APPENDIX A

TEST FUEL INSPECTIONS,
FUEL SYSTEM RIG FUEL ANALYSIS MEASUREMENTS,
AND
FUEL SYSTEM RIG TEARDOWN PROCEDURES

APPENDIX A.1

TEST FUEL INSPECTIONS

Gage Products Company
Certificate of Analysis / QC Results

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Date: 11/30/10 at 10:24 AM

Customer PO # :

Packaged Product: BPF0031-55F
E0 Regular Gasoline

Property	Test Method	UOM	Specification	Value
SPECIFIC GRAVITY @ 60F	ASTM D4052	REPORT	REPORT	0.7527
DENSITY @60F	Report	LB/GAL	REPORT	6.272
DISTILLATION, IBP	ASTM D86	DEG F	REPORT	88.5
DISTILLATION, 5%	ASTM D86	DEG F	REPORT	107.4
DISTILLATION, 10%	ASTM D86	DEG F	REPORT	119.5
DISTILLATION, 20%	ASTM D86	DEG F	REPORT	144.0
DISTILLATION, 30%	ASTM D86	DEG F	REPORT	172.4
DISTILLATION, 40%	ASTM D86	DEG F	REPORT	202.6
DISTILLATION, 50%	ASTM D86	DEG F	REPORT	230.9
DISTILLATION, 60%	ASTM D86	DEG F	REPORT	255.0
DISTILLATION, 70%	ASTM D86	DEG F	REPORT	279.9
DISTILLATION, 80%	ASTM D86	DEG F	REPORT	307.9
DISTILLATION, 90%	ASTM D86	DEG F	REPORT	335.7
DISTILLATION, 95%	ASTM D86	DEG F	REPORT	353.7
DISTILLATION, DP	ASTM D86	DEG F	REPORT	400.6
RECOVERY	ASTM D86	VOL.%	REPORT	97.8
RESIDUE	ASTM D86	VOL.%	REPORT	1.2
LOSS	ASTM D86	VOL.%	REPORT	1.0
RVP @ 100F	ASTM D5191	PSI	REPORT	10.98
AROMATICS	ASTM D1319	VOL.%	REPORT	39.19
OLEFINS	ASTM D1319	VOL.%	REPORT	3.14
SATURATES	ASTM D1319	VOL.%	REPORT	57.67
TOTAL SULFUR	ASTM D5453	PPM	80, MAX.	16.23

Lot # 2188100 Made 11/16/10

In sealed unopened containers this product is good until 05/05/11

Approved By: Robert Patzelt

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Date: 11/30/10 at 10:25 AM

Gage Products Company
Certificate of Analysis / QC Results

Customer PO # :

Packaged Product: BPF0032-55F
E10 Regular Gasoline

Property	Test Method	UOM	Specification	Value
SPECIFIC GRAVITY @ 60F	ASTM D4052	REPORT	REPORT	0.7561
DENSITY @60F	Report	LB/GAL	REPORT	6.301
ETHANOL CONTENT	Gas Chromatography	VOL.%	9.00 - 10.00	10.00
DISTILLATION, IBP	ASTM D86	DEG F	REPORT	86.5
DISTILLATION, 5%	ASTM D86	DEG F	REPORT	105.6
DISTILLATION, 10%	ASTM D86	DEG F	REPORT	115.2
DISTILLATION, 20%	ASTM D86	DEG F	REPORT	131.5
DISTILLATION, 30%	ASTM D86	DEG F	REPORT	145.4
DISTILLATION, 40%	ASTM D86	DEG F	REPORT	156.0
DISTILLATION, 50%	ASTM D86	DEG F	REPORT	199.8
DISTILLATION, 60%	ASTM D86	DEG F	REPORT	245.3
DISTILLATION, 70%	ASTM D86	DEG F	REPORT	271.2
DISTILLATION, 80%	ASTM D86	DEG F	REPORT	301.6
DISTILLATION, 90%	ASTM D86	DEG F	REPORT	333.0
DISTILLATION, 95%	ASTM D86	DEG F	REPORT	354.9
DISTILLATION, DP	ASTM D86	DEG F	REPORT	397.9
RECOVERY	ASTM D86	VOL.%	REPORT	97.4
RESIDUE	ASTM D86	VOL.%	REPORT	1.2
LOSS	ASTM D86	VOL.%	REPORT	1.4
RVP @ 100F	ASTM D5191	PSI	REPORT	11.79
TOTAL SULFUR	ASTM D5453	PPM	REPORT	13.23

Lot # 2188300 **Made** 11/18/10

In sealed unopened containers this product is good until 05/05/11

Approved By: Robert Patzelt

Page: 1

Date: 11/30/10 at 10:26 AM

Gage Products Company

Certificate of Analysis / QC Results

Customer PO # :

Packaged Product: BPF0033-55C
Aggressive E20 Gasoline

Property	Test Method	UOM	Specification	Value
SPECIFIC GRAVITY @ 60F	ASTM D4052	REPORT	REPORT	0.7595
DENSITY @60F	Report	LB/GAL	REPORT	6.329
ETHANOL CONTENT	Gas Chromatography	VOL.%	19.00 - 20.00	19.53
DISTILLATION, IBP	ASTM D86	DEG F	REPORT	90.5
DISTILLATION, 5%	ASTM D86	DEG F	REPORT	107.2
DISTILLATION, 10%	ASTM D86	DEG F	REPORT	117.9
DISTILLATION, 20%	ASTM D86	DEG F	REPORT	135.9
DISTILLATION, 30%	ASTM D86	DEG F	REPORT	149.4
DISTILLATION, 40%	ASTM D86	DEG F	REPORT	159.4
DISTILLATION, 50%	ASTM D86	DEG F	REPORT	165.7
DISTILLATION, 60%	ASTM D86	DEG F	REPORT	169.2
DISTILLATION, 70%	ASTM D86	DEG F	REPORT	259.9
DISTILLATION, 80%	ASTM D86	DEG F	REPORT	289.9
DISTILLATION, 90%	ASTM D86	DEG F	REPORT	326.5
DISTILLATION, 95%	ASTM D86	DEG F	REPORT	348.6
DISTILLATION, DP	ASTM D86	DEG F	REPORT	397.9
RECOVERY	ASTM D86	VOL.%	REPORT	97.4
RESIDUE	ASTM D86	VOL.%	REPORT	0.8
LOSS	ASTM D86	VOL.%	REPORT	1.8
RVP @ 100F	ASTM D5191	PSI	REPORT	11.49
TOTAL SULFUR	ASTM D5453	PPM	REPORT	11.86
WATER CONTENT	ASTM E1064	PPM	REPORT	0.298
PEROXIDE CONTENT	ASTM D3703	PPM	REPORT	6.15
ACID NUMBER	ASTM D974	MG KOH/G	REPORT	0.056
INORGANIC CHLORIDE CONTENT	ION CHROMATOGRAPHY	PPM	REPORT	1.0
NITRATE CONTENT	IC	PPM	REPORT	2.9
TOTAL SULFATE CONTENT	ION CHROMATOGRAPHY	PPM	REPORT	0.8
INORGANIC CHLORIDE CONTENT (CALCULATED)	CALCULATED	PPM	REPORT	2.0
NITRATE CONTENT (CALCULATED)	CALCULATED	PPM	REPORT	3.7
TOTAL SULFATE CONTENT (CALCULATED)	CALCULATED	PPM	REPORT	0.8

Lot # 2188500 **Made** 11/24/10

In sealed unopened containers this product is good until 05/05/11

Approved By: Robert Patzett

Gage Products Company
821 Wanda Ave ♦ Ferndale MI 48220
(248) 541-3824 ♦ Fax (248) 541-0643

