Effect of Gasoline Properties on Exhaust Emissions from Tier 2 Light-Duty Vehicles—Final Report: Phases 4, 5, & 6

July 28, 2008 – July 27, 2013

K. Whitney and B. Shoffner
Southwest Research Institute
San Antonio, Texas

NREL Technical Monitor: Matthew Thornton

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Subcontract Report
NREL/SR-5400-61099
June 2014

Contract No. DE-AC36-08GO28308

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15013 Denver West Parkway
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FOREWORD

This report covers work the Southwest Research Institute (SwRI®) Office of Automotive Engineering has conducted for the National Renewable Energy Laboratory (NREL) in support of the Energy Policy Act of 2005 (EPAct). Section 1506 of EPAct requires EPA to produce an updated fuel effects model representing the 2007 light-duty gasoline fleet, including determination of the emissions impacts of increased renewable fuel use.

This report covers the room-temperature, 95°F, and 20°F exhaust emissions testing of three ethanol fuel blends using six Tier 2 vehicles (Phase 4); room-temperature, 95°F, and 20°F exhaust emissions testing of three ethanol fuel blends using three high-emitting vehicles (Phase 5); and the determination of oil consumption for a subset of the tested vehicles (Phase 6). This work was conducted as part of the EPAct Gasoline Light-Duty Exhaust Fuel Effects Test Program, which is also referred to as the EPAct/V2/E-89 Program.

This effort was authorized by NREL Subcontract Nos. ACI-8-88613-01, AFT-9-99319-01 and AFT-9-99155-01. The project was based on SwRI Proposal Nos. 03-55287 versions A through E. The overall program was identified within SwRI under Project Nos. 03.14175.03, 03.14936.03, 03.14993, and 03.15777.01.

The NREL project technical monitors were Dr. Douglas Lawson until his retirement, and then Mr. Matthew Thornton. The SwRI Program Manager was Kevin Whitney. Eugene Jimenez oversaw day-to-day emissions operations and Brent Shoffner coordinated oil consumption determinations. Testing occurred between May 2010 and July 2013.

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- The Department of Energy Office of Biomass Programs and Office of Vehicle Technologies for their financial support provided through the National Renewable Energy Laboratory
- The Coordinating Research Council for technical support and for providing the test vehicles following the expiration of their leases
- The Lubrizol Corporation for supplying all crankcase lubricants used in this program

ACRONYMS AND ABBREVIATIONS

°F....................degrees Fahrenheit
IBP ....initial boiling point
API.................American Petroleum Institute
ASTM ....American Society for Testing and Materials
Btu..................British thermal unit
CARB............California Air Resources Board
CH_4................methane
CO..................carbon monoxide
CO_2................carbon dioxide
CRC ....Coordinating Research Council
DTC ....diagnostic trouble code
DVPE.............dry vapor pressure equivalent
EPA................U.S. Environmental Protection Agency
EPAct.............2005 Energy Policy Act
E0...................gasoline with no ethanol
E10................gasoline nominally containing 10 percent volume of ethanol
E15................gasoline nominally containing 15 percent volume of ethanol
E20................gasoline nominally containing 20 percent volume of ethanol
E85…………gasoline nominally containing 85 percent volume of ethanol
FBP ....final boiling point
FTP................Federal Test Procedure
g ....gram
H_2O ....water
HP ....horsepower
HPLC ....high performance liquid chromatography
IBP ....initial boiling point
kg ....kilogram
kPa ....kilopascal
lb ....pound mass
LOD ....limit of detection
LOQ ....limit of quantification
LTFT..............long-term fuel trim
mg ....milligram
MIL................malfunction indicator light

ACRONYMS AND ABBREVIATIONS (CONT'D)

MJ ....megajoule
ml ....milliliter
MON ....motor octane number
mph ....miles per hour
NH_3 ....ammonia
NMHC ....non-methane hydrocarbons
NMOG ....non-methane organic gases
NO..................nitric oxide
NO_2 ....nitrogen dioxide
NO_X................oxides of nitrogen
NREL.............National Renewable Energy Laboratory
O_2 ....oxygen
OBD ....on-board diagnostics
PM..................particulate matter
ppm ....parts per million
psi...................pounds per square inch
RON ....research octane number
RPM ....revolutions per minute
RUL ....regular unleaded
RVP................Reid vapor pressure
STFT ....short-term fuel trim
SwRI ....Southwest Research Institute
THC ....total hydrocarbons
VOC………...volatile organic compounds
vol... ....volume
WA.................work assignment
WAM ....work assignment manager

1.0 INTRODUCTION

Since September 2007, Southwest Research Institute (SwRI) has been conducting work on a series of tasks and assignments, the results of which are now collectively known as the EPAct/V2/E-89 emissions test program. The work began under the direction of the U.S. Environmental Protection Agency (EPA) to fulfill requirements for emissions modeling outlined in the Energy Policy Act of 2005 (EPAct). Section 1506 of the EPAct requires the production of an updated fuel effects model representing the 2007 light-duty gasoline fleet, including assessment of the emissions impacts of increased renewable fuel use. By January 2009, SwRI had completed Phases 1 and 2 of the EPAct/V2/E-89 program. These phases, described in a separate report, involved testing of 19 light duty cars and trucks (subsequently referred to as the "EPAct fleet") on three fuels, at two temperatures.

In March 2009, SwRI began work on Phase 3, which was jointly supported by EPA, the U.S. Department of Energy through the National Renewable Energy Laboratory (NREL), and the Coordinating Research Council (CRC). Phase 3 involved the testing of fifteen vehicles from the EPAct fleet using twenty-seven test fuels with ethanol content ranging from 0 to 20 percent by volume, and testing of four flexible-fuel vehicles (FFVs) from the EPAct fleet on an E85 fuel. Phase 3 testing was completed in June 2010 and was described in a separate report.

This report covers work conducted for NREL as Phases 4, 5, and 6, which includes room-temperature, 95°F, and 20°F exhaust emissions testing of three fuels using six Tier 2 vehicles; room-temperature, 95°F, and 20°F exhaust emissions testing of three fuels using three high-emitting vehicles; and the determination of oil consumption for a subset of the tested vehicles.

2.0 TECHNICAL APPROACH FOR PHASES 4 & 5

2.1 Test Fuels

Twenty-eight test fuels were evaluated in Phase 3 of the EPAct/V2/E-89 Program. Fuel procurement is detailed in SwRI Final Report 03.14295/03-51563E "*V2/EPAct/E-89 Fuel Blending,*" which has been submitted separately. The properties of test fuel as determined from the EPAct/V2/E-89 Fuels Round Robin are listed in Table 1.

Twenty-seven of the twenty-eight test fuels were procured by SwRI from Haltermann Products. EPA established a fuel development protocol for this program. Using this protocol, all test fuels were formulated by Rafal Sobotowski of the EPA in conjunction with Haltermann, who provided EPA with data for all their blendstock components. The procurement of Fuels 1 through 16, Fuel 30, and Fuel 31 was funded by EPA Contract No. EP-C-07-028, while NREL Subcontract No. ACI-8-88612-01 funded the procurement of Fuels 20 through 28. The E85 Fuel 29 was provided to the program by the CRC.

Phases 4 and 5 utilized Fuels 6, 7, and 20 for testing at room temperature and at 95°F. Fuels 4, 8, and 24 were boosted with butane to a nominal RVP of 13.4 psi for testing at 20°F.

2.2 Test Vehicles

A total of nine vehicles were utilized during Phases 4 and 5 of the test program. The normal-emitting vehicles were leased by SwRI for two years at the initiation of Phase 1 of the V2/EPAct/E-89 program. Due to changes and additions to the overall program, the term of the two-year leases expired prior to the completion of all Phase 3 testing. The Coordinating Research Council then purchased the test vehicles and made them available to the test program for the remainder of its duration. The three high-emitting vehicles were procured by SwRI for use during Phase 5.

2.3 Test Procedure

All vehicle/fuel combinations were tested using the California Unified Cycle, also known as the LA92. For this program, the LA92 was conducted as a three-phase, cold-start test in a manner similar to the FTP, and FTP weighting factors were used to calculate composite emission rates.

All vehicle soaks and tests were conducted at the nominal test temperature of either 20°F, 72°F, or 95°F. The representative bulk oil temperature of a vehicle's sump was stabilized to ± 3°F of the test temperature prior to conducting any emission test.

TABLE 1. TEST FUEL PROPERTIES DETERMINED FROM THE EPACT/V2/E-89 FUELS ROUND ROBIN

PROPERTY	UNIT	TEST METHOD	FUEL								
			1	2	3	4	5	6	7	8	9
Density, 60°F	g/cm^3	D4052	0.7211	0.7220	0.7350	0.7346	0.7573	0.7342	0.7208	0.7191	0.7454
API Gravity, 60°F	°API	D4052	64.6	64.3	60.8	60.9	55.2	61.1	64.6	65.1	58.2
Ethanol	**vol. %**	**D5599**	**10.03**	**<0.10**	**10.36**	**9.94**	**<0.10**	**10.56**	**<0.10**	**<0.10**	**<0.10**
Total Content of Oxygenates Other Than Ethanol	vol. %	D5599	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Distillation IBP	°F	D86 (**OptiDist** or equivalent for E10, E15 and E20 fuels)	92.9	83.5	106.4	89.9	94.1	106.7	100.1	83.7	85.3
5% evap	°F		112.5	105.4	136.0	115.9	128.6	130.4	127.6	108.1	105.1
10% evap	°F		117.3	121.7	141.7	126.3	145.4	135.9	137.0	123.4	115.1
20% evap	°F		123.9	154.4	148.9	140.9	172.6	142.6	149.0	151.6	130.3
30% evap	°F		131.2	190.6	155.0	151.7	199.4	148.3	161.7	185.1	147.2
40% evap	°F		139.9	218.5	175.1	161.2	222.1	153.4	176.6	204.4	167.7
50% evap	°F		**148.9**	**236.7**	**217.5**	**221.9**	**237.0**	**188.5**	**193.1**	**221.1**	**192.8**
60% evap	°F		172.3	252.7	230.2	245.9	247.2	228.2	210.2	233.5	224.7
70% evap	°F		224.1	271.7	243.6	270.0	258.5	267.7	228.6	246.4	260.3
80% evap	°F		254.6	305.9	257.1	303.5	273.1	310.1	251.5	264.0	292.2
90% evap	°F		**300.2**	**340.1**	**295.9**	**337.5**	**300.0**	**340.4**	**298.4**	**303.1**	**341.8**
95% evap	°F		334.5	353.0	334.4	352.0	323.5	352.7	329.3	330.5	363.5
FBP	°F		368.0	375.3	368.9	369.8	357.8	369.2	361.8	360.9	384.7
DVPE (EPA equation)	**psi**	**D5191**	**10.07**	**10.20**	**6.93**	**10.01**	**6.95**	**7.24**	**7.15**	**10.20**	**10.30**
Aromatics	**vol. %**	**D1319**	**15.4**	**14.1**	**15.0**	**15.5**	**34.7**	**15.0**	**17.0**	**15.7**	**35.8**
Olefins	vol. %	D1319	7.6	6.8	7.6	6.8	6.9	8.8	7.5	6.4	6.2
Saturates	vol. %	calculated[a]	67.0	79.1	67.0	67.8	58.4	65.6	75.5	78.0	58.0
Benzene	vol. %	D3606	0.62	0.51	0.61	0.54	0.51	0.68	0.55	0.50	0.54
Sulfur	mg/kg	D5453	30	23	22	21	24	23	23	23	23
RON	-	D2699	94.8	96.0	98.0	97.1	96.7	96.3	91.2	95.5	94.5
MON	-	D2700	86.3	88.6	87.6	87.6	86.3	86.6	84.2	87.8	84.8
(RON+MON)/2	-	calculated	90.6	92.3	92.8	92.4	91.5	91.5	87.7	91.7	89.7
C	mass %	D5291 mod.	81.70	85.12	81.61	82.21	86.58	81.52	85.16	85.12	87.03
H	mass %	D5291 mod.	14.02	14.43	14.17	14.12	12.92	14.21	14.25	14.32	12.82
O	mass %	D5599	3.9	<0.1	3.9	3.7	<0.1	4.0	<0.1	<0.1	<0.1
Net Heat of Combustion	MJ/kg	D4809	41.950	43.960	41.536	41.952	42.948	41.785	43.735	44.037	43.209
Water	mass %	E-1064	0.071	0.010	0.059	0.077	0.014	0.073	0.019	0.020	0.009
Lead	g/l	D3237	-	<0.001	-	-	<0.003	-	<0.001	0.001	<0.001
Copper Strip Corrosion	-	D130	1A	1A	1A	1A	1A	1A	1A	1A	1A
Solvent Washed Gum Content	mg/100ml	D381	<0.5	<0.5	<0.5	1.5	<0.5	<0.5	<0.5	<0.5	<0.5
Oxidation Stability	min.	D525	>240	>240	>240	>240	>240	>240	>240	>240	>240

[a] Saturates = 100 - D1319 Aromatics - D1319 Olefins - D5599 Ethanol

NOTE: Properties in bold were varied within the fuel matrix.

