in Code of Federal Regulations (Title 40, Part 86, Subpart N).
- THC speciation and Carbonyls related test procedures will follow the appropriate methods in the California Non-Methane Organic Gas Test Procedures (Published by California Environmental Protection Agency, Air Resources Board).

2. Test Order, LPG Fuel Blends and Analyses

Test order	Fuel	Propane	Propylene	N-butane
1	Cert. fuel	94.42%	3.68%	1.90%
2	Test fuel #1	85.28%	9.86%	4.86%
3	Test fuel #2	81.15%	14.15%	4.70%
4	Cert. fuel	94.42%	3.68%	1.90%
5	Test fuel #3	80.07%	9.97%	9.96%
6	Test fuel #4	76.34%	3.78%	19.88%
7	Cert. fuel	94.42%	3.68%	1.90%

3. Engine Parameter Setup

Run engine at rated condition (2600 rpm, WOT), stabilize oil and coolant temperatures, and set the following parameters:

- Intake restriction: 4.4 kPa (17.5 "H_2O)
- Exhaust back pressure: 13.5 kPa (4 "Hg)
- Charge air temperature in intake manifold: 52 °C (125 °F)
- Air pressure drop from compressor outlet to mixer inlet: 13.5 kPa (4 "Hg)
- ECU supply voltage: 13.3 volt

4. Transient Emissions Tests on Five LPG Fuel Blends

4.1 Prior to official emission tests, complete following items:

- Tune the dynamometer and the throttle to pass transient cycle validation criteria using certification fuel. The settings will be used in all subsequent tests.
- Condition the emission tunnel for PM and THC
- Identify analyzer ranges for gaseous emissions
- Quality control setup and preliminary sample range setup on GC speciation analyzer.

Commence Official Emission Tests

4.2 Run engine on the certification fuel, and confirm the engine parameter setup at rated condition (refer to Item 3).

4.3 Conduct an auto torque map to generate a baseline transient test cycle to be used for all subsequent tests.

- Mapping speed: 800 rpm ~ 2870 rpm @8 rpm/sec. increment
- Curb idle transmission torque: 10 ft-lb @ 800 rpm

Emission Tests on Certification Fuel (i.e. Baseline)

4.4 Day 1: Run 1 cold start transient cycle and 2 hot start transient cycles, measure and calculate the following emissions:

- Total Hydrocarbon (THC)
- Methane (CH_4)
- Non-Methane Hydrocarbons (NMHC)
- Carbon Monoxide (CO)
- Oxides of Nitrogen (NOx)
- Carbon Dioxide (CO_2)
- Particulate Matter (PM), post analyzed
- THC speciation and Carbonyls, 1 cold and 1 hot samples, post analyzed for

4.5 Day 2: Repeat preceding tests without THC speciation and Carbonyls measurement. Perform a manual torque map after the emission tests.

Emission Tests on LPG Fuel Blends

4.6 Change fuels as described in Item 5 below.

4.7 Repeat Item 4.2, 4.4 and 4.5 using the test fuels in the order listed in Item 2.

4.8 Note: After testing fuel #2, change to certification fuel (Item 5), and run 3 hot start transient cycles with only gaseous and PM measurements.

5. LPG Fuel Switching

5.1 Close the valve on the fuel cylinder, and run engine to deplete all fuel in the fuel line.

5.2 Change the fuel cylinder, and replace the liquid / vapour fuel filters. Run engine on the new test fuel for 15 min. to flush the fueling system.

5.3 Perform a manual torque map and listen for engine knock. Stop test if knocking is observed!

5.4 Run two transient cycles to identify analyzer ranges for gaseous emissions, to condition the emission tunnel, and to check cycle validation (i.e. regression) criteria. Continue Item 4.7.

Y. Tao

5/5/98