Certificate of Analysis

Product Name: FUEL GRADE ETHANOL **[E98]**

Date: 11/30/10

PROPERTY	TEST METHOD	UOM	SPECIFICATION	RESULTS
WATER	E1064	VOL %	1.0, MAX.	0.79
SPEC.GRAV. @ 60 F	ASTM D1298		REPORT	0.7943
FLASHPOINT	ASTM D93	C	REPORT	< 40 F
GUM (SOLVENT WASHED)	ASTM D381	mg/100 ml	5, MAX.	1
SULFUR	ASTM D5453	ppm	30, MAX.	2
SULFATE	ASTM D7328	ppm	4, MAX.	< 0.1
NITRATE	ASTM D7328	ppm	REPORT	< 0.1
CHLORIDE	ASTM D7328	ppm	10, MAX.	< 0.1
COPPER CONTENT	ICP	mg/kg	0.1, MAX.	< 0.01
TOTAL ACID NUMBER	ASTM D974	mg KOH/g	REPORT	19
pHe	ASTM D6423		6.5 – 9.0	7.46
SODIUM	ICP	ppm	REPORT	< 0.1
CALCIUM	ICP	ppm	REPORT	< 0.1
POTASSIUM	ICP	ppm	REPORT	< 0.1

This information is offered for your consideration, investigation and verification. It should not be construed as a warranty or guaranty.

Gage Products Company
821 Wanda Ave ♦ Ferndale MI 48220
(248) 541-3824 ♦ Fax (248) 541-0643

Certificate of Analysis

Product Name: AGGRESSIVE ETHANOL **[E98$_A$]**

Date: 11/30/10

PROPERTY	TEST METHOD	UOM	SPECIFICATION	RESULTS
WATER	ASTM E1064	VOL %	1.0, MAX.	0.79
SPEC.GRAV. @ 60 F	ASTM D1298		REPORT	0.7956
TOTAL ACID NUMBER	ASTM D974	mg KOH/g	REPORT	140.
pHe	ASTM D6423		REPORT	2.3
SULFATE	ASTM D7328	ppm	4, MAX.	3.8
NITRATE	ASTM D7328	ppm	REPORT	14.3
CHLORIDE	ASTM D7328	ppm	10, MAX.	4.9
SULFATE (CALCULATED)	ASTM D7328	ppm	4, MAX.	4.0
NITRATE (CALCULATED)	ASTM D7328	ppm	REPORT	18.6
CHLORIDE (CALCULATED)	ASTM D7328	ppm	10, MAX.	10.0

This information is offered for your consideration, investigation and verification. It should not be construed as a warranty or guaranty.

APPENDIX A.2

FUEL SYSTEM RIG FUEL MEASUREMENTS

The following table summarizes the test rigs by test fuel type (E10, $E20_A$) and vehicle fuel system.

Rig #	Test Fuel	Vehicle Fuel System Description
1	E10	Vehicle M
2	$E20_A$	Vehicle M
3	$E20_A$	Vehicle A
4	E10	Vehicle A
5	$E20_A$	Vehicle C
6	E10	Vehicle F
7	E10	Vehicle C
8	$E20_A$	Vehicle F
9	$E20_A$	Vehicle J
10	$E20_A$	Vehicle K
11	E20	Vehicle G
12	E10	Vehicle K
13	E10	Vehicle G

FUEL SAMPLE TESTS AND SCHEDULE

The types of analyses that were performed on fuel samples drawn from the test rigs and the frequency with which the measurements were conducted is shown in the table below. The fuel in the rigs was changed once per week up to, and including, Week 14. The fuel was then changed every two weeks up to, and including, Week 28. Thereafter, it was changed every three weeks until the end of the rig evaluation. Fuel samples from each rig were taken at each fuel change out, and some of the samples were analyzed to determine the condition of the fuel. These data were used to determine if any metals from the fuel rigs were dissolving into the fuel, and to determine if the rig test temperatures were degrading the fuel.

		Week of Soak										
Type of Analysis	Method Reference	1	2	3	4	5	6	8	11	12	13	14
PHe	ASTM D6423		X			X				X		
Karl Fisher Water Content	ASTM E203			X			X				X	
Metals by ICP-MS*	EPA SW 846-6020	X	X	X				X			X	X
Inorganic Chloride in Fuel	Paragon SOP A0205				X				X			
Peroxide Content	ASTM D3703	X			X							
Total Acid Number	ASTM D664	X			X							

		Week of Soak											
Type of Analysis	Method Reference	16	20	22	24	28	31	34	37	40	43	46	49
PHe	ASTM D6423		X	X			X			X			
Karl Fisher Water Content	ASTM E203				X	X		X			X		
Metals by ICP-MS*	EPA SW 846-6020												
Inorganic Chloride in Fuel	Paragon SOP A0205					X							X
Peroxide Content	ASTM D3703	X							X				
Total Acid Number	ASTM D664	X							X				

The test fuel analysis measurements made throughout the program are summarized in the 24 tables below.

Total Acid Number (TAN) at Week 1 was higher for the $E20_A$ test rigs than it was for the E10 test rigs, but this was expected since the $E20_A$ test fuel contained aggressive components. However, the TANs of the samples taken from fuels that had soaked in the rigs both for 2 weeks between fuel change intervals (e.g., Week 16 sample) and for 3 weeks between fuel change intervals (e.g., Week 37 sample) were similar, i.e. the E10 and $E20_A$ rigs.

Table A.1[1]

Total Acid Number - ASTM D664
(mg KOH/g)

Fuel	Fuel Rig Description	Week 1	Week 4	Week 16	Week 37
E10	Vehicle M	Below	Below	0.02	0.23
$E20_A$	Vehicle M	0.03	Below	0.05	0.1
E10	Vehicle A	0.01	Below	0.03	0.08
$E20_A$	Vehicle A	0.02	Below	0.05	0.11
E10	Vehicle C	Below	0.46		0.06
$E20_A$	Vehicle C	0.02	Below	0.05	0.11
E10	Vehicle F	0.02	Below	0.02	0.08
$E20_A$	Vehicle F	0.04	Below	0.03	0.08
$E20_A$	Vehicle J	0.04	Below	0.04	0.08
E10	Vehicle K	Below	Below		0.06
$E20_A$	Vehicle K	0.05	0.02	0.04	0.09
E10	Vehicle G	Below	Below	0.02	0.06
$E20_A$	Vehicle G	Below	0.03	0.02	0.09

As with the TANs, the peroxide numbers of the samples from the $E20_A$ rigs were generally higher than those measured from the rigs soaked with E10 at Week 1. However, at Weeks 4, 16, and 37, the peroxide numbers of fuel samples drawn from the E10 and $E20_A$ rigs were generally comparable. It is interesting to note that the Week 4 sample and Week 1 sample were both in the

[1] Note: In Tables A.1 through A.24, an entry with the word "below" means below detection limits, and detection limits for most all of the measured properties are provided in Table A.25. A blank entry indicates that no measurement was made.

rigs for only one week (due to weekly fuel change outs), yet the Week 4 samples had higher peroxide numbers for the E10 blends. One possible explanation is that the E10 fuel in bulk storage had an increase in peroxide number.

Table A.2

Peroxide Number - ASTM D3703 (mg/Kg)

Fuel	Fuel Rig Description	Week 1	Week 4	Week 16	Week 37
E10	Vehicle M	13.9	16.3	35.6	46.3
$E20_A$	Vehicle M	21.9	30.7	44.1	34.3
E10	Vehicle A	4.8	21.5	52.6	48.7
$E20_A$	Vehicle A	5.7	27.9	46.2	48.9
E10	Vehicle C	5.5	18.0	27.5	36
$E20_A$	Vehicle C	18.2	17.1	55.2	27.6
E10	Vehicle F	13.1	10.2	23.6	37.1
$E20_A$	Vehicle F	10.0	11.1	25.5	23.1
$E20_A$	Vehicle J	21.6	23.9	33.1	28.4
E10	Vehicle K	2.0	21.2	44.9	46.7
$E20_A$	Vehicle K	14.4	27.1	51.3	46.3
E10	Vehicle G	3.6	12.3	44.7	33.7
$E20_A$	Vehicle G	12.3	26.6	46.2	46.3

pHe - The pHe of the fuel varied from week to week and from rig to rig, but all of the samples were relatively "neutral" throughout the trial. However, it must be stated that this test method for pHe, ASTM D6423, is intended for denatured ethanol, and not $E20_A$.