TABLE 1 (CONT'D). TEST FUEL PROPERTIES DETERMINED FROM THE EPACT/V2/E-89 FUELS ROUND ROBIN

PROPERTY	UNIT	TEST METHOD	FUEL								
			10	11	12	13	14	15	16	20	21
Density, 60°F	g/cm^3	D4052	0.7644	0.7596	0.7517	0.7540	0.7223	0.7428	0.7636	0.7425	0.7754
API Gravity, 60°F	°API	D4052	53.4	54.6	56.5	56.0	64.2	58.8	53.6	58.9	50.8
Ethanol	**vol. %**	**D5599**	**9.82**	**10.30**	**9.83**	**<0.10**	**<0.10**	**<0.10**	**10.76**	**20.31**	**20.14**
Total Content of Oxygenates Other Than Ethanol	vol. %	D5599	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Distillation IBP	°F		104.7	92.0	91.3	96.6	100.4	84.7	104.5	107.9	106.3
5% evap	°F		130.0	115.4	110.7	127.0	126.5	105.5	133.0	137.3	134.7
10% evap	°F		136.3	124.4	116.9	139.8	135.5	115.6	139.2	142.6	141.3
20% evap	°F		144.3	137.6	125.0	158.7	147.3	130.5	147.8	149.7	150.3
30% evap	°F		151.0	148.1	133.8	178.2	160.0	146.6	155.1	155.3	157.1
40% evap	°F	D86 (**OptiDist** or equivalent for E10, E15 and E20 fuels)	161.6	156.5	142.8	199.9	175.1	166.3	172.1	159.6	162.6
50% evap	°F		**217.1**	**189.3**	**152.2**	**222.5**	**192.8**	**189.7**	**218.8**	**162.7**	**167.6**
60% evap	°F		261.5	231.1	198.5	245.2	212.0	216.2	237.5	179.9	217.3
70% evap	°F		290.4	251.4	275.1	269.8	237.3	243.0	251.9	234.8	255.2
80% evap	°F		317.5	270.0	307.9	303.5	280.1	265.9	268.6	253.1	275.3
90% evap	°F		**340.2**	**298.6**	**339.8**	**337.9**	**338.5**	**299.4**	**300.6**	**298.7**	**305.0**
95% evap	°F		354.3	325.0	357.7	354.4	354.5	329.3	330.8	336.6	331.3
FBP	°F		372.4	360.8	375.9	377.5	377.5	363.7	365.6	371.9	360.5
DVPE (EPA equation)	**psi**	**D5191**	**7.11**	**9.93**	**10.13**	**6.92**	**7.14**	**10.23**	**7.12**	**6.70**	**7.06**
Aromatics	**vol. %**	**D1319**	**34.0**	**35.0**	**34.8**	**34.1**	**16.9**	**35.3**	**35.6**	**15.2**	**35.5**
Olefins	vol. %	D1319	6.1	6.9	6.9	6.3	8.5	7.2	6.8	7.4	7.1
Saturates	vol. %	calculated[a]	50.1	47.8	48.5	59.6	74.6	57.4	46.9	57.1	37.3
Benzene	vol. %	D3606	0.52	0.54	0.57	0.51	0.52	0.54	0.62	0.61	0.61
Sulfur	mg/kg	D5453	25	24	19	23	24	24	23	22	22
RON	-	D2699	98.5	97.8	100.4	95.8	91.5	95.0	101.0	101.9	101.4
MON	-	D2700	87.2	85.6	88.0	85.8	84.6	84.9	88.3	89.3	87.5
(RON+MON)/2	-	calculated	92.9	91.7	94.2	90.8	88.1	90.0	94.7	95.6	94.5
C	mass %	D5291 mod.	83.47	83.68	83.32	86.76	85.28	86.88	83.40	78.06	79.90
H	mass %	D5291 mod.	12.83	12.61	12.68	13.15	14.29	12.79	12.66	14.01	12.43
O	mass %	D5599	3.6	3.7	3.6	<0.1	<0.1	<0.1	3.9	7.6	7.1
Net Heat of Combustion	MJ/kg	D4809	41.210	41.175	41.373	43.171	43.519	43.108	41.013	40.057	39.285
Water	mass %	E-1064	0.067	0.066	0.066	0.014	0.015	0.012	0.066	0.138	0.128
Lead	g/l	D3237	<0.003	-	<0.003	<0.001	<0.001	<0.001	-	<0.003	0.009
Copper Strip Corrosion	-	D130	1A	1A	1A	1A	1A	1A	1A	1A	1A
Solvent Washed Gum Content	mg/100ml	D381	<0.5	0.5	<0.5	1.5	<0.5	0.5	1	<0.5	0.5
Oxidation Stability	min.	D525	>240	>240	>240	>240	>240	>240	>240	>240	>240

[a] Saturates = 100 - D1319 Aromatics - D1319 Olefins - D5599 Ethanol

NOTE: Properties in bold were varied within the fuel matrix.

TABLE 1 (CONT'D). TEST FUEL PROPERTIES DETERMINED FROM THE EPACT/V2/E-89 FUELS ROUND ROBIN

PROPERTY	UNIT	TEST METHOD	FUEL								
			22	23	24	25	26	27	28	30	31
Density, 60°F	g/cm^3	D4052	0.7371	0.7476	0.7422	0.7702	0.7593	0.7434	0.7699	0.7508	0.7742
API Gravity, 60°F	°API	D4052	60.3	57.6	58.9	52.0	54.6	58.6	52.1	56.8	51.1
Ethanol	**vol. %**	**D5599**	**20.51**	**20.32**	**20.51**	**20.03**	**15.24**	**14.91**	**14.98**	**9.81**	**20.11**
Total Content of Oxygenates Other Than Ethanol	vol. %	D5599	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Distillation IBP	°F	D86 (**OptiDist** or equivalent for E10, E15 and E20 fuels)	89.8	109.0	89.7	89.0	88.7	104.8	103.9	90.9	105.8
5% evap	°F		118.8	133.3	115.9	113.7	109.6	135.3	136.3	110.3	132.5
10% evap	°F		129.6	138.9	126.9	125.5	117.1	142.3	144.2	116.7	139.1
20% evap	°F		144.3	146.2	142.8	142.1	127.8	152.0	154.0	125.4	147.7
30% evap	°F		153.7	152.3	153.2	153.3	138.6	158.0	160.2	133.9	155.1
40% evap	°F		159.5	157.8	160.4	160.9	149.8	163.8	165.8	143.1	161.3
50% evap	°F		**163.2**	**162.5**	**165.1**	**166.9**	**160.3**	**221.5**	**216.6**	**152.9**	**167.3**
60% evap	°F		167.2	171.6	172.9	191.3	174.7	265.1	240.2	197.2	214.0
70% evap	°F		233.9	270.9	266.1	281.6	277.0	274.9	251.6	267.3	271.6
80% evap	°F		253.6	311.4	305.5	310.3	306.5	311.3	268.4	294.6	297.0
90% evap	°F		**297.3**	**338.2**	**338.1**	**337.9**	**338.7**	**340.3**	**298.8**	**323.8**	**325.2**
95% evap	°F		334.5	350.0	350.3	352.7	356.7	351.9	327.3	341.8	342.1
FBP	°F		369.9	364.6	368.2	371.8	377.3	372.2	363.2	366.1	365.6
DVPE (EPA equation)	**psi**	**D5191**	**10.21**	**6.84**	**10.12**	**10.16**	**10.21**	**6.97**	**6.87**	**10.23**	**6.98**
Aromatics	**vol. %**	**D1319**	**15.0**	**15.9**	**15.3**	**35.2**	**35.6**	**14.9**	**34.5**	**35.5**	**35.5**
Olefins	vol. %	D1319	6.9	7.5	7.3	6.6	6.5	7.4	7.0	6.5	6.8
Saturates	vol. %	calculated[a]	57.6	56.4	56.9	38.1	42.7	62.9	43.5	48.2	37.6
Benzene	vol. %	D3606	0.59	0.63	0.62	0.65	0.62	0.56	0.59	0.58	0.60
Sulfur	mg/kg	D5453	21	21	21	26	23	26	24	23	25
RON	-	D2699	101.8	97.4	100.8	102.2	101.7	100.8	102.7	100.5	101.7
MON	-	D2700	89.3	86.8	88.6	88.3	88.5	89.2	89.4	88.1	88.2
(RON+MON)/2	-	calculated	95.6	92.1	94.7	95.3	95.1	95.0	96.1	94.3	95.0
C	mass %	D5291 mod.	78.24	78.34	78.47	80.62	81.48	80.27	81.78	83.17	79.90
H	mass %	D5291 mod.	13.85	13.86	13.86	12.38	12.45	14.01	12.62	13.00	12.49
O	mass %	D5599	7.7	7.5	7.6	7.2	5.6	5.5	5.4	3.6	7.2
Net Heat of Combustion	MJ/kg	D4809	40.031	39.915	40.114	38.855	40.384	41.062	40.383	41.304	39.391
Water	mass %	E-1064	0.113	0.112	0.108	0.117	0.088	0.090	0.091	0.086	0.143
Lead	g/l	D3237	0.004	<0.003	0.005	0.001	<0.003	<0.003	<0.003	-	<0.003
Copper Strip Corrosion	-	D130	1A	1A	1A	1A	1A	1A	1A	1A	1A
Solvent Washed Gum Content	mg/100ml	D381	<0.5	0.5	0.5	<0.5	<0.5	0.5	<0.5	<0.5	0.5
Oxidation Stability	min.	D525	>240	>240	>240	>240	>240	>240	>240	>240	>240

[a] Saturates = 100 - D1319 Aromatics - D1319 Olefins - D5599 Ethanol

NOTE: Properties in bold were varied within the fuel matrix.

TABLE 1 (CONT'D). TEST FUEL PROPERTIES DETERMINED FROM THE EPACT/V2/E-89 FUELS ROUND ROBIN

PROPERTY		UNIT	TEST METHOD	FUEL 29
Density, 60°F		g/cm^3	D4052	0.7797
API Gravity, 60°F		°API	D4052	49.8
Uncorrected Ethanol		mass %	D5501 mod.	79.59
Uncorrected Methanol		mass %	D5501 mod.	0.01
Ethanol		vol. %	D5501 mod.	77.15
Methanol		vol. %	D5501 mod.	<0.01
Estimated Hydrocarbon Content		vol. %	calculated[a]	22.14
Distillation	IBP	°F	D86	99.0
	5% evap	°F		132.9
	10% evap	°F		154.3
	20% evap	°F		167.6
	30% evap	°F		170.3
	40% evap	°F		171.2
	50% evap	°F		171.8
	60% evap	°F		172.1
	70% evap	°F		172.5
	80% evap	°F		172.9
	90% evap	°F		173.9
	95% evap	°F		176.2
	FBP	°F		265.8
DVPE (EPA equation)		psi	D5191	8.92
Benzene		vol. %	D5580	0.12
S		mg/kg	D5453	16
C		mass %	D5291 mod.	57.74
H		mass %	D5291 mod.	12.80
O		mass %	D5501 mod.	27.19
Water		mass %	E203	0.93
		vol. %	E203	0.72
Net Heat of Combustion		MJ/kg	D4809	30.058
Solvent Washed Gum		mg/100 ml	D381	1.9
Unwashed Gum		mg/100 ml	D381	1.8
Acidity (as acetic acid)		mass %	D1613	0.0021
pHe		-	D6423	8.08
Inorganic Chloride		mg/kg	D7319	nd
Copper		mg/l	D1688[b]	0.02

[a] Estimated hydrocabon contenet = 100 - D5501 Ethanol - E203 Water
[b] D1688 modified as outlined in D4806
NOTE: Fuel provided by CRC

Duplicate tests were conducted "back-to-back" for each vehicle/fuel/temperature combination, with the option for a third test based on repeatability criteria. Each vehicle/fuel/temperature combination was tested at least twice. After two tests were completed and the acquired data passed all quality control verifications, the need for a third test was determined by following the variability criteria shown in Table 2. If the ratio of any of the criteria pollutants (THC, NO_X, or CO_2) on a pair of tests for a given vehicle/fuel combination exceeded the levels shown in Table 2, a third test was conducted.