Table A.3

pHe - ASTM D6423

Fuel	Fuel Rig Description	Week 2	Week 5	Week 12	Week 20	Week 22	Week 31	Week 40
E10	Vehicle M	7.84	7.27	6.45	5.58	6.67	6.33	7.35
$E20_A$	Vehicle M	6.94	6.42	5.7	6	6.62	5.85	6.87
E10	Vehicle A	6.94	7.04	6.25	7.03	7.02	6.53	8.2
$E20_A$	Vehicle A		6.37	5.44	5.3	6.35	5.59	7.23
E10	Vehicle C	5.90	7.00	6.59	6.01	7.76	6.69	8.31
$E20_A$	Vehicle C	6.58	6.65	5.45	6.25	6.36	5.98	7.18
E10	Vehicle F	6.88	6.85	7.26	6.28	7.53	6.84	8.46
$E20_A$	Vehicle F	7.17	6.65	6.21	6.43	6.79	6.36	7.75
$E20_A$	Vehicle J	6.67	6.08	6.1	6.64	6.94	6.1	7.56
E10	Vehicle K	7.46	7.08	7.03	6.86	6.28	6.58	7.45
$E20_A$	Vehicle K	6.38	5.99	5.92	6.04	5.08	5.83	7.1
E10	Vehicle G	6.28	7.34	7.28	7.12	6.79	6.75	7.67
$E20_A$	Vehicle G	7.16	6.23	5.82	6.53	5.45	5.72	6.87

The water content also was measured for the fuel samples. The water content at Week 13 (after one week in rigs) was lower for the E10 than it was on Week 3 (also after one week in the rigs). The lower amount of water can also be seen in the samples drawn during Week 24 and 28, both of which were in the rigs for two weeks. The most probable cause for this change is a temperature change in the bulk fuel storage that allowed more or less water to dissolve in the fuel depending on the ambient storage conditions.

Table A.4

Water Content - ASTM E203
(ppm m/m)

Fuel	Fuel Rig Description	Week 3	Week 6	Week 13	Week 24	Week 28	Week 34	Week 43
E10	Vehicle M	2,254	3,598	971	939	917	1,022	1,032
$E20_A$	Vehicle M	1,751	3,255	1,784		1,668	1,886	1,808
E10	Vehicle A	1,685	1,658	970	898	831	1,011	1,223
$E20_A$	Vehicle A	1,685	1,729	1,971	1,577	1,662	2,079	1,734
E10	Vehicle C	1,360	1,206	960	926	825	1,128	1,107
$E20_A$	Vehicle C		2,605	1,418	1,681	1,578	1,574	1,710
E10	Vehicle F	1,626	1,197	976	847	849	2,247	1,358
$E20_A$	Vehicle F	3,129	1,972	1,678	1,499	1,775	1,998	1,765
$E20_A$	Vehicle J	2,753	3,193	1,448	1,579	1,703	1,849	1,921
E10	Vehicle K	2,887	2,365	1,693	1,607	1,607	1,890	1,803
$E20_A$	Vehicle K	1,580	1,235	1,083	891	801	900	998
E10	Vehicle G	3,206	1,411	963	870	838		1,051
$E20_A$	Vehicle G	1,649	3,175	1,398	1,590	1,696	1,834	1,856

The inorganic chloride levels measured in the fuel samples drawn from the $E20_A$ rigs was always higher than those obtained from the E10 rigs, but this was expected since chlorides were purposely added to the $E20_A$ fuel to make it aggressive.

Table A.5

Inorganic Chloride - EPA 300.0
(0.74 mg/L)

Fuel	Fuel Rig Description	Week 4	Week 11	Week 28	Week 49
E10	Vehicle M	0.74	0.50	0.35	0.36
$E20_A$	Vehicle M	0.72	0.77	0.73	0.7
E10	Vehicle A	0.40	0.48	0.37	0.34
$E20_A$	Vehicle A	0.91	0.69	0.78	0.58
E10	Vehicle C	0.37	0.30	0.33	0.28
$E20_A$	Vehicle C	0.74	1.20	0.74	0.55
E10	Vehicle F	0.44	0.34	0.36	0.33
$E20_A$	Vehicle F	0.87	3.70	0.66	
$E20_A$	Vehicle J	0.74	0.69	0.68	0.47
E10	Vehicle K	0.31	0.35	0.34	0.33
$E20_A$	Vehicle K	0.84	1.30	0.62	
E10	Vehicle G	0.29	0.35	0.75	0.33
$E20_A$	Vehicle G	0.66	0.74	0.85	0.57

Tables A.6 through A.24 present analysis results for select metals using the Inductively Coupled Plasma – Mass Spectroscopy (ICP-MS) test per EPA 6020A. The results are all in parts per million (ppm). There is nothing remarkable about these results.

Table A.6

Boron

Fuel	Fuel Rig Description	Week 1	Week 2	Week 3	Week 8	Week 13	Week 14
E10	Vehicle M	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle M	Below	Below	Below	Below	Below	Below
E10	Vehicle A	0.009	0.005	Below	Below	Below	Below
$E20_A$	Vehicle A	0.013		0.016	Below	Below	Below
E10	Vehicle C	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle C	Below	Below		Below	Below	Below
E10	Vehicle F	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle F	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle J	Below	Below	Below	Below	Below	Below
E10	Vehicle K	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle K	Below	Below	Below	Below	Below	Below
E10	Vehicle G	0.012	Below	Below	Below	Below	Below
$E20_A$	Vehicle G	Below	Below	Below	Below	Below	Below

Table A.7

Sodium

Fuel	Fuel Rig Description	Week 1	Week 2	Week 3	Week 8	Week 13	Week 14
E10	Vehicle M	0.36	0.40	0.62	0.50	0.41	0.38
$E20_A$	Vehicle M	0.51	0.72	0.64	0.45	0.5	0.4
E10	Vehicle A	0.48	0.48	0.46	0.36	0.38	0.41
$E20_A$	Vehicle A	0.67		0.82	0.58	0.61	0.52
E10	Vehicle C	0.31	0.49	0.55	0.32	0.38	0.34
$E20_A$	Vehicle C	0.54	0.41		0.42	0.59	0.31
E10	Vehicle F	0.36	0.76	0.56	0.32	0.38	0.38
$E20_A$	Vehicle F	0.63	0.44	1.00	0.56	0.53	0.57
$E20_A$	Vehicle J	0.51	0.60	0.71	0.42	0.51	0.46
E10	Vehicle K	0.67	0.48	0.32	0.30	0.46	0.34
$E20_A$	Vehicle K	0.52	0.58	0.54	0.43	0.44	0.42
E10	Vehicle G	0.48	0.35	0.68	0.34		0.56
$E20_A$	Vehicle G	0.42	0.50	0.59	0.54	0.45	0.66

Table A.8

Magnesium

Fuel	Fuel Rig Description	Week 1	Week 2	Week 3	Week 8	Week 13	Week 14
E10	Vehicle M	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle M	Below	Below	Below	Below	Below	Below
E10	Vehicle A	0.11	Below	Below	Below	Below	Below
$E20_A$	Vehicle A	Below		Below	Below	Below	Below
E10	Vehicle C	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle C	Below	Below		Below	Below	Below
E10	Vehicle F	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle F	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle J	Below	Below	Below	Below	Below	Below
E10	Vehicle K	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle K	Below	Below	Below	Below	Below	Below
E10	Vehicle G	Below	Below	Below	Below	0.4	Below
$E20_A$	Vehicle G	Below	0.14	Below	Below	Below	Below