TABLE 2. REPEATABILITY CRITERIA FOR TRIPLICATE TESTING

Dilute Gaseous Emission	Criteria For Requiring A Third Test (Composite Cycle Emissions)
CO_2	Ratio of higher / lower > 1.03
NO_X	Ratio of higher / lower > 2.7
THC	Ratio of higher / lower > 2.0

The vehicle fuel change and conditioning procedure used for this portion of the study was developed during the conduct of Phase 3. The beginning of Phase 3 included a study to assess the vehicle conditioning procedure. Long-term fuel trim (LTFT) and short-term fuel trim (STFT) were monitored during the conduct of successive two-phase LA-92 test cycles and were analyzed by EPA for stabilization. Based on the results of this study, all vehicles were conditioned with three successive two-phase LA92s except for the Honda Civic, Chevrolet Cobalt, and Nissan Altima, which were all conditioned with five successive two-phase LA92s. The final vehicle fuel change and conditioning sequence is given in Table 3. Example test requests for vehicle conditioning and testing are given in Appendix A.

2.4 Regulated and Unregulated Emissions

The emissions measured and reported were THC, NMHC (by FID), NMOG, NO_X, NO_2, CO, CO_2, PM, alcohols, carbonyl compounds, and speciated hydrocarbons.

Gaseous emissions were determined in a manner consistent with EPA protocols for light-duty emission testing as given in the CFR, Title 40, Part 86. A constant volume sampler was used to collect proportional dilute exhaust in Kynar bags for analysis of carbon monoxide (CO), carbon dioxide (CO_2), total hydrocarbons (THC), methane (CH_4), and oxides of nitrogen (NO_X). For the determination of particulate matter (PM) mass emissions, a proportional sample of dilute exhaust was drawn through Whatman Teflon membrane filters. The PM sampling method was compliant to CFR, Title 40, Part 1065.

TABLE 3. FUEL CHANGE, CONDITIONING, AND TEST EXECUTION SEQUENCE

STEP	DESCRIPTION
1	Drain vehicle fuel completely via fuel rail whenever possible.
2	Turn vehicle ignition to RUN position for 30 seconds (60 seconds when switching to E85) to allow controls to allow fuel level reading to stabilize. Confirm the return of fuel gauge reading to zero.
3	Turn ignition off. Fill fuel tank to 40% with next test fuel in sequence. Fill-up fuel temperature must be less than 50°F.
4	Start vehicle and execute catalyst sulfur removal procedure described in Appendix C of CRC E-60 Program report. Apply side fan cooling to the fuel tank to alleviate the heating effect of the exhaust system. Engine oil temperature in the sump will be measured and recorded during the sulfur removal cycle.
5[a]	Perform four vehicle coast downs from 70 to 30 mph, with the last two measured. If the individual run fails to meet the repeatability criteria established in Phases 1 and 2 of the program, the vehicle will be checked for any obvious and gross source of change in the vehicle's mechanical friction.
6	Drain fuel and refill to 40% with test fuel. Fill-up fuel must be less than 50°F.
7	Drain fuel again and refill to 40% with test fuel. Fill-up fuel must be less than 50°F.
8	Soak vehicle for at least 12 hours to allow fuel temperature to stabilize to the test temperature.
9[b]	Move vehicle to test area without starting engine. Start vehicle and perform three 2-phase (bags 1 and 2) LA92 cycles. During these prep cycles, apply side fan cooling to the fuel tank to alleviate the heating effect of the exhaust system. Following the first two prep cycles, allow vehicle to idle in park for two minutes, then shut-down the engine for 2-5 minutes. Following the last prep cycle, allow the vehicle to idle for two minutes, then shut down the engine in preparation for the soak.
10	Move vehicle to soak area without starting the engine.
11	Park vehicle in soak area at proper temperature (75 °F) for 12-36 hours. During the soak period, maintain the nominal charge of the vehicle's battery using an appropriate charging device.
12	Move vehicle to test area without starting engine.
13	Perform LA92 cycle emissions test.
14	Move vehicle to soak area without starting the engine.
15	Park vehicle in soak area of proper temperature for 12-36 hours. During the soak period, maintain the nominal charge of the vehicle's battery using an appropriate charging device.
16	Move vehicle to test area without starting the engine.
17	Perform LA92 emissions test.
18	Determine whether third replicate is necessary, based on data variability criteria (see Table 6).
19	If a third replicate is required, repeat steps 14, 15, 16 and 17.
20	If third replicate is not required, return to step 1 and proceed with next vehicle in test sequence.

a – Vehicle coastdown repeatability criteria referred to in Step 5 were provided by EPA as follows:

- maximum difference of 0.5 seconds between back-to-back coastdown runs from 70 to 30 mph
- maximum ±7 percent difference in average 70 to 30 mph coastdown time from the running average for a given vehicle

b – Conduct five 2-phase LA92 test cycles for the following vehicles: CCOB, NALT, and HCIV.

In addition to the dilute, bagged exhaust samples, continuous raw exhaust mass emissions rates were measured on a second-by-second basis for THC, CH_4, CO, NO_X, CO_2 and O_2 at the tailpipe. These measurements were performed during the first test of each vehicle/fuel combination at a sampling frequency of 1 Hz. For Phase 4 tetsing at 72°F and 95°F, dilution air flow was measured with a smooth approach orifice, and a critical flow venturi measured bulkstream dilute exhaust flow. Measured dilution air flow was subtracted from the bulkstream flow to calculate raw exhaust flow to determine continuous raw mass emission rates. For tetsing during Phase 5 and during Phase 4 at 20°F, an exhaust flow meter manufactured by Sensors Incorporated was used to measure raw exhaust flow.

Select alcohols and carbonyls were also measured during emission tests. The measurement of alcohols in exhaust was accomplished by bubbling the exhaust through glass impingers containing deionized water after which samples were analyzed by gas chromatography. An HPLC procedure was utilized for the analysis of carbonyls. Samples were collected using DNPH cartridges and were extracted with acetonitrile. Speciated hydrocarbons were determined by gas chromatography.

Exhaust emissions were measured as shown below.

Constituent	Analysis Method
Total Hydrocarbon	Heated Flame Ionization Detector (bag, modal)
Methane	Gas Chromatography (bag, modal)
Carbon Monoxide	Non-Dispersive Infrared Analysis (bag, modal)
Carbon Dioxide	Non-Dispersive Infrared Analysis (bag, modal)
Oxides of Nitrogen	Chemiluminescence Analysis (bag, modal)
Nitric Oxide	Chemiluminescence Analysis (bag only)
Oxygen	Magnetopneumatic Detector (modal only)
Particulate Matter	Part 1065 Gravimetric Measurement (bag only)
Non-methane Hydrocarbons	Calculated from THC and CH_4 (bag, modal)
Non-methane Organic Gases	Calculated as specified in Section 2.5.2 (bag only)
Nitrogen Dioxide	Calculated from difference of NO_X and NO (bag only)
C_1 – C_{12} HC Speciation	Gas Chromatography (bag only)
Alcohols	Gas Chromatography (bag only)
Carbonyls	Liquid Chromatography (bag only)

2.4.1 Speciation of Volatile Organic Compounds

Phase-level (bag-by-bag) speciated volatile organic compounds (VOCs) included C_1 - C_{12} hydrocarbons, light alcohols, aldehydes, and ketones. Sampling and analysis of C_2-C_{12} hydrocarbons was conducted in a manner similar to CARB method 1002/1003, "Procedure for the Determination of C_2-C_{12} Hydrocarbons in Automotive Exhaust Samples by Gas Chromatography". Sampling and analysis of alcohols was done in a manner similar to CARB method 1001, "Determination of Alcohols in Automotive Source Samples by Gas Chromatography". Sampling and analysis of carbonyl compounds was conducted in a manner similar to CARB method 1004, "Determination of Aldehyde and Ketone compounds in Automotive Source Samples by High Performance Liquid Chromatography". Analysis of C_2 - C_4 HC samples was conducted within one hour of completion of an emissions test. Subsequent analysis of the additional compounds of interest was done within 4 hours of emission test completion.

During the analysis of C_2 - C_4 hydrocarbons, special consideration was given to 1,3-butadiene. Because of the instability of 1,3-butadiene, the analysis of C_2 - C_4 hydrocarbon samples collected during Bag 1 of a test cycle was initiated within one hour of collection. The speciation of C_5 - C_{12} hydrocarbon samples collected in Bag 1 of the test cycle was completed within 4 hours of collection.

Sampling and analysis of light alcohols was accomplished by bubbling exhaust through glass impingers containing deionized water, and samples were analyzed with a gas chromatograph. Analysis included the following compounds: methanol, ethanol, isopropanol, and n-propanol. Alcohol samples were sealed and stored at a temperature below 40^{o}F immediately following collection. Most of these samples were analyzed on the day they were collected, but no later than within six calendar days.

Samples of carbonyl compounds were collected in cartridge type samplers. These samples were extracted immediately following collection (within 15 minutes) and the extracts sealed and stored immediately at a temperature below 40^{o}F. Most of these extracts were analyzed on the day they were collected, but no later than within three calendar days. An effort was made to detect the presence of a tautomer of acrolein, acrolein-x, which can be a measurement artifact. No acrolein-x was found in any exhaust sample.

Storage of alcohol and carbonyl samples was segregated to prevent any cross-contamination of samples.

2.4.2 Determination of NMOG

An EPA-provided protocol for calculating NMHC and NMOG (Appendix B) was followed. Bag-level NMHC and NMOG were calculated for all bags. These bag-level NMHC and NMOG calculations were then used to calculate composite weighted NMHC and NMOG mass emissions.

2.4.3 Particulate Matter and Semi-Volatile Organic Compounds

Constant volume sampling (CVS) systems, including stainless steel dilution tunnels, were used for all PM sample collection. A separate CVS system was used at 20°F and for the high-emitting vehicles. All dilution air was filtered prior to entering the CVS systems. HEPA filters were used to remove particles from the dilution air and charcoal filters were used to adsorb background hydrocarbons. Multiple sample probes were used in each tunnel to facilitate the simultaneous collection of PM samples for subsequent analysis as follows:

- 47-mm Teflon membrane filters: PM mass emission rate, elements by EDXRF and ICP-MS,
- 47-mm glass-fiber filters: SOF
- 47-mm quartz fiber filter: OC and EC by TOR and TOT, sulfate by IC
- 10-cm TIGF backed up by XAD-4: PAH, hopanes and steranes, higher molecular weight alkanes, cycloalkanes

Proportional PM samples drawn from a dilution tunnel were simultaneously collected on all filter media and XAD cartridges. For integrated PM samples that were collected over multiple days, filters were stored in their holders in the weighing chambers when not in use. Following collection, all PM and SVOC samples were stored at -10°C prior to shipment to DRI. Samples were shipped overnight to DRI in coolers packed with Blue Ice. Analytical results as determined by DRI are reported separately.

2.5 OBD Data

Additional available data were acquired at 1 Hz from each vehicle's onboard diagnostic (OBD) system during all emissions tests using a DBK70 data acquisition system. The data, when available, included:

- RPM
- Vehicle speed
- Engine load
- Short term fuel trim-bank 1
- Long term fuel trim-bank 1
- MIL status
- Absolute throttle position
- Engine coolant temperature
- Short term fuel trim-bank 2
- Long term fuel trim-bank 2
- Fuel/air commanded equivalence ratio
- Alcohol fuel percent (if available)
- Manifold absolute pressure
- Spark advance
- PID $42 Control Module Voltage
- Air flow rate from mass air flow sensor

3.0 PHASE 6 TECHNICAL APPROACH AND RESULTS

3.1 Test Matrix

Six test vehicles were designated for the program as noted in Table 4. Additional vehicle information is given in Appendix C. The “high emitter vehicles” were available for test in September of 2011 and the evaluation of these vehicles, designated “Segment 1”, was completed in December of 2011. The “normal emitters” were noticeable to testing in May of 2013. The evaluation of these vehicles is designated as “Segment 2”. When these three vehicles were available for test, the original batch of fuel used for the “high emitters” was no longer in storage at SwRI and the original batch of the 5W-30 engine oil used in the EPAct program was depleted.

TABLE 4. PHASE 6 TEST MATRIX

Matrix Test Number	Vehicle				Previous Program	NREL Oil Vehicle Test
	Number	Model Year	Make	Model		
1	HEDDAK	1993	Dodge	Dakota	EPAct Phase 5	Test A
2	HECTAH	1996	Chevrolet	Tahoe	EPAct Phase 5	Test A
3	HEFTAU	1990	Ford	Taurus	EPAct Phase 5	Test A
4	EPA-TSIE	2008	Toyota	Sienna	EPAct	Test A
5	EPA-JLIB	2008	Jeep	Liberty	EPAct	Test A
6					EPAct	Test B*
7	EPA-HCIV	2008	Honda	Civic	EPAct	Test A
8					EPAct	Test B**

* Repeat of vehicle test A
**Repeat of vehicle test B with 5-hour soaks

3.2 Fuel

Two fuel batches were used for the program: “Batch 1” for Segment 1 (matrix tests 1 through 3) for the “high emitters” and “Batch 2” for Segment 2 (matrix tests 4 through 8). Analytical evaluations were performed on each fuel batch, the results were sent to the NREL Project Manager, and the fuel batches were approved for test. The analytical evaluation results of the fuel batches are given in Appendix D.

3.3 Engine Oil

The original plan was to conduct Phase 6 with the 5W-20 and 5W-30 engine oil used in EPAct program. However, there was insufficient quantity of the 5W-30 engine oil (SwRI oil code LO-249418) to conduct the test on the Toyota Sienna (TSIE). The supplier of the EPAct oil was contacted, but the supplier did not have any remaining oil in storage and was not able to blend another batch in time to complete the program. Therefore, commercially available, nonsynthetic Pennzoil 5W-30 was procured, co-mingled and used for the Toyota Sienna test. The lubricants used in Phase 6 are given in Table 5.

TABLE 5. PHASE 6 ENGINE OILS

	SwRI Oil Code Number		
	LO-249419	LO-249418	LO-296236
	EPAct Program	EPAct Program	Commercial Pennzoil
	5W-20	5W-30	5W-30
NREL1		X	
NREL2		X	
NREL3		X	
EPA-TSIE			X
EPA-JLIB	X		
EPA-HCIV	X		

3.4 Procedure

The following procedure was used for the eight matrix tests.

1. The vehicle's engine exterior was cleaned and the vehicle was driven for approximately 10 miles on the SwRI campus and track. The vehicle was raised on a hoist and inspected thoroughly for engine oil leaks. The Dodge Dakota and the Ford Taurus had engine oil leaks that were repaired.

2. To enhance the accuracy of the oil consumption measurement the tires were set to specification and the vehicle parked in the same location on the drive-on hoist for all the oil drain operations in this program. Using a digital level the angles from horizontal (front-to-back and side-to-side) on a flat area of the engine or transmission were measured at the start-of-test and duplicated for the end-of-test oil drain. This was done to enhance the precision of the engine oil drain weights.

3. At the start of test before the final engine oil fill for mileage accumulation, several drain and fill operations were performed to confirm that the weight of oil added to the engine was approximately the same as the amount drained. A new original equipment manufacturer (OEM) engine oil filter was weighed and installed prior to each engine oil fill.

   After each engine oil fill operation, the engine was idled for 12 minutes prior to the drain operation. Engine oil drains were always made with a warmed-up engine and the drain continued until the oil stream turned to drips.

4. Each vehicle was set up for mileage accumulation dynamometer (MAD) operation, which included a safety that would have discontinued test if a tire had lost air pressure. This did not occur during the program. Limits were also set up in the MAD control software for engine speed, throttle position, coolant temperature, and

illumination of a malfunction indicator light (MIL). If the limits were exceeded or the MIL was illuminated, the control system discontinued mileage accumulation.

5. The inertia weight settings for the MADs for all six vehicles were based on the equivalent test weight published on the US Environmental Protection Agency (EPA) website. Because of the age of the “high emitter” vehicles in Segment 1, there were no published road load coefficients. The road load coefficients for Segment 1 were determined by simulating the published 50-mph horsepower with A, B, and C target coefficients. The road load coefficients for Segment 2 were the same as those used in the EPAct program. The inertia and coefficient values for this program are given in Appendix C, Results.

6. Mileage was accumulated on each vehicle using the Unified Cycle driving profile, which averages about 25 mph. During mileage accumulation the vehicles’ fuel tanks were filled using a dispenser at the appropriate MAD lane. During the pause for refueling the engine oil level was also checked with the dipstick. If during the 5,000 miles, the verified (checked on level ground) oil level was below the “one-quart low” line on the dipstick, the mileage accumulation was discontinued and the oil consumption determined based on the vehicle test miles at that point.

   The vehicles in Segment 1 all indicated that the oil level was more than 1-quart low prior to reaching 5,000 miles. The Segment 2 vehicles all completed the 5,000-mile test.

7. Mileage accumulation was conducted using the Unified Cycle driving profile. Matrix tests 1 through 7 were conducted by continuously repeating the Unified Cycle except when the vehicle was fueled. For Matrix test 8, one “cold” start Unified Cycle & 10 more repetitions of the Unified Cycle were conducted followed by a 5-hour soak with the hood raised and an external fan directed at the engine compartment.

8. The complete drain sample from the first end-of-test engine oil drain was retained. Samples of the 5W-20 and 5W-30 new oil were also taken and retained.

9. At the end of each test, fuel dilution on a sample of the post-mileage engine oil was determined by ASTM D3525. The approximate weight of the fuel in the oil was subtracted from the drain weight prior to calculating the oil consumption.

3.5 Results

The oil consumption results are given in Appendix E.

4.0 CLOSURE

SwRI conducted room-temperature, 95°F, and 20°F exhaust emissions testing of three fuels using six Tier 2 vehicles; room-temperature, 95°F, and 20°F exhaust emissions testing of three fuels using three high-emitting vehicles; and the determination of oil consumption for a subset of the tested vehicles as part of Phases 4, 5, and 6 of the EPAct/V2/E-89 test program. Vehicle testing for this phase of the program was carried out between May 2010 and July 2013. This work was conducted for the National Renewable Energy Laboratory (NREL) and was authorized NREL Subcontract Nos. ACI-8-88613-01, AFT-9-99319-01 and AFT-9-99155-01. All test results have been posted on SwRI's secure file transfer site to which NREL has access.

APPENDIX A

VEHICLE CONDITIONING AND TEST EXECUTION REQUESTS

Fuel Change Procedure / Coastdown Sequence
EPAct Test Fleet
03.14936.03.202

Date: Tuesday, April 13, 2010 **Vehicle: Chevrolet Impala FFV : EPA-CIMP**

Test #: EPA-CIMP-P3-23-3FC T3 **Fuel #: 23**

First Fuel Change

- ☑ With key off, drain fuel from vehicle
- ☑ drain until fuel flow drops off. Stop drain immediately. **DO NOT OVERDRAIN.**
- ☑ Turn ignition to run position for 30 seconds allowing fuel gauge level to stabilize. Confirm fuel level reads zero. If gage does not read zero, use the Bosch scan tool to verify fuel level.
- ☑ Turn ignition key off.
- ☑ Locate fuel drum:

EPA Fuel No.	**23**
SwRI Fuel Name	**SFO**
SwRI Fuel Code	**EM-7059-F**
Drum No.	6

(Record Drum Number)

Verify fuel fill drum matches using "2-person rule"

Initials: A.G., AGW

Verify fuel temperature: 45 should be 45 ± 2 °F

- ☑ Fill tank with **6.8** gallons of fuel. Record time 4:48.
- ☑ Record fuel information from box above on vehicle windshield.
- ☑ Place fuel drum back into cold box.
- ☑ PUSH vehicle into lab within 10 minutes of refueling. Record time 4:50.
- ☑ Install vehicle on Dyno. Record drive wheel tire pressures. RT 30 LF 30.
- ☑ Connect the correct transfer pipe to the vehicle and run out the roof with flex pipe.
- ☑ Place cooling fans to cool the exhaust.

Page 1 of 5
R:\03Projects\DEER\03-13363_EPA\Forms (Lab Check Lists)\Kent's Master EPA Forms Generator LA92 (Phase-3) with NREL Filters & charge numbers 4-2010.xlsm
Revised 12/01/2009. Julia DeGrace

Fuel Change Procedure / Coastdown Sequence
EPAct Test Fleet
03.14936.03.202

Date: Tuesday, April 13, 2010 **Vehicle: Chevrolet Impala FFV : EPA-CIMP**

Test #: EPA-CIMP-P3-23-3FC **Fuel #: 23** odo 7565

Run 8115

- ☑ Dyno computer setup procedure
- ☑ Horiba trace setup procedure
- ☑ Connect thermocouple #1 to record oil temperature.
- ☑ Start the vehicle. Idle in neutral. Using the OBD scan tool, read and record the long term fuel trim LTFT: -6.9%
- ☑ Run the sulfur purge procedure described on the last page.
- ☑ Record sulfur purge completion time. 8:11
- ☑ Place vehicle in neutral with engine idling. Using the OBD scan tool, read and record the long term fuel trim LTFT = -10.2%
- ☑ Within 5 minutes of completing the sulfur purge procedure begin coast downs. Use the speed range from 70 - 10 mph and record in 5 mph increments.
- ☑ Coast down 1.
- ☑ Coast down 2.
- ☑ Coast down 3, print.
- ☑ Coast down 4, print.
- ☑ Type the coastdown data from runs 3 and 4 into the coastdown analysis Excel program. If the program notes a repeatability failure, check for incorrect inputs. **If repeatability cannot be accomplished, remove vehicle and begin fuel change procedure on backup vehicle** and notify supervisor. If test repeatability is indicated OK, continue with this procedure.
- ☑ Remove vehicle from dyno and move to the fuel drain area.

EPAct Test Fleet
03.14936.03.202

Date: Tuesday, April 13, 2010 **Vehicle#: Chevrolet Impala FFV : EPA-CIMP**

Test #: EPA-CIMP-P3-23-3FC **Fuel #: 23**

Second Fuel Change

☑ Drain fuel from vehicle until flow drops off. Stop drain immediately.
DO NOT OVERDRAIN.

☑ Turn ignition to run position for 30 seconds allowing fuel gauge level to stabilize. Confirm fuel level reads zero. If gage does not read zero, use the Bosch scan tool to verify fuel level.

☑ Locate fuel drum:

EPA Fuel No.	**23**
SwRI Fuel Name	**SFO**
SwRI Fuel Code	**EM-7059-F**
Drum No.	6

(Record Drum Number)

Verify fuel fill drum matches using "2-person rule"

Initials: LA , ms

Verify fuel temperature: 45 should be 45 ± 2 °F

☑ Fill tank with **6.8** gallons of fuel. Record time 11:07.

Note: For vehicles HODY, NALT, TSIE, HCIV, TCAM

These vehicles (only) require a third fuel change. If you are not working on one of these five vehicles, skip the third fuel change and return fuel drum to the cold box.

#N/A

Date: Tuesday, April 13, 2010 **Vehicle#:** Chevrolet Impala FFV : EPA-CIMP

Test #: EPA-CIMP-P3-23-3FC **Fuel #:** 23

Third Fuel Change For Odyssey, Altima, Sienna, Civic, and Camry only.

- ☑ Drain fuel from vehicle until flow drops off. Stop drain immediately. **DO NOT OVERDRAIN.**
- ☑ Turn ignition to run position for 30 seconds allowing fuel gauge level to stabilize.
- ☑ Locate fuel drum:

EPA Fuel No.	23
SwRI Fuel Name	SFO
SwRI Fuel Code	EM-7059-F
Drum No.	6

(Record Drum Number)

Verify fuel fill drum matches using "2-person rule"

Initials: RA , mS

Verify fuel temperature: 45 should be 45 ± 2 °F

- ☑ Fill tank with 6.8 gallons of fuel. Record time 11:16.

- ☑ Place fuel drum back into cold box.
- ☑ PUSH vehicle into lab and park in 75° F soak area for at least 12 hours..