Table A.9

Aluminum

Fuel	Fuel Rig Description	Week 1	Week 2	Week 3	Week 8	Week 13	Week 14
E10	Vehicle M	0.028	0.644	0.046	0.020	0.06	2
$E20_A$	Vehicle M	0.031	0.022	0.062	0.044	0.03	0.02
E10	Vehicle A	0.559	0.030	0.024	0.017	0.05	0.09
$E20_A$	Vehicle A	0.039		0.019	0.026	0.06	0.03
E10	Vehicle C	0.027	0.015	0.069	0.021		0.09
$E20_A$	Vehicle C	0.028	0.016		0.054	0.1	0.01
E10	Vehicle F	0.024	0.027	0.040	0.013	0.04	0.22
$E20_A$	Vehicle F	0.013	0.028	0.045	0.022	0.07	0.04
$E20_A$	Vehicle J	0.015	0.024	0.039	0.011	0.02	0.03
E10	Vehicle K	0.037	0.011	0.014	0.016	0.04	0.2
$E20_A$	Vehicle K	0.023	0.018	0.023	0.010	0.05	0.06
E10	Vehicle G	0.027	0.061	0.016	0.020	0.05	0.02
$E20_A$	Vehicle G	0.051	0.054	0.031	0.010	0.05	0.04

Table A.10

Potassium

Fuel	Fuel Rig Description	Week 1	Week 2	Week 3	Week 8	Week 13	Week 14
E10	Vehicle M	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle M	Below	Below	Below	Below	Below	Below
E10	Vehicle A	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle A	Below		Below	Below	0.12	Below
E10	Vehicle C	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle C	Below	Below		Below	Below	Below
E10	Vehicle F	Below	Below	0.34	Below	Below	Below
$E20_A$	Vehicle F	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle J	Below	Below	Below	Below	Below	Below
E10	Vehicle K	Below	Below	Below	0.11	Below	Below
$E20_A$	Vehicle K	Below	Below	Below	Below	Below	Below
E10	Vehicle G	0.10	Below	Below	Below	Below	0.12
$E20_A$	Vehicle G	Below	Below	Below	Below	Below	Below

Table A.11

Calcium

Fuel	Fuel Rig Description	Week 1	Week 2	Week 3	Week 8	Week 13	Week 14
E10	Vehicle M	0.4	0.3	0.2	0.1	0.23	0.1
$E20_A$	Vehicle M	0.2	0.7	1.0	0.2	0.14	Below
E10	Vehicle A	1.1	0.3	0.1	0.2	0.19	Below
$E20_A$	Vehicle A	2.1		0.3	0.1	0.28	Below
E10	Vehicle C	0.2	Below	0.1	Below	Below	0.28
$E20_A$	Vehicle C	0.3	0.2		0.2	0.37	Below
E10	Vehicle F	0.0	0.2	Below	0.1	0.26	0.51
$E20_A$	Vehicle F	0.2	0.1	Below	0.1	0.27	0.25
$E20_A$	Vehicle J	0.1	0.1	0.2	Below	Below	0.13
E10	Vehicle K	0.2	0.2	0.1	Below	0.18	0.7
$E20_A$	Vehicle K	0.1	0.2	0.2	Below	0.24	0.24
E10	Vehicle G	1.1	0.1	0.2	0.2	0.21	0.18
$E20_A$	Vehicle G	0.6	1.3	0.3	0.1	0.18	0.16

Table A.12

Titanium

Fuel	Fuel Rig Description	Week 1	Week 2	Week 3	Week 8	Week 13	Week 14
E10	Vehicle M	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle M	Below	Below	Below	Below	Below	Below
E10	Vehicle A	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle A	Below		Below	Below	Below	Below
E10	Vehicle C	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle C	Below	Below		Below	Below	Below
E10	Vehicle F	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle F	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle J	Below	Below	Below	Below	Below	Below
E10	Vehicle K	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle K	Below	Below	Below	Below	Below	Below
E10	Vehicle G	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle G	Below	Below	Below	Below	Below	Below

Table A.13

Chromium

Fuel	Fuel Rig Description	Week 1	Week 2	Week 3	Week 8	Week 13	Week 14
E10	Vehicle M	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle M	Below	Below	Below	Below	Below	Below
E10	Vehicle A	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle A	0.007		Below	Below	Below	Below
E10	Vehicle C	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle C	Below	Below		Below	Below	Below
E10	Vehicle F	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle F	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle J	Below	Below	Below	Below	Below	Below
E10	Vehicle K	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle K	Below	Below	Below	Below	Below	Below
E10	Vehicle G	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle G	0.005	Below	Below	Below	Below	Below

Table A.14

Manganese

Fuel	Fuel Rig Description	Week 1	Week 2	Week 3	Week 8	Week 13	Week 14
E10	Vehicle M	Below	Below	0.011	Below	Below	Below
$E20_A$	Vehicle M	Below	Below	Below	Below	Below	Below
E10	Vehicle A	Below	Below	Below	0.014	Below	Below
$E20_A$	Vehicle A	Below		Below	Below	Below	Below
E10	Vehicle C	Below	Below	Below	0.013	Below	Below
$E20_A$	Vehicle C	0.010	Below		Below	0.01	0.03
E10	Vehicle F	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle F	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle J	Below	Below	Below	0.034	Below	0.01
E10	Vehicle K	Below	Below	Below	Below	Below	0.02
$E20_A$	Vehicle K	Below	Below	Below	Below	Below	Below
E10	Vehicle G	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle G	Below	Below	Below	Below	Below	Below

Table A.15

Iron

Fuel	Fuel Rig Description	Week 1	Week 2	Week 3	Week 8	Week 13	Week 14
E10	Vehicle M	Below	Below	3.75	Below	Below	0.14
$E20_A$	Vehicle M	Below	Below	Below	Below	Below	Below
E10	Vehicle A	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle A	Below		Below	Below	Below	Below
E10	Vehicle C	Below	Below	Below	Below	Below	0.11
$E20_A$	Vehicle C	Below	Below		Below	Below	0.16
E10	Vehicle F	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle F	Below	Below	Below	Below	Below	0.11
$E20_A$	Vehicle J	Below	Below	Below	Below	Below	0.12
E10	Vehicle K	Below	Below	Below	Below	Below	0.13
$E20_A$	Vehicle K	Below	Below	Below	Below	Below	0.03
E10	Vehicle G	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle G	Below	Below	Below	Below	Below	Below

Table 16

Cobalt

Fuel	Fuel Rig Description	Week 1	Week 2	Week 3	Week 8	Week 13	Week 14
E10	Vehicle M	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle M	Below	Below	Below	Below	Below	Below
E10	Vehicle A	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle A	Below		Below	Below	Below	Below
E10	Vehicle C	Below	Below		Below	Below	Below
$E20_A$	Vehicle C	Below	Below	Below	Below	Below	Below
E10	Vehicle F	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle F	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle J	Below	Below	Below	Below	Below	Below
E10	Vehicle K	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle K	Below	Below	Below	Below	Below	Below
E10	Vehicle G	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle G	Below	Below	Below	Below	Below	Below

Table A.17

Nickel

Fuel	Fuel Rig Description	Week 1	Week 2	Week 3	Week 8	Week 13	Week 14
E10	Vehicle M	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle M	Below	Below	Below	Below	Below	Below
E10	Vehicle A	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle A	Below		Below	Below	Below	Below
E10	Vehicle C	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle C	Below	Below		Below	Below	Below
E10	Vehicle F	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle F	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle J	Below	Below	Below	Below	Below	Below
E10	Vehicle K	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle K	Below	Below	Below	Below	Below	Below
E10	Vehicle G	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle G	Below	Below	Below	Below	Below	Below