Lead Technician's Signature: [signature]

03.14936.03.202

Date: Tuesday, April 13, 2010 **Vehicle#: Chevrolet Impala FFV** **: EPA-CIMP**

Test #: EPA-CIMP-P3-23-3FC **Fuel #: 23**

	SULFUR PURGE PROCEDURE		
6 0	☐ idle	30 seconds	
5 90	☑ 55 mph	5 minutes	
5 03	☑ 30 mph	1 minute	
6 26	☑ WOT acceleration	>5 seconds	>70 mph
6 41	☑ hold speed	15 seconds	
6 48	☑ 30 mph	1 minute	
8 11	☑ WOT acceleration	>5 seconds	>70 mph
8 26	☑ hold speed	15 seconds	
8 30	☑ 30 mph	1 minute	
9 45	☑ WOT acceleration	>5 seconds	>70 mph
10 00	☑ hold speed	15 seconds	
10 05	☑ 30 mph	1 minute	
11 22	☑ WOT acceleration	>5 seconds	>70 mph
11 37	☑ hold speed	15 seconds	
11 42	☑ 30 mph	1 minute	
11 58	☑ WOT acceleration	>5 seconds	>70 mph
13 13	☑ hold speed	15 seconds	
13 17	☑ 30 mph	1 minute	
14 20	☑ idle	30 seconds	
14 59	☑ 55 mph	5 minutes	
20 05	☑ 30 mph	1 minute	
21 20	☑ WOT acceleration	>5 seconds	>70 mph
21 35	☑ hold speed	15 seconds	
21 41	☑ 30 mph	1 minute	
23 10	☑ WOT acceleration	> 5 seconds	>70 mph
23 25	☑ hold speed	15 seconds	
23 31	☑ 30 mph	1 minute	
24 46	☑ WOT acceleration	>5 seconds	>70 mph
25 01	☑ hold speed	15 seconds	
25 05	☑ 30 mph	1 minute	
26 18	☑ WOT acceleration	>5 seconds	>70 mph
26 33	☑ hold speed	15 seconds	
26 39	☑ 30 mph	1 minute	
27 55	☑ WOT acceleration	>5 seconds	>70 mph
28 10	☑ hold speed	15 seconds	
28 16	☑ 30 mph	1 minute	
29 23	☑ idle	30 seconds	

Precondition Sequence
EPAct Test Fleet
03.14936.03.202

Date: **Wednesday, April 14, 2010** **Vehicle#: Chevrolet Impala FFV : EPA-CIMP**

Test #: EPA-CIMP-P3-23-3P **Fuel #: 23**

- ☑ PUSH the vehicle to the dyno.
- ☑ Place cooling fans to cool exhaust.
- ☑ Connect DBK 70 cable to vehicle OBDII connector. ODO: 7597
- ☑ **PC Host:** Open DBK 70 PidPro. Select "Connect". Select "Load config file". Select "Obdcan-EPA". Select "Display current channel values".
- ☑ Dyno Computer setup procedure:

Set Coefficients: **A:**	**8.32**	lb.
B:	**0.1121**	lb/mph.
C:	**0.018601**	lb/mph2/
ETW:	**3875**	lbs.

- ☑ Horiba trace setup procedure
- ☑ Run the number of LA92 precondition cycles as indicated by the test number.
  - ☑ LA92 Run # 8124
    - After each LA92 sequence, idle in neutral for two minutes before shutdown
    - Shut down engine for a min of 2 minutes and 5 minutes (max) between precondition cyc
  - ☑ LA92 Run# 8125
    - After each LA92 sequence, idle in neutral for two minutes before shutdown
    - Shut down engine for a min of 2 minutes and 5 minutes (max) between precondition cyc
  - ☑ LA92 Run # 8126
    - After each LA92 sequence, idle in neutral for two minutes before shutdown
    - Shut down engine for a min of 2 minutes and 5 minutes (max) between precondition cyc
  - ☐ LA92
    - After each LA92 sequence, idle in neutral for two minutes before shutdown
    - Shut down engine for a min of 2 minutes and 5 minutes (max) between precondition cyc
  - ☐ LA92
    - After each LA92 sequence, idle in neutral for two minutes before shutdown

-5P = five 2-bag LA92 -3P = three 2-bag LA92 -1P = single LA92

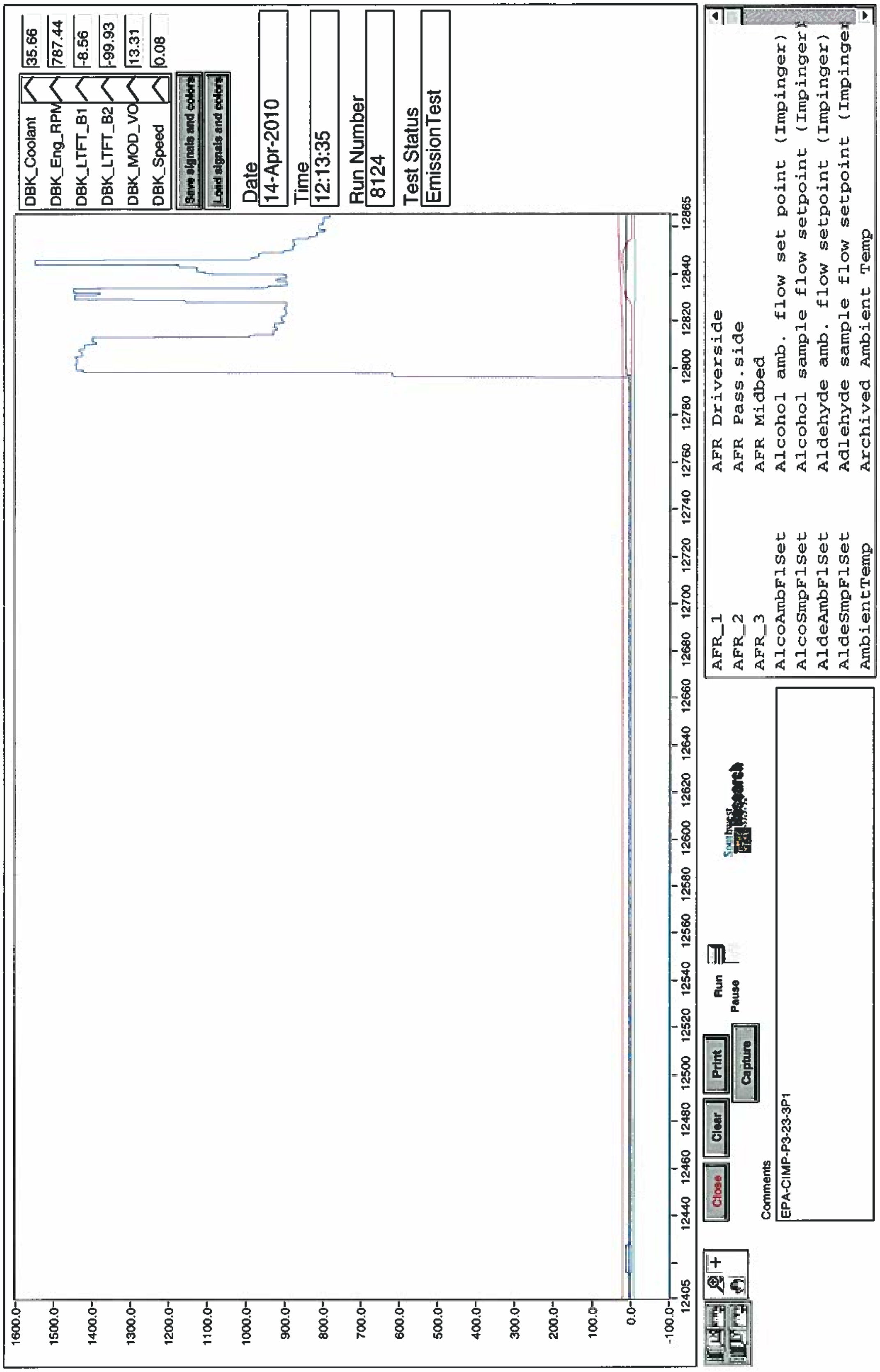
Precondition Sequence
EPAct Test Fleet
03.14936.03.202

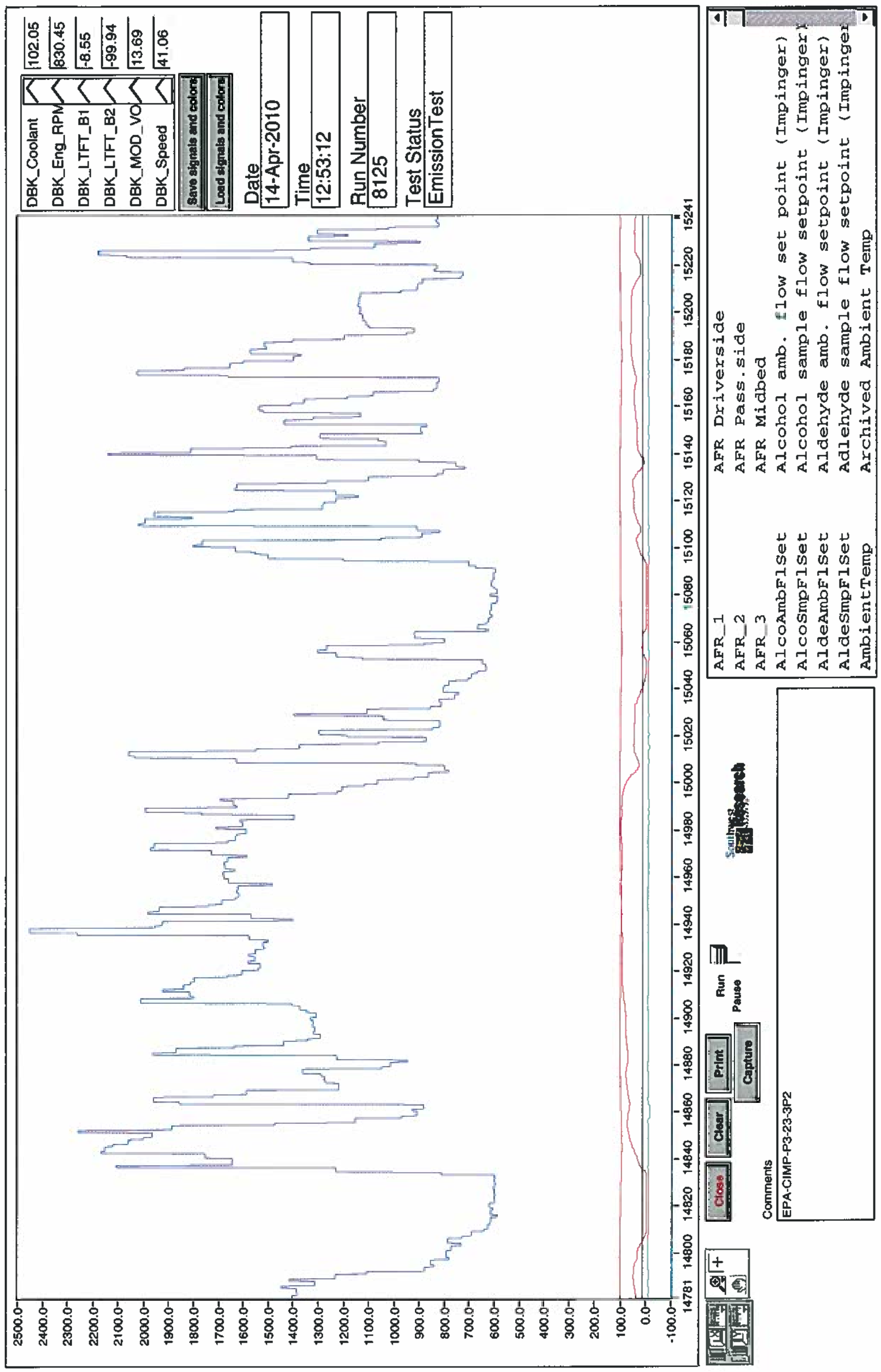
Date: Wednesday, April 14, 2010 **Vehicle#: Chevrolet Impala FFV : EPA-CIMP**

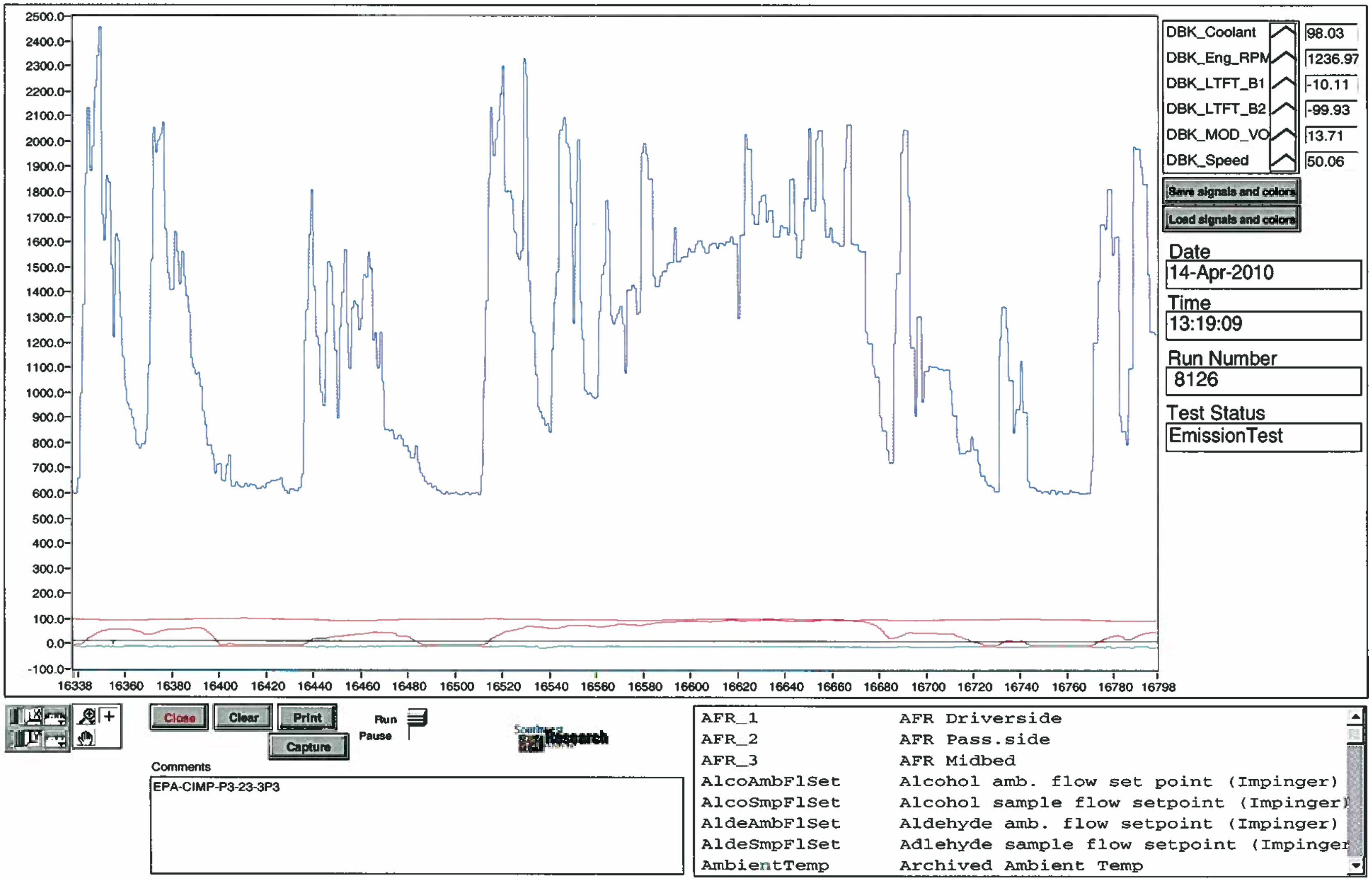
Test #: EPA-CIMP-P3-23-3P **Fuel #: 23**

- ☐ Select "Disconnect" on the DBK70 PidPro.
- ☑ Remove the vehicle from the dyno and PUSH to a 75°F soak area for 12 - 36 hrs. Time: 1:34
- ☑ Place a battery charger on vehicle and set to trickle charge at 2 amps.
- ☑ Transfer data and rename file.

Lead Technician's Signature: ____________________


DBK_Coolant 35.66
DBK_Eng_RPM 787.44
DBK_LTFT_B1 -8.56
DBK_LTFT_B2 -99.93
DBK_MOD_VO 13.31
DBK_Speed 0.08
Save signals and colors
Load signals and colors
Date
14-Apr-2010
Time
12:13:35
Run Number
8124
Test Status
EmissionTest
1600.0
1500.0
1400.0
1300.0
1200.0
1100.0
1000.0
900.0
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
-100.0
12405
12440
12460
12480
12500
12520
12540
12560
12580
12600
12620
12640
12660
12680
12700
12720
12740
12760
12780
12800
12820
12840
12865
Close
Clear
Print
Capture
Run
Pause
Comments
EPA-CIMP-P3-23-3P1
AFR_1 AFR Driverside
AFR_2 AFR Pass.side
AFR_3 AFR Midbed
AlcoAmbFlSet Alcohol amb. flow set point (Impinger)
AlcoSmpFlSet Alcohol sample flow setpoint (Impinger)
AldeAmbFlSet Aldehyde amb. flow setpoint (Impinger)
AldeSmpFlSet Adlehyde sample flow setpoint (Impinger
AmbientTemp Archived Ambient Temp


DBK_Coolant 102.05
DBK_Eng_RPM 830.45
DBK_LTFT_B1 -8.55
DBK_LTFT_B2 -99.94
DBK_MOD_VO 13.69
DBK_Speed 41.06
Save signals and colors
Load signals and colors
Date
14-Apr-2010
Time
12:53:12
Run Number
8125
Test Status
EmissionTest
2500.0
2400.0
2300.0
2200.0
2100.0
2000.0
1900.0
1800.0
1700.0
1600.0
1500.0
1400.0
1300.0
1200.0
1100.0
1000.0
900.0
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
-100.0
14781 14800 14820 14840 14860 14880 14900 14920 14940 14960 14980 15000 15020 15040 15060 15080 15100 15120 15140 15160 15180 15200 15220 15241
Close
Clear
Print
Capture
Run
Pause
Comments
EPA-CIMP-P3-23-3P2
AFR_1 AFR Driverside
AFR_2 AFR Pass.side
AFR_3 AFR Midbed
AlcoAmbFlSet Alcohol amb. flow set point (Impinger)
AlcoSmpFlSet Alcohol sample flow setpoint (Impinger)
AldeAmbFlSet Aldehyde amb. flow setpoint (Impinger)
AldeSmpFlSet Adlehyde sample flow setpoint (Impinger
AmbientTemp Archived Ambient Temp



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2400.0
2300.0
2200.0
2100.0
2000.0
1900.0
1800.0
1700.0
1600.0
1500.0
1400.0
1300.0
1200.0
1100.0
1000.0
900.0
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
-100.0
16338 16360 16380 16400 16420 16440 16460 16480 16500 16520 16540 16560 16580 16600 16620 16640 16660 16680 16700 16720 16740 16760 16780 16798
DBK_Coolant 98.03
DBK_Eng_RPM 1236.97
DBK_LTFT_B1 -10.11
DBK_LTFT_B2 -99.93
DBK_MOD_VO 13.71
DBK_Speed 50.06
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Load signals and colors
Date
14-Apr-2010
Time
13:19:09
Run Number
8126
Test Status
EmissionTest
Close
Clear
Print
Capture
Run
Pause
Comments
EPA-CIMP-P3-23-3P3
AFR_1 AFR Driverside
AFR_2 AFR Pass.side
AFR_3 AFR Midbed
AlcoAmbFlSet Alcohol amb. flow set point (Impinger)
AlcoSmpFlSet Alcohol sample flow setpoint (Impinger)
AldeAmbFlSet Aldehyde amb. flow setpoint (Impinger)
AldeSmpFlSet Adlehyde sample flow setpoint (Impinger
AmbientTemp Archived Ambient Temp

Driver Test Sheet
EPAct Test Fleet
03.14936.03.202

Date: **Thursday, April 15, 2010** **Vehicle: Chevrolet** **Impala FFV** **: EPA-CIMP**

Test #: EPA-CIMP-P3-23-T3 **Fuel #: 23**

- ☑ **Dyno RTM**: Perform 30 min. Dyno warm-up against Loss No. 106.
  Enter Record No. : 903 and Loss Record No.: 106.
- ☑ **Dyno RTM**: Perform parasitic friction curve against Loss No. 106.
  (Save this record - Do Not make it the current record). Enter Record No. 1495 and Loss Record No. 106.
- ☑ **Dyno RTM**: Select "Road Load Simulation".
- ☑ **Dyno RTM**: Select "Vehicle Database". Select " **EPA-CIMP**
- ☑ **Dyno RTM**: Select "Set Up" and select "Aug Braking **off**
- ☑ **Dyno RTM**: Select "**Host Mode**".
- ☑ Check oil sump temperature and record : 70.7 should be 72 ± 3°F
- ☑ Install vehicle on chassis dyno. Align vehicle using laser level.
- ☑ Tie down vehicle. Adjust tie down straps at 150 to 200 lbs/ft.
- ☑ Connect RMT to vehicle.
- ☑ Record front tire pressures; (Veh. Spec = **30** psi).
  LR: 30.0 RR: 30.0.
- ☑ Record vehicle odometer: 7627.
- ☑ Connect DBK 70 cable to vehicle OBDII connector.
- ☑ Verify correct bags installed at CVS.
- ☑ **PC Host:** Open DBK 70 PidPro. Select "Connect". Select "Load config file".
  Select "Obdcan-EPA". Select "Display current channel values".
- ☑ **Dyno RTM:** Enter test number in comment box on "Road Load Simulation" screen.
- ☑ **MEXA:** Turn off blower.
- ☑ **Dyno RTM:** Enter Record No. 4087 and Loss Record No. 106.
- ☑ **MEXA:** Select "Online".

- ☑ **Verify** that humidity is between **9.9 and 11.4** on the Multi Signal Chart
  If not, notify Supervisor or Project Leader

Driver Test Sheet
EPAct Test Fleet
03.14936.03.202

Date: **Thursday, April 15, 2010** **Vehicle: Chevrolet** **Impala FFV** **: EPA-CIMP**

Test #: EPA-CIMP-P3-23-T3 **Fuel #: 23**

- ☑ **CDTCS:** Select "Run". Select "Test Schedule". Select "Emissions Test".
- ☑ **CDTCS:** Select "File". Select "Open Answer File. Select file " **EPA-CIMP**
- ☑ **CDTCS:** Select "File". Select "ID/Preferences" and make correct entries.

- ☑ **CDTCS:** Select "Test Options".
  - ☑ Select "Measure Emissions".
  - ☑ Select "PostCat" sample. Check applicable ranges for AUTO mode.
  - ☑ Select "Bags".
  - ☑ Select "Clean" Bagline.
- ■ Select Shift Schedule
  - ☑ Select "LA92".
  - ☑ Turn on Dilution Heat.
  - ☑ Shift 1: LA92 phase 1 & 2
  - ☑ Shift 2: LA92 phase 3
  - ☐ Shift 3: None.
- ■ Select CVS flow rates:
  - ☑ Select "Do Cert Z/S/Z" in "Zero Span Options".
    - ☑ Bag 1: **390** cfm.
    - ☑ Bag 2: **390** cfm.
    - ☑ Bag 3: **390** cfm.
- ☑ **CDTCS:** Select "Vehicle Data" and make correct entries.
- ☑ **CDTCS:** Select "Fuel Table". **EM-7059-F** **Fuel** **23** **SFO**
- ☑ **CDTCS:** Select "Dyno Data" and verify coeff. with RTM values:
  - ☑ a= **8.32** lb.
  - ☑ b= **0.1121** lb/mph.
  - ☑ c= **0.018601** lb/mph2/

Driver Test Sheet
EPAct Test Fleet
03.14936.03.202

Date: **Thursday, April 15, 2010** **Vehicle: Chevrolet** **Impala FFV** **: EPA-CIMP**

Test #: EPA-CIMP-P3-23-T3 **Fuel #: 23**

- ☑ **CDTCS:** Select "File". Select "Save Answer File". Select "OK". Select "Overwrite" EPA file.
- ☑ **CDTCS:** Record Horiba Run No. 8133 .
- ☑ **CDTCS:** Select "File". Select "Run Test".

- ☑ **Dyno RTM:** Select "Start Test" when CDTCS is ready to start test.
  - ☑ Verify green dyno light in test cell is on.
  - ☑ Verify chemistry ready
  - ☑ Verify PM ready
- ☑ **Start of Test.** Turn vehicle Traction Control (T/C) to OFF.
- ☑ **PC Host:** DBK70 PidPro: Select "Disconnect".
- ☑ **MEXA:** Take MEXA offline.