Table A.18

Copper

Fuel	Fuel Rig Description	Week 1	Week 2	Week 3	Week 8	Week 13	Week 14
E10	Vehicle M	0.018	0.019	0.015	0.014	0.019	0.014
$E20_A$	Vehicle M	0.022	0.026	0.033	0.021	0.029	0.024
E10	Vehicle A	0.020	0.022	0.011	0.012	0.015	0.015
$E20_A$	Vehicle A	0.048		0.058	0.034	0.055	0.038
E10	Vehicle C	0.006	0.007	0.009	0.008	0.006	0.01
$E20_A$	Vehicle C	0.005	0.005		0.008	0.008	0.012
E10	Vehicle F	0.013	0.016	0.024	0.011	0.014	0.016
$E20_A$	Vehicle F	0.024	0.031	0.026	0.019	0.026	0.025
$E20_A$	Vehicle J	0.013	0.017	0.025	0.021	0.031	0.024
E10	Vehicle K	0.011	0.009	Below	0.006	0.01	0.012
$E20_A$	Vehicle K	0.022	0.020	0.016	0.023	0.02	0.017
E10	Vehicle G	0.016	0.010	0.009	Below	0.01	0.01
$E20_A$	Vehicle G	0.011	0.017	0.010	0.009	0.015	0.016

Table A.19

Zinc

Fuel	Fuel Rig Description	Week 1	Week 2	Week 3	Week 8	Week 13	Week 14
E10	Vehicle M	0.17	0.38	4.71	0.10	0.12	0.14
$E20_A$	Vehicle M	0.21	0.27	0.62	0.25	0.17	0.19
E10	Vehicle A	0.97	0.27	0.59	0.24	0.1	0.12
$E20_A$	Vehicle A	1.24		0.36	0.20	0.26	0.18
E10	Vehicle C	0.50	1.73	0.11	0.22	0.24	0.14
$E20_A$	Vehicle C	0.21	0.26		1.56	0.24	0.29
E10	Vehicle F	0.44	10.70	0.23	0.18	0.13	0.19
$E20_A$	Vehicle F	2.19	1.04	0.95	0.28	0.31	0.33
$E20_A$	Vehicle J	0.17	0.13	0.29	0.65	0.3	0.23
E10	Vehicle K	8.63	0.12	0.14	0.13	0.11	0.93
$E20_A$	Vehicle K	1.17	0.39	0.33	0.18	0.37	0.25
E10	Vehicle G	0.66	0.76	0.09	0.09	0.12	0.08
$E20_A$	Vehicle G	0.32	0.39	4.94	0.16	0.27	0.28

Table A.20

Molybdenum

Fuel	Fuel Rig Description	Week 1	Week 2	Week 3	Week 8	Week 13	Week 14
E10	Vehicle M	Below	Below	Below	Below	Below	0.02
$E20_A$	Vehicle M	Below	Below	Below	0.013	Below	0.01
E10	Vehicle A	Below	Below	Below	0.016	Below	Below
$E20_A$	Vehicle A	Below		0.121	0.006	Below	0.01
E10	Vehicle C	Below	Below	0.046	0.025	Below	Below
$E20_A$	Vehicle C	Below	Below		0.026	0.04	Below
E10	Vehicle F	Below	Below	Below	0.082	Below	Below
$E20_A$	Vehicle F	Below	Below	0.005	0.012	0.03	Below
$E20_A$	Vehicle J	Below	0.034	0.013	0.034	Below	Below
E10	Vehicle K	Below	0.008	0.050	Below	Below	Below
$E20_A$	Vehicle K	Below	0.076	0.012	Below	Below	Below
E10	Vehicle G	Below	0.029	0.025	0.012	0.01	Below
$E20_A$	Vehicle G	Below	0.242	0.023	0.009	Below	Below

Table A.21

Silver

Fuel	Fuel Rig Description	Week 1	Week 2	Week 3	Week 8	Week 13	Week 14
E10	Vehicle M	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle M	Below	Below	Below	Below	Below	Below
E10	Vehicle A	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle A	Below		Below	Below	Below	Below
E10	Vehicle C	Below	0.031	Below	0.007	Below	Below
$E20_A$	Vehicle C	Below	Below		Below	Below	Below
E10	Vehicle F	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle F	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle J	Below	Below	Below	Below	Below	Below
E10	Vehicle K	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle K	Below	Below	Below	Below	Below	Below
E10	Vehicle G	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle G	Below	Below	Below	Below	Below	Below

Table A.22

Cadmium

Fuel	Fuel Rig Description	Week 1	Week 2	Week 3	Week 8	Week 13	Week 14
E10	Vehicle M	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle M	Below	Below	Below	Below	Below	Below
E10	Vehicle A	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle A	Below		Below	Below	Below	Below
E10	Vehicle C	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle C	Below	Below		Below	Below	Below
E10	Vehicle F	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle F	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle J	Below	Below	Below	Below	Below	Below
E10	Vehicle K	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle K	Below	Below	Below	Below	Below	Below
E10	Vehicle G	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle G	Below	Below	Below	Below	Below	Below

Table A.23

Tin

Fuel	Fuel Rig Description	Week 1	Week 2	Week 3	Week 8	Week 13	Week 14
E10	Vehicle M	Below	0.014	0.296	Below	0.13	Below
$E20_A$	Vehicle M	Below	0.054	0.054	0.008	0.12	0.01
E10	Vehicle A	0.023	0.024	0.019	Below	Below	0.02
$E20_A$	Vehicle A	0.016		0.260	0.010	0.03	Below
E10	Vehicle C	Below	Below	0.415	Below	Below	0.02
$E20_A$	Vehicle C	Below	Below		Below	0.25	0.04
E10	Vehicle F	Below	0.027	0.023	0.006	0.05	0.04
$E20_A$	Vehicle F	0.021	0.044	0.119	Below	0.04	0.1
$E20_A$	Vehicle J	Below	0.011	0.010	Below	Below	0.02
E10	Vehicle K	0.006	0.066	Below	Below	0.02	0.01
$E20_A$	Vehicle K	0.008	0.012	Below	Below	0.04	0.04
E10	Vehicle G	0.017	0.014	Below	Below	Below	0.02
$E20_A$	Vehicle G	0.006	0.024	Below	Below	0.01	0.06

Table A.24

Lead

Fuel	Fuel Rig Description	Week 1	Week 2	Week 3	Week 8	Week 13	Week 14
E10	Vehicle M	Below	Below	0.017	0.006	0.01	Below
$E20_A$	Vehicle M	Below	0.016	0.153	0.017	0.02	0.01
E10	Vehicle A	0.007	0.005	0.010	0.005	Below	Below
$E20_A$	Vehicle A	0.044		0.016	0.007	0.01	Below
E10	Vehicle C	0.005	Below	Below	0.006	0.02	Below
$E20_A$	Vehicle C	0.005	0.007		0.007	Below	Below
E10	Vehicle F	Below	0.015	0.014	0.022	Below	Below
$E20_A$	Vehicle F	0.162	0.093	0.347	0.330	0.91	0.75
$E20_A$	Vehicle J	0.008	0.007	0.016	0.014	0.02	0.04
E10	Vehicle K	Below	Below	Below	Below	Below	Below
$E20_A$	Vehicle K	0.010	0.008	0.007	Below	Below	Below
E10	Vehicle G	0.008	Below	Below	Below	Below	Below
$E20_A$	Vehicle G	0.007	0.010	0.007	0.006	0.02	0.02