- ☑ **TURN BLOWER ON AFTER IT SHUTS DOWN AUTOMATICALLY.**

BAG 1 Start: (1), 2, 3 1: Good Start 2: Hesitate Start 3: Restart

BAG 3 Start: (1), 2, 3 1: Good Start 2: Hesitate Start 3: Restart

- ☑ **CDTCS:** Run these reports: "Bag Data", "Bag-Model Summary", "Zero/Span Data", and "1 HZ Data", then select "Print".
- ☑ **PC Host:** Rename vertical reports in "Results on Workstation" folder, then copy reports to both "Results on PC Host" folder and "EPA" folder.
- ☑ Disconnect vehicle and push off dyno into designated soak space.
- ☐ Connect battery charger and set for 2 amp trickle charge.

Lead Technician's Signature: P White

Driver's Signature: P White

R:\03Projects\DEER\03-13363_EPA\Forms (Lab Check Lists)\Kent's Master EPA Forms Generator LA92 (Phase-3) with NREL Filters & charge numbers 4-2010.xlsm
Revised 12/01/2009 Julia DeGrace

PM Sampling
Daily Test Sheet
EPAct Test Fleet
03.14936.03.202

Date: Thursday, April 15, 2010 **Vehicle:** Chevrolet Impala FFV : EPA-CIMP

Test #: EPA-CIMP-P3-23-T3 **Fuel #:** 23

- ☑ Perform a leak check on the PM Sampling system.

- ☑ Make sure PM sample pumps are off.
- ☑ Make sure ball valves on NREL composite filters are closed.
- ☑ Make sure ball valves on RMT impinger cart and dilution air are closed (2)
- ☑ Make sure impinger cart ball valve is closed.

- ☑ Within 10 minutes of SOT, checkout filters for NREL positions 1-5 and EPA positions 1 and 2.

- ☑ Record filter numbers for all positions on attached test form.

- ☑ Install filters in appropriate holders.

- ☑ Wait for driver's signal before proceeding.
  (approximately four minutes after start of CVS calibrations)

- ☑ Verify the EPA cart is set to AUTO. Start sample pumps 1 & 2.
  - ☑ Clear counters and timer.
  - ☑ Verify flow setting on pumps: Dilution = 1.09 Sample = 1.90

PM Sampling
Daily Test Sheet
EPAct Test Fleet
03.14936.03.202

Date: Thursday, April 15, 2010 **Vehicle:** Chevrolet Impala FFV : EPA-CIMP

Test #: EPA-CIMP-P3-23-T3 **Fuel #:** 23

- [x] Open RMT ball valves (2 valves)
- [x] Open impinger cart ball valve.
- [x] After SOT, verify sample flow rates on all carts.
  EPA cart: Dilution = 1, Sample = 2
- [x] Close ball valves
  - [x] Impinger cart sample @ CVS
  - [x] Impinger cart B6 @ RMT
  - [x] Dilution air sample @ RMT
- [x] Turn off all PM sample pumps.

Lead Technician's Signature ____________________

R:\03Projects\DEER\03-13363_EPA\Forms (Lab Check Lists)\Kent's Master EPA Forms Generator LA92 (Phase-3) with NREL Filters & charge numbers 4-2010.xlsm
Revised 12/01/2009. Julia DeGrace

PM Filters
Daily Test Sheet
EPAct Test Fleet
03.14936.03.202

Date: Thursday, April 15, 2010 **Vehicle:** Chevrolet Impala FFV EPA-CIMP

Test #: EPA-CIMP-P3-23-T3 **Fuel #:** 23 **NREL Filter Set: None**

GM	Sample Probe	Flow	Filter Description	Filter No.	GM Temp. (°F)	GM Press. (" H_2O)	GM Counts
1	Single	Dilute = 1 Sample = 2	EPA PP47 Bag 1	21492			Dilute 506 Sample 1346
2	Single	Dilute = 1 Sample = 2	EPA PP47 Bag 2	21493			Dilute 1903 Sample 5215
1	Single	Dilute = 1 Sample = 2	EPA PP47 Bag 3	21494			Dilute 511 Sample 1388
1	1	100	DRI G47 Bag 1,2,3		Bag 1 Bag 2 Bag 3		
2	2	100	DRI Q47 Bag 1,2,3		Bag 1 Bag 2 Bag 3		
3	3	100	DRI T47 Bag 1,2,3		Bag 1 Bag 2 Bag 3		
4	RMT	90	SwRI PP47 Bags 1,2,3		Bag 1 Bag 2 Bag 3		
Puf	5	2	100 mm XAD Bags 1,2,3		Bag 1 Bag 2 Bag 3		

Lead Technician's Signature: [signature]

Page 1 of 1

R:\03Projects\DEER\03-13363_EPA\Forms (Lab Check Lists)\Kent's Master EPA Forms Generator LA92 (Phase-3) with NREL Filters & charge numbers 4-2010.xlsm

Revised 12/01/2009. Julia DeGrace

APPENDIX B

EPACT NMOG CALCULATION PROTOCOL

EPAct NMOG Calculation Protocol

19-Feb-2009

The series of calculations shown here (Equations (1) through (6)) must be performed separately for each test phase (bag). The NMOG mass results can then be weighed in the usual way to form a test cycle composite emission rate.

First we calculate corrected NMHC concentration for dilute exhaust (subscript e) and dilution air (subscript d) as follows:

$$NMHC_e = FIDHC_e - r_{CH4} \cdot CH4_e - r_{MeOH} \cdot MeOH_e - r_{EtOH} \cdot EtOH_e - r_{PrOH} \cdot PrOH_e - r_{AcetHO} \cdot AcetHO_e \quad (1)$$

$$NMHC_d = FIDHC_d - r_{CH4} \cdot CH4_d - r_{MeOH} \cdot MeOH_d - r_{EtOH} \cdot EtOH_d - r_{PrOH} \cdot PrOH_d - r_{AcetHO} \cdot AcetHO_d \quad (2)$$

Note that these values are all as ppmC (so speciation results for EtOH, PrOH, and AcetHO reported in ppm of the particular chemical compound will need to be multiplied by 2 or 3 depending on the number of C atoms in the compound).

The following constant values shall be used for FID response factors:

r_{CH4} = 1.15 ppmC/ppmC (this program)
r_{MeOH} = 0.63 ppmC/ppmC (this program)
r_{EtOH} = 0.74 ppmC/ppmC (this program)
r_{PrOH} = 0.85 ppmC/ppmC (CARB)
r_{FormHO} = 0.00 ppmC/ppmC (various sources)
r_{AcetHO} = 0.51 ppmC/ppmC (this program)

Next, we must calculate the dilution factor to be used in generating the net NMHC concentration:

$$DF = \frac{100 \cdot \left[\frac{x}{x + 0.5y + 3.76 \cdot (x + 0.25y - 0.5z)} \right]}{CO2_e + (NMHC_e + CH4_e + MeOH_e + PrOH_e + EtOH_e + FormHO_e + AcetHO_e + CO_e) \cdot 10^{-4}} \quad (3)$$

The parameters x, y and z in Eq. (3) are coefficients taken from the chemical formula $C_xH_yO_z$ of a test fuel. The procedure to calculate their values is provided in Appendix 2.

Once the DF is determined, we calculate the net NMHC concentration as follows:

$$NMHC_{conc} = NMHC_e - NMHC_d \cdot \left(1 - \frac{1}{DF}\right) \quad (4)$$

Then we compute $NMHC_{mass}$:

$$NMHC_{mass} = V_{mix} \cdot Density_{NMHC} \cdot NMHC_{conc} \cdot 10^{-6} \quad (5)$$

Equations (4) and (5) must be repeated for each emission being considered. V_{mix} is the volume of dilute exhaust collected during a given phase of the test cycle, measured in standard cubic feet. Density is the calculated gas phase density of a particular species treated as a $C_1H_yO_z$ ideal gas.

The following values of gas phase density shall be used:

$Density_{NMHC} = 16.334\ g/ft^3$
$Density_{MeOH} = 37.718\ g/ft^3$
$Density_{EtOH} = 27.115\ g/ft^3$
$Density_{PrOH} = 23.581\ g/ft^3$
$Density_{FormHO} = 35.345\ g/ft^3$
$Density_{AcetHO} = 25.929\ g/ft^3$

To generate the NMOG figure, we need methanol, ethanol, 2-propanol, formaldehyde and acetaldehyde mass emissions as computed using Eq. (4) and (5) based on measured concentration values form the speciation results (as in Eq. (1) and (2)).

Finally, then, NMOG mass emissions can be computed as follows:

$$NMOG_{mass} = NMHC_{mass} + MeOH_{mass} + EtOH_{mass} + PrOH_{mass} + FormHO_{mass} + AcetHO_{mass} \qquad (6)$$

Once $NMOG_{mass}$ calculations have been completed for all three phases (cold transient (ct), stabilized (s) and hot transient (ht)) of the LA92 test cycle they, calculate the total weighted NMOG emissions using the following formula:

$$NMOG_{wm} = 0.43 \cdot \left(\frac{NMOG_{mass.ct} + NMOG_{mass.s}}{D_{ct} + D_s} \right) + 0.57 \cdot \left(\frac{NMOG_{mass.ht} + NMOG_{mass.s}}{D_{ht} + D_s} \right) \qquad (7)$$

For tests where there is no bag 2 or 3 speciation data, NMOG shall be computed assuming emission levels for oxygenated species in bags 2 and 3 are zero.

Attachment 1

Definitions

$NMHC_e$ – Concentration of NMHC in dilute exhaust sample, ppm C equivalent
$FIDHC_e$ - Uncorrected concentration of HC in dilute exhaust sample as measured by the FID, ppm C equivalent
$CH4_e$ – Concentration of methane in dilute exhaust sample as measured, ppm C equivalent
$MeOH_e$ - Concentration of methanol in dilute exhaust sample as measured, ppm C equivalent
$EtOH_e$ - Concentration of ethanol in dilute exhaust sample as measured, ppm C equivalent
$PrOH_e$ - Concentration of 2-propanol in dilute exhaust sample as measured, ppm C equivalent
$FormHO_e$ - Concentration of formaldehyde in dilute exhaust sample as measured, ppm C equivalent
$AcetHO_e$ - Concentration of acetaldehyde in dilute exhaust sample as measured, ppm C equivalent
$CO2_e$ - Concentration of carbon dioxide in dilute exhaust sample as measured, percent
CO_e - Concentration of carbon monoxide in dilute exhaust sample as measured, ppm
r_{CH4} - FID response to methane, ppmC/ppmC
r_{MeOH} - FID response to methanol, ppmC/ppmC
r_{EtOH} - FID response to ethanol, ppmC/ppmC
r_{PrOH} - FID response to 2-propanol, ppmC/ppmC
r_{FormHO} - FID response to formaldehyde, ppmC/ppmC
r_{AcetHO} - FID response to acetaldehyde, ppmC/ppmC
$NMHC_d$ - NMHC concentration in dilution air, ppm C equivalent
$FIDHC_d$ - Uncorrected HC concentration in dilution air sample as measured by the FID, ppm C equivalent
$CH4_d$ - Concentration of methane in dilution air sample as measured, ppm C equivalent
$MeOH_d$ - Concentration of methanol in dilution air sample as measured, ppm C equivalent
$EtOH_d$ - Concentration of ethanol in dilution air sample as measured, ppm C equivalent
$PrOH_d$ - Concentration of 2-propanol in dilution air sample as measured, ppm C equivalent
$FormHO_d$ - Concentration of formaldehyde in dilution air sample as measured, ppm C equivalent
$AcetHO_d$ - Concentration of acetaldehyde in dilution air sample as measured, ppm C equivalent
DF - Dilution factor
x - Carbon-to-carbon ratio in formula $C_xH_yO_z$ determined as in Appendix 2 for the fuel used (by definition x=1)
y - Hydrogen-to-carbon ratio in formula $C_xH_yO_z$ determined as in Appendix 2 for the fuel used
z - Oxygen-to-carbon ratio in formula $C_xH_yO_z$ determined as in Appendix 2 for the fuel used
X – Carbon mass fraction of the fuel
Y – Hydrogen mass fraction of the fuel
Z – Oxygen mass fraction of the fuel
$NMHC_{conc}$ – Concentration of NMHC in dilute exhaust sample corrected for background, ppm C equivalent
$MeOH_{conc}$ - Concentration of methanol in dilute exhaust sample corrected for background, ppm C equivalent
$EtOH_{conc}$ - Concentration of ethanol in dilute exhaust sample corrected for background, ppm C equivalent

$PrOH_{conc}$ - Concentration of 2-propanol in dilute exhaust sample corrected for background, ppm C equivalent
$FormHO_{conc}$ - Concentration of formaldehyde in dilute exhaust sample corrected for background, ppm C equivalent
$AcetHO_{conc}$ - Concentration of acetaldehyde in dilute exhaust sample corrected for background, ppm C equivalent
V_{mix} - Volume of dilute exhaust collected during a given phase of the test cycle, scf
$Density_{NMHC}$ – Density of NMHC treated as a C_1H_y ideal gas at standard conditions of 293.16°K and 760 mm Hg, g/ft^3
$Density_{MeOH}$ - Density of methanol treated as a $C_1H_yO_z$ ideal gas at standard conditions of 293.16°K and 760 mm Hg, g/ft^3
$Density_{EtOH}$ - Density of ethanol treated as a $C_1H_yO_z$ ideal gas at standard conditions of 293.16°K and 760 mm Hg, g/ft^3
$Density_{PrOH}$ - Density of 2-propanol treated as a $C_1H_yO_z$ ideal gas at standard conditions of 293.16°K and 760 mm Hg, g/ft^3
$Density_{FormHO}$ - Density of formaldehyde treated as a $C_1H_yO_z$ ideal gas at standard conditions of 293.16°K and 760 mm Hg,ft^3
$Density_{AcetHO}$ - Density of acetaldehyde treated as a $C_1H_yO_z$ ideal gas at standard conditions of 293.16°K and 760 mm Hg, g/ft^3
M_{NMHC} - Molecular mass of NMHC treated as a C_1H_y, g/mole, calculated according to the formula provided in Appendix 3
$NMOG_{mass}$ - NMOG mass, g/test phase
$NMHC_{mass}$ - NMHC mass, g/test phase
$MeOH_{mass}$ - Methanol mass, g/test phase
$EtOH_{mass}$ - Ethanol mass, g/test phase
$PrOH_{mass}$ - 2-propanol mass, g/test phase
$FormHO_{mass}$ - Formaldehyde mass, g/test phase
$AcetHO_{mass}$ - Acetaldehyde mass, g/test phase
$NMOG_{wm}$ – Weighted NMOG emissions, g/mile
$NMOG_{mass.ct}$ - NMOG mass emitted during the cold transient phase of the test cycle, g/test phase
$NMOG_{mass.s}$ - NMOG mass emitted during the stabilized phase of the test cycle, g/test phase
$NMOG_{mass.ht}$ - NMOG mass emitted during the hot transient phase of the test cycle, g/test phase
D_{ct} - Distance driven by the test vehicle on a chassis dynamometer during the cold transient phase of the LA92 test cycle, miles
D_s - Distance driven by the test vehicle on a chassis dynamometer during the stabilized phase of the LA92 test cycle, miles
D_{ht} - Distance driven by the test vehicle on a chassis dynamometer during the hot transient phase of the LA92 test cycle, miles

Attachment 2

Calculation of x, y and z Coefficients in Formula $C_xH_yO_z$ Using Fuel C, H and O Content Data

The carbon-to-carbon ratio x in formula $C_xH_yO_z$ by definition equals 1. The hydrogen-to-carbon and oxygen-to-carbon ratios y and z, respectively, can be calculated using the following equations:

$$y = \frac{\frac{Y}{1.008}}{\frac{X}{12.011}} \quad \text{(A2.1)} \qquad \text{and} \qquad z = \frac{\frac{Z}{15.999}}{\frac{X}{12.011}} \quad \text{(A2.2)}$$

where:

X – Carbon mass fraction of the fuel
Y – Hydrogen mass fraction of the fuel
Z – Oxygen mass fraction of the fuel

The values of X, Y and Z will be provided by the EPA for all fuels tested in the EPAct Program.

APPENDIX C

PHASE 6 TEST VEHICLE SPECIFICATIONS

TABLE C-1. PHASE 6 TEST VEHICLE SPECIFICATIONS

	NREL1	NREL2	NREL3	EPA-TSIE	EPA-JLIB	EPA-HCIV
Vehicle make	Dodge	Chevrolet	Ford	Toyota	Jeep	Honda
Vehicle model	Dakota	Tahoe	Taurus	Sienna	Liberty	Civic
Model year	1993	1996	1990	2008	2008	2008
VIN	1B7FL23X2DS156882	1GNEC13R5TJ350825	1FACP52U3LA176843	5TDZK23C88S122102	1J8GP28K88W156753	2HGFA16538H313195
Tire size (wheel size)	P205/70R15	235/75R15	P205/70R15	P215/65R16	P225/75R16	P205/55R16
Odometer	230,444	221,514	90,917	13,476	12,678	13,669
Engine displacement	3.9L	5.7L	3.0L	3.5L	3.7L	1.8L
Cylinders / Configuration (i.e. V6)	V6	V8	V6	V6	V6	I4
Engine code (Engine family)	*	TGM5.75PGFEK	LFM3.0V5FXD2	8TYXR0165P22	8CRXR0150GHH	8HNXR0106BBY
Engine evap code	*	TGM1098AYPBA	TWC/H025/EGR/MPI (F0AE-9C485)	8TYXT03.5BEM	8CRXT03.7NE0	8HNXV01.8LKR

* The emissions identification sticker was no longer on the vehicle.

APPENDIX D

ANALYTICAL EVALUATION RESULTS OF FUEL BATCHES

TABLE D-1. ANALYTICAL EVALUATION RESULTS OF THE FUEL BATCHES

			Batch 1	Batch 2	
			Matrix Tests 1-3	Matrix Tests 4-7	
		Description	Tank #75>19	Run Tank 160	Run Tank 161
			Bullet Sample	Bullet Sample	Bullet Sample
		Date	2/7/2011	06/04/13	06/04/13
ASTM Method	**TEST PROPERTY/DESCRIPTION**	**TEST UNITS**	**TEST RESULTS**	**RESULTS**	**RESULTS**
D5191	RVP by Grabner	psi	10.85	7.16	7.17
	RVP by Grabner (duplicate)	psi		7.18	7.22
D381	Existent Gums				
	Unwashed Wt.	mg/100 mL	17.5	17.0	18.5
	Washed Wt.	mg/100 mL	<0.5	<0.5	<0.5
	Duplicate GUMS				
	Unwashed Wt.	mg/100 mL	17.0	18.0	17.5
	Washed Wt.	mg/100 mL	<0.5	<0.5	<0.5
D4052	API Gravity	--	61.8	56.1	56.1
	Specific Gravity	--	0.7321	0.7542	0.7544
	Density @ 15°C	grams/L	731.8	754	754
D5599	Oxygen and Oxygenates				
	Diisopropylether (DIPE)	vol%	<0.1	<0.1	<0.1
	Ethyl tert-butylether (ETBE)	vol%	<0.1	<0.1	<0.1
	Ethanol (EtOH)	vol%	9.8	9.63	9.64
	Isobutanol (iBA)	vol%	<0.1	<0.1	<0.1
	Isopropanol (iPA)	vol%	<0.1	<0.1	<0.1
	Methanol (MeOH)	vol%	<0.1	<0.1	<0.1
	Methyl tert-butylether (MTBE)	vol%	<0.1	<0.1	<0.1
	n-Butanol (nBA)	vol%	<0.1	<0.1	<0.1
	n-Propanol (nPA)	vol%	<0.1	<0.1	<0.1
	sec-Butanol (sBA)	vol%	<0.1	<0.1	<0.1
	tert-amyl methylether (TAME)	vol%	<0.1	<0.1	<0.1
	tert-Butanol (tBA)	vol%	<0.1	<0.1	<0.1
	tert-Pentanol (tPA)	vol%	<0.1	<0.1	<0.1
	Total Oxygen	wt%	3.69	3.52	3.52
D86	Distillation (°F)				
	IBP	Deg. F	86	107	104
	5%	Deg. F	110	126	126
	10%	Deg. F	118	133	133
	15%	Deg. F	123	137	136
	20%	Deg. F	129	141	140
	30%	Deg. F	138	148	148
	40%	Deg. F	147	155	158
	50%	Deg. F	156	205	205
	60%	Deg. F	213	238	238
	70%	Deg. F	249	267	267
	80%	Deg. F	292	300	299
	90%	Deg. F	334	340	340
	95%	Deg. F	359	369	367
	FBP	Deg. F	397	424	422
	Recoverd	mL	98.6	97.5	98.4
	Residue	mL	1.1	0.6	0.6
	Loss	mL	0.3	1.9	1
D5453	Sulfur	ppm	19.9	40.0	40.6
	Sulfur	ppm	0.0019%	0.0040%	0.0041%
D5291	Carbon	%	82.79%	83.08	82.97
	Hydrogen	%	14.19%	13.45%	13.37%

APPENDIX E

OIL CONSUMPTION RESULTS

TABLE E-1. NREL OIL CONSUMPTION RESULTS

	Segment 1		
	Unified Cycle with No Cold Soaks		
Vehicle	HEDDAK	HECTAH	HEFTAU
Matrix Test Number	1	2	3
Vehicle Test Number	Test A	Test A	Test A
Vehicle make	Dodge	Chevrolet	Ford
Vehicle model	Dakota	Tahoe	Taurus
Model year	1993	1996	1990
VIN	1B7FL23X2DS156882	1GNEC13R5TJ350825	1FACP52U3LA176843
Engine Displacement (liters)	3.9L	5.7L	3.0L
Engine oil viscosity grade	5W-30	5W-30	5W-30
Inertia weight (lbs.)	3750	5250	3500
F2 (lbs./mph^2)	0.0332	0.0372	0.0101
F1 (Lbs./mph)	-0.3196	-0.3757	0.1614
F0 (Lbs.)	24.5	32.4	15.0
Start odometer (miles)	231,324	221,518	90,949
End odometer (miles)	232,065	222,119	94,751
Interval mileage	741	601	3,802
Oil installed (lbs.)	7.360	8.940	8.150
Oil drained including fuel dilution (lbs.)	3.480	5.840	5.500
Fuel dilution by D3525 (wt%)	4.2%	1.8%	5.8%
Oil drained minus fuel (lbs.)	3.33	5.73	5.18
Oil Consumed corrected for fuel dilution (lbs.)	4.03	3.21	2.97
Oil Consumption (lbs. per 1000 miles)	5.44	5.34	0.78
Oil Consumption (grams per 1000 miles)	2466.9	2422.7	354.3

* With fuel dilution

** Not yet corrected for fuel dilution

TABLE E-1 (CONT'D). NREL OIL CONSUMPTION RESULTS

	Segment 2				
	Unified Cycle with No Cold Soaks				Unified Cycle w/Cold Soaks
Vehicle	EPA-TSIE	EPA-JLIB	EPA-JLIB	EPA-HCIV	EPA-HCIV
Matrix Test Number	4	5	6	7	8
Vehicle Test Number	Test A	Test A	Test B	Test A	Test B
Vehicle make	Toyota	Jeep	Jeep	Honda	Honda
Vehicle model	Sienna	Liberty	Liberty	Civic	Civic
Model year	2008	2008	2008	2008	2008
VIN	5TDZK23C88S122102	1J8GP28K88W156753	1J8GP28K88W156753	2HGFA16538H313195	2HGFA16538H313195
Engine Displacement (liters)	3.5L V6	3.7L V6	3.7L V6	1.8L I4	1.8L I4
Engine oil viscosity grade	5W-30	5W-20	5W-20	5W-20	5W-20
Inertia weight (lbs.)	4500	4250	4250	3000	3000
F2 (lbs./mph^2)	0.02946	0.02955	0.02955	0.01699	0.01699
F1 (Lbs./mph)	0.0249	0.404	0.404	0.1904	0.1904
F0 (Lbs.)	38.41	29.53	29.53	23.18	23.18
Start odometer (miles)	13,476	12,678	17,678	13,681	18,692
End odometer (miles)	18,476	17,678	22,678	18,692	23,692
Interval mileage	5,000	5,000	5,000	5,011	5,000
Oil installed (lbs.)	11.120	8.840	8.850	6.895	6.900
Oil drained including fuel dilution (lbs.)	11.150	7.690	8.390	6.635	6.805
Fuel dilution by D3525 (wt%)	1.5%	1.4%	1.1%	2.7%	2.1%
Oil drained minus fuel (lbs.)	10.980	7.580	8.300	6.460	6.660
Oil Consumed corrected for fuel dilution (lbs.)	0.140	1.260	0.550	0.435	0.240
Oil Consumption (lbs. per 1000 miles)	0.028	0.252	0.110	0.087	0.048
Oil Consumption (grams per 1000 miles)	12.7	114.3	49.9	39.4	21.8