Table A.25

Detection Limits for Select Properties Reported In Tables A.1 through A.24

Boron	<0.005 ppm m/m
Sodium	<0.10 ppm m/m
Magnesium	<0.10 ppm m/m
Aluminum	<0.005 ppm m/m
Potassium	<0.10 ppm m/m
Calcium	<0.10 ppm m/m
Titanium	<0.005 ppm m/m
Chromium	<0.005 ppm m/m
Manganese	<0.005 ppm m/m
Iron	<0.10 ppm m/m
Cobalt	<0.005 ppm m/m
Nickel	<0.005 ppm m/m
Copper	<0.005 ppm m/m
Zinc	<0.005 ppm m/m
Molybdenum	<0.005 ppm m/m
Silver	<0.005 ppm m/m
Cadmium	<0.005 ppm m/m
Tin	<0.005 ppm m/m
Lead	<0.005 ppm m/m

APPENDIX A.3
FUEL RIG TEARDOWN PROCEDURE

CRC Program - AVFL-15 Fuel System Rig – Teardown Analysis Procedure

The objective of this project is to determine the durability of selected wetted fuel system components when exposed to higher levels of ethanol fuels (up to 20 volume-% ethanol). In addition to visual evaluations, functional testing of individual components may be used to evaluate the fuel's impact on wear of fuel pumps, fuel injectors, fuel level units and regulators. Qualitative information on the impact of ethanol on the performance of plastics and elastomers will also be assessed. The research will focus on vehicles that are considered to be at risk for durability issues, and are still a substantial fraction of the in-use fleet.

If needed, the required time for dry storage after analysis should be no longer than nine months, and locations can be TRC, component supplier or the OEM. *Note: this project did not require dry storage.*

The teardown meeting will be held at TRC with members of the committee and respective component suppliers present. If the component supplier cannot attend the meeting, an expert from the respective OEM should be present to cover their components.

The procedure below should only be used as a guideline. The participants in the teardown should use good engineering assessments and any anomaly should be noted.

Procedure:

Visually inspect and photograph the rig assembly.

- Document any unusual visual observations.
- Look for signs of leaking around the joints/interfaces.

Perform leak test of rig assembly.

- Pressurize the system to 28 inches of water and hold for 60 seconds, periodically recording pressure.
- If system does not maintain the applied 28" of pressure after 60 seconds, continue the test, periodically recording for 5 min. Release pressure and repeat the test above a second time on any leaking assemblies.
- Spray soapy water on joints to verify joints have integrity.

Disassemble the fuel system rig.

- Remove fuel cap.
- Remove filler neck and hose from tank spud.
- Disconnect fuel line from fuel rail and fuel tank sending unit.
- Disconnect canister assembly hoses.
- Remove fuel tank sending unit from tank using the service tool, if available.

Visually inspect and photograph the all components.

- Document any unusual visual observations with both photograph and written description.

Areas of focus to include, but are not limited to:

- Corrosion
  - Further analysis may be required to examine possibly pitting corrosion.
  - Document by photograph and written description any item with evidence of corrosion.
- Contamination
  - Collect sample of contamination for possible lab analysis.
  - Possible locations include: inside the tank assembly and fuel sending unit bucket, especially inside the reservoir, or on any pre-filters.
  - Document contamination with photograph and written description.
- Seal degradation (i.e., cracking, drying, tearing)
  - Further analysis may be required to understand degradation of seal properties.
  - Document any degraded materials with photograph and written description.
  - Measure component properties and dimensions. *Note: the project panel did not deem it necessary to perform these measurements.*
    - Swell/Volume
    - Weight
    - Tensile
    - Strain
    - Hardness (Durometer)
    - Modulus of Elasticity

<u>Supplier list:</u>

Fuel Tank

Fuel Lines

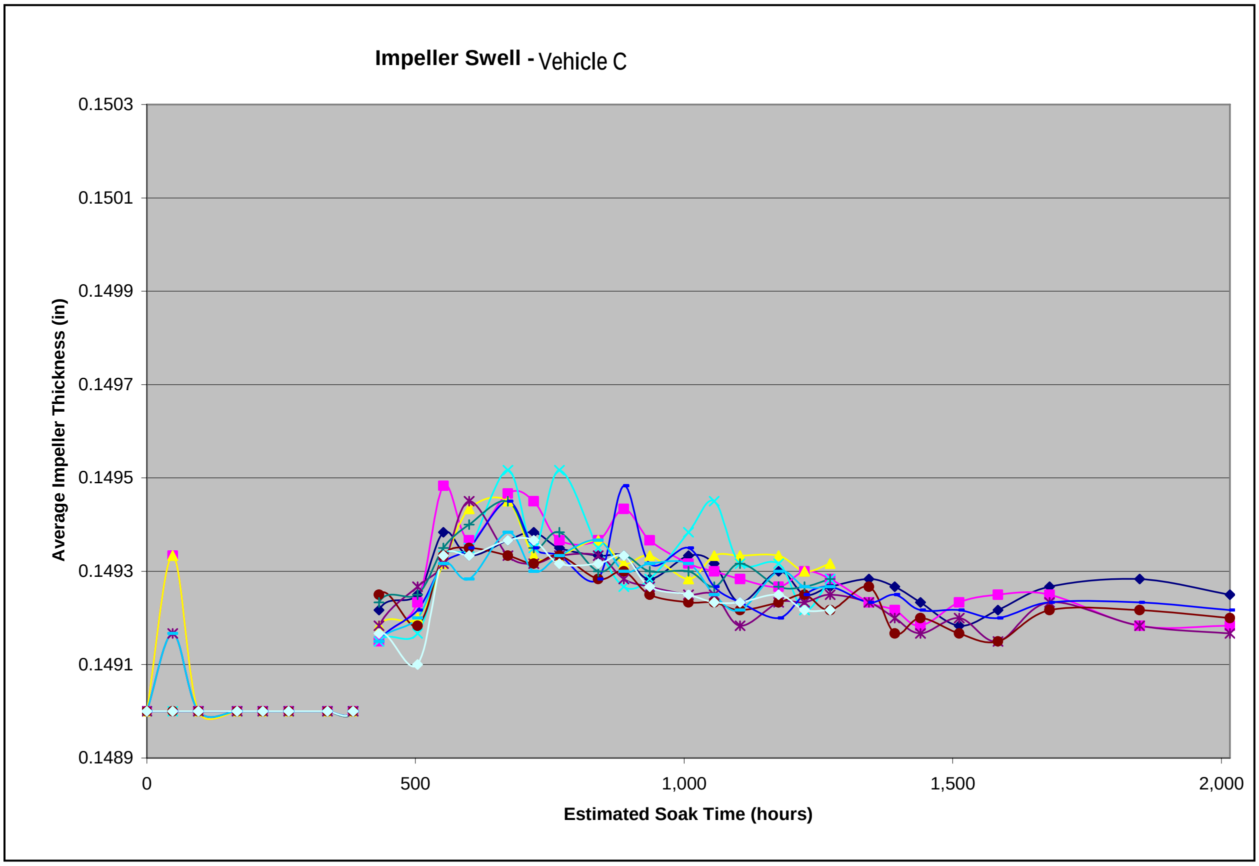
Fillers Tube

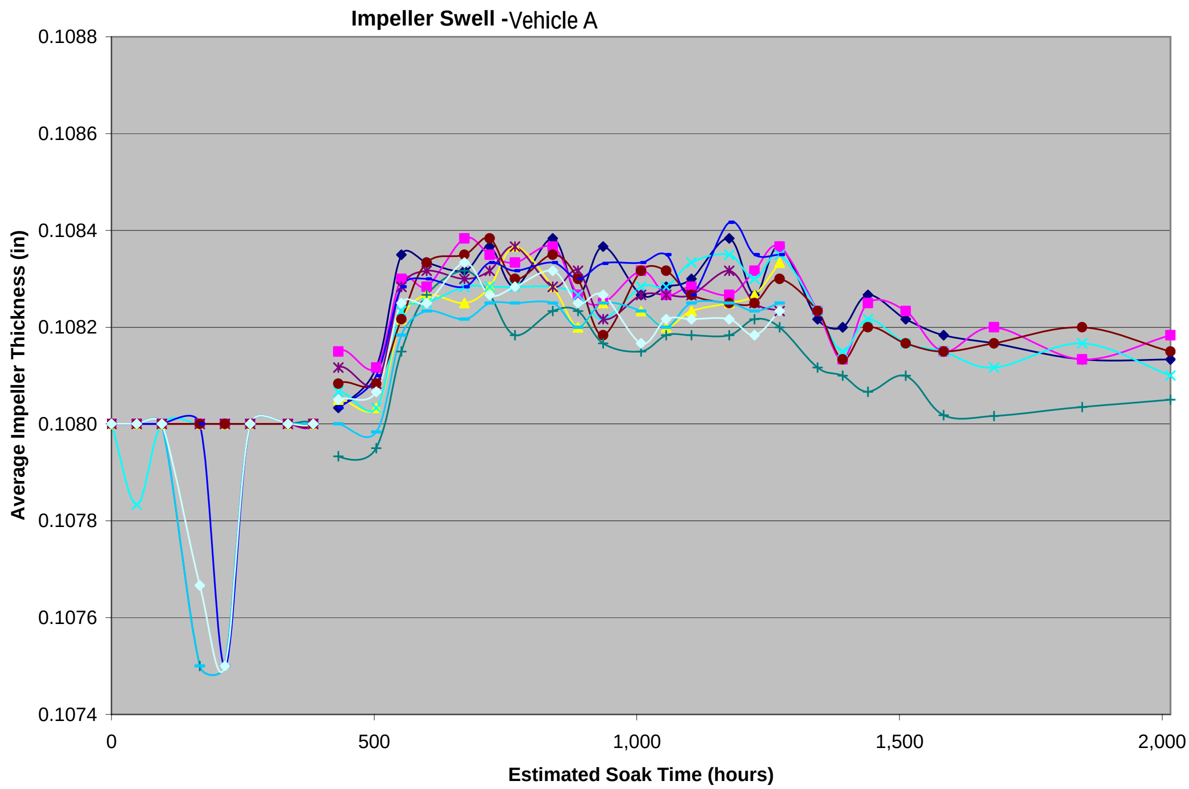
Seals and Hoses

Valves

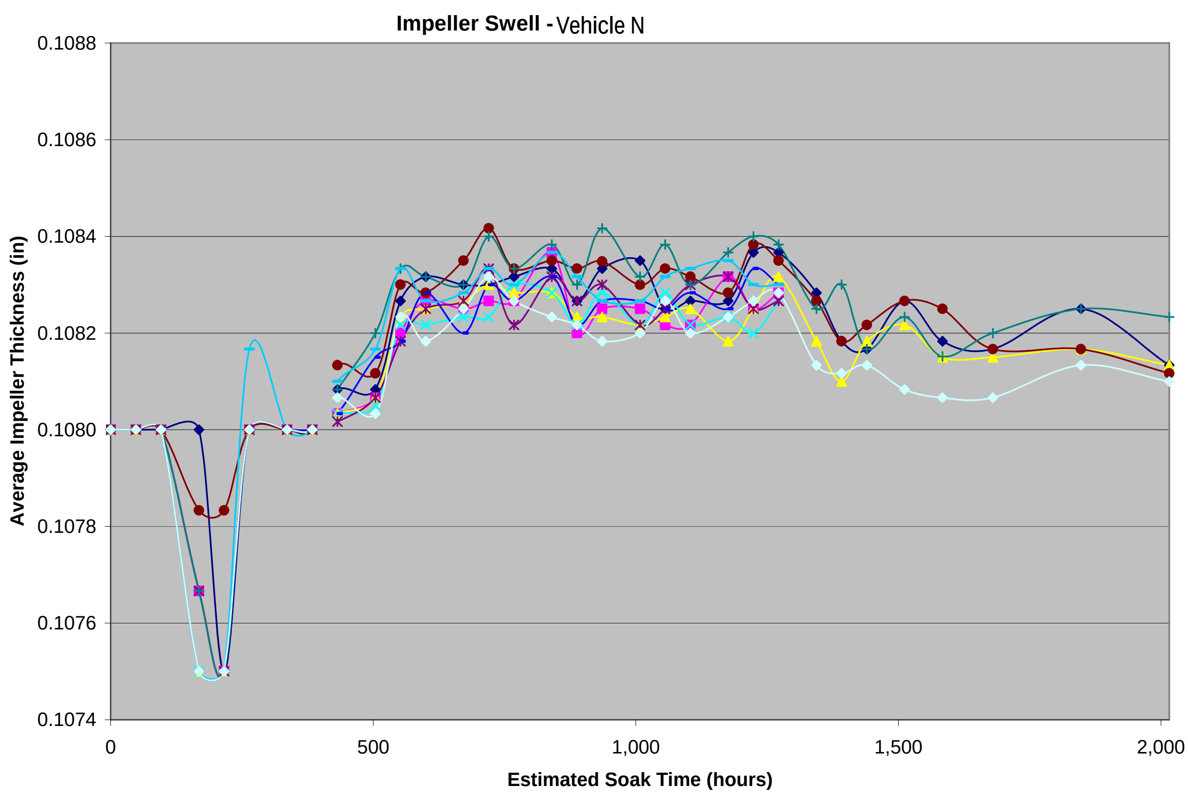
Note: Fuel pump module teardowns will be performed at a separate location (using the fuel pump module teardown procedure), to the project panel will invite component suppliers to attend to witness the rig teardown and inspect the fuel pump modules. Fuel cap suppliers are also welcomed to attend, however cap teardown and analysis will only be performed if deemed necessary (possibly at a separate location).

APPENDIX B
FUEL PUMPS: PILOT PROGRAM


Impeller Swell - Vehicle C
Average Impeller Thickness (in)
0.1503
0.1501
0.1499
0.1497
0.1495
0.1493
0.1491
0.1489
0
500
1,000
1,500
2,000
Estimated Soak Time (hours)

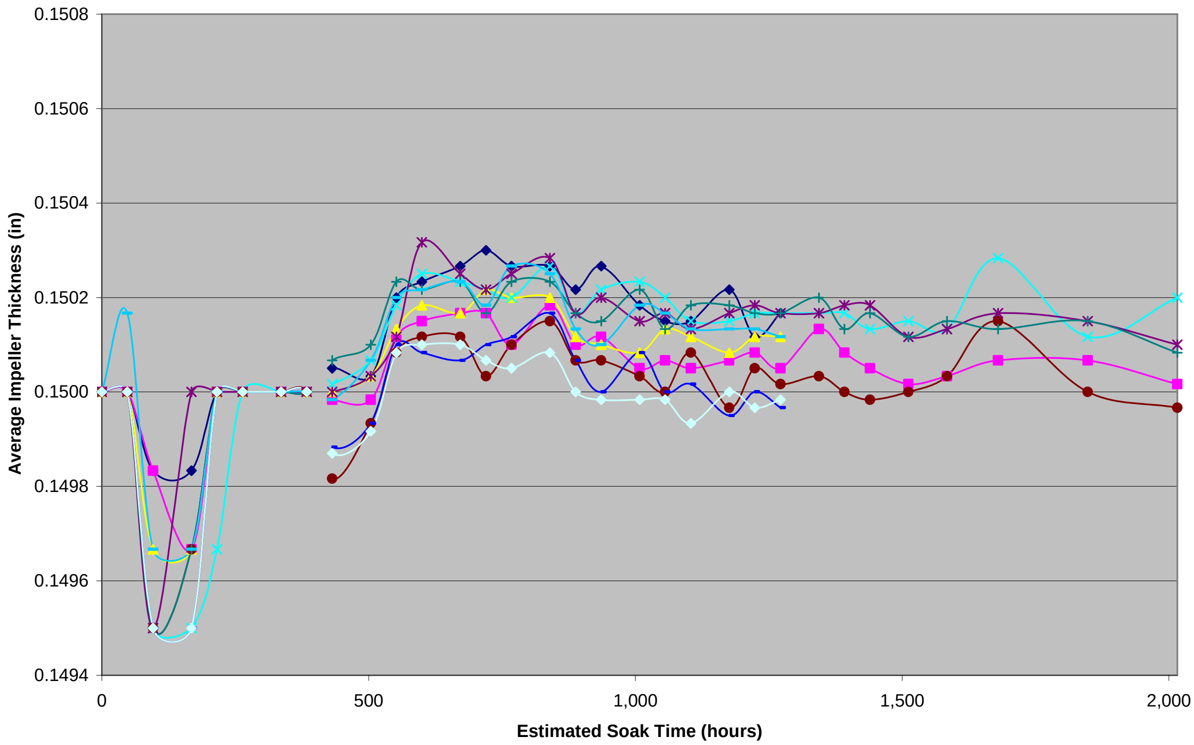


Impeller Swell -Vehicle A
Average Impeller Thickness (in)
0.1088
0.1086
0.1084
0.1082
0.1080
0.1078
0.1076
0.1074
0
500
1,000
1,500
2,000
Estimated Soak Time (hours)

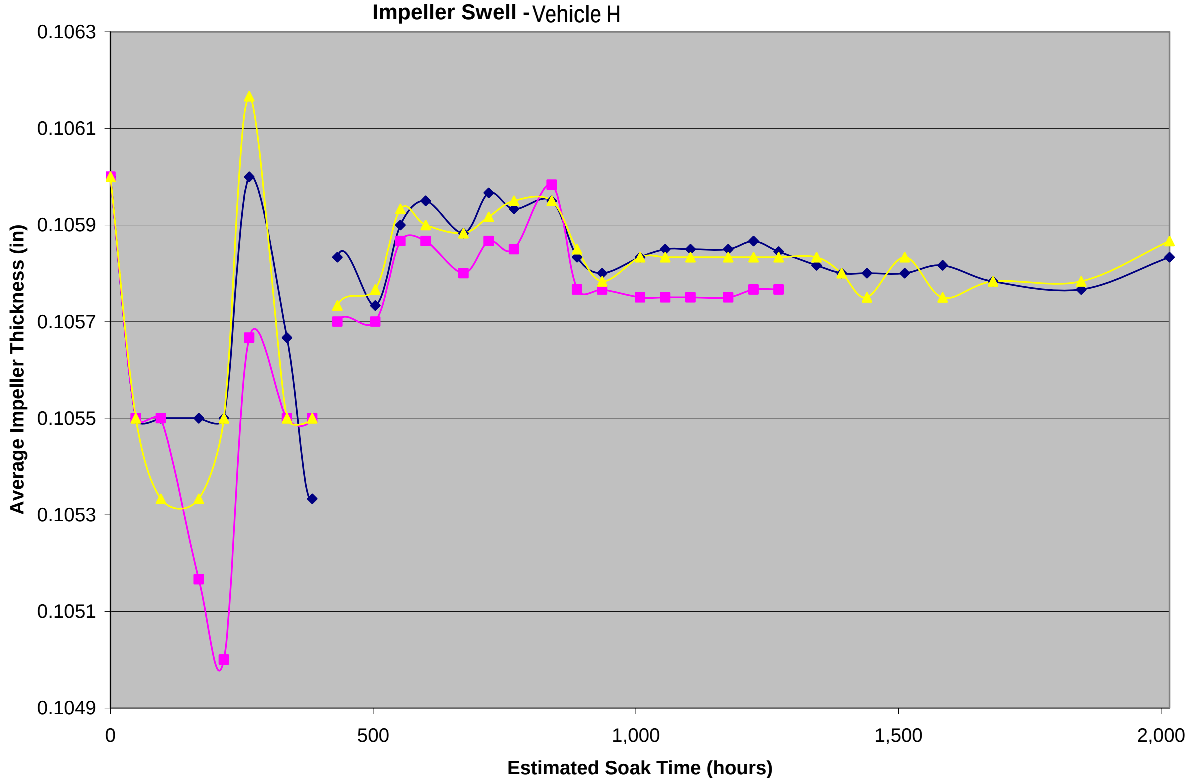


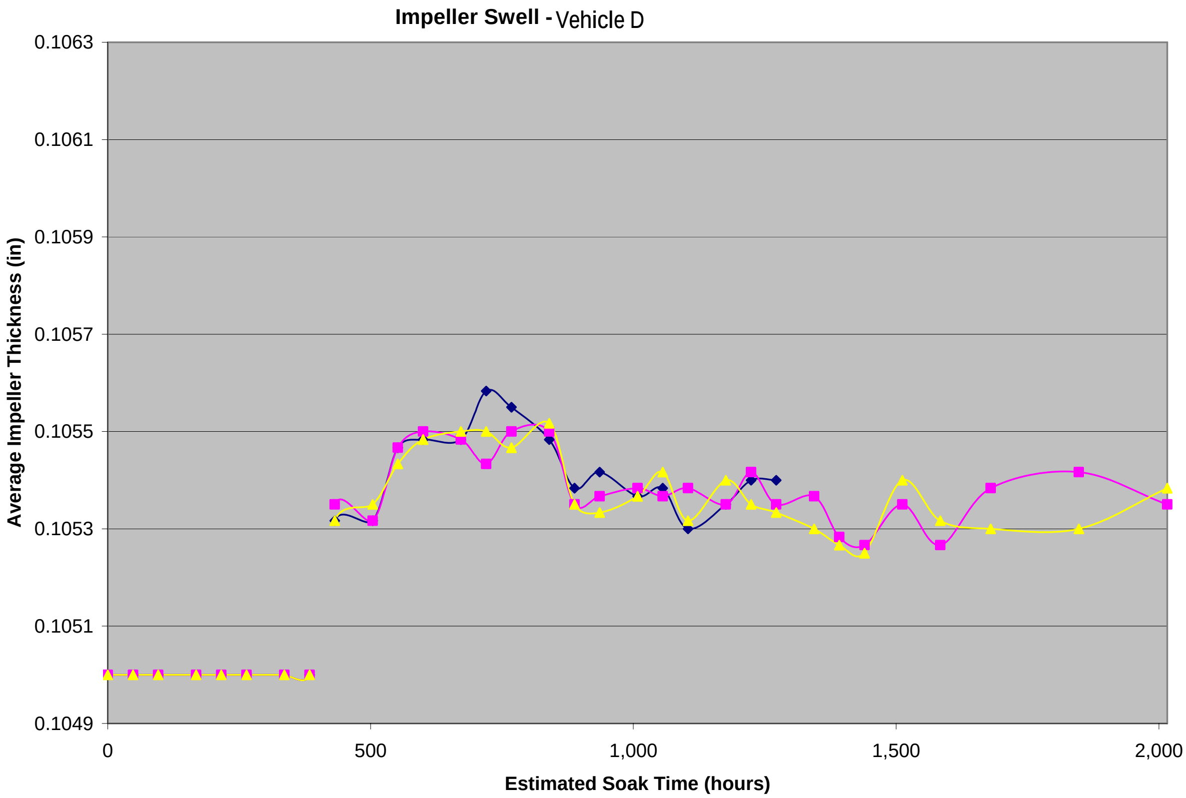
Impeller Swell -Vehicle N
Average Impeller Thickness (in)
0.1088
0.1086
0.1084
0.1082
0.1080
0.1078
0.1076
0.1074
0
500
1,000
1,500
2,000
Estimated Soak Time (hours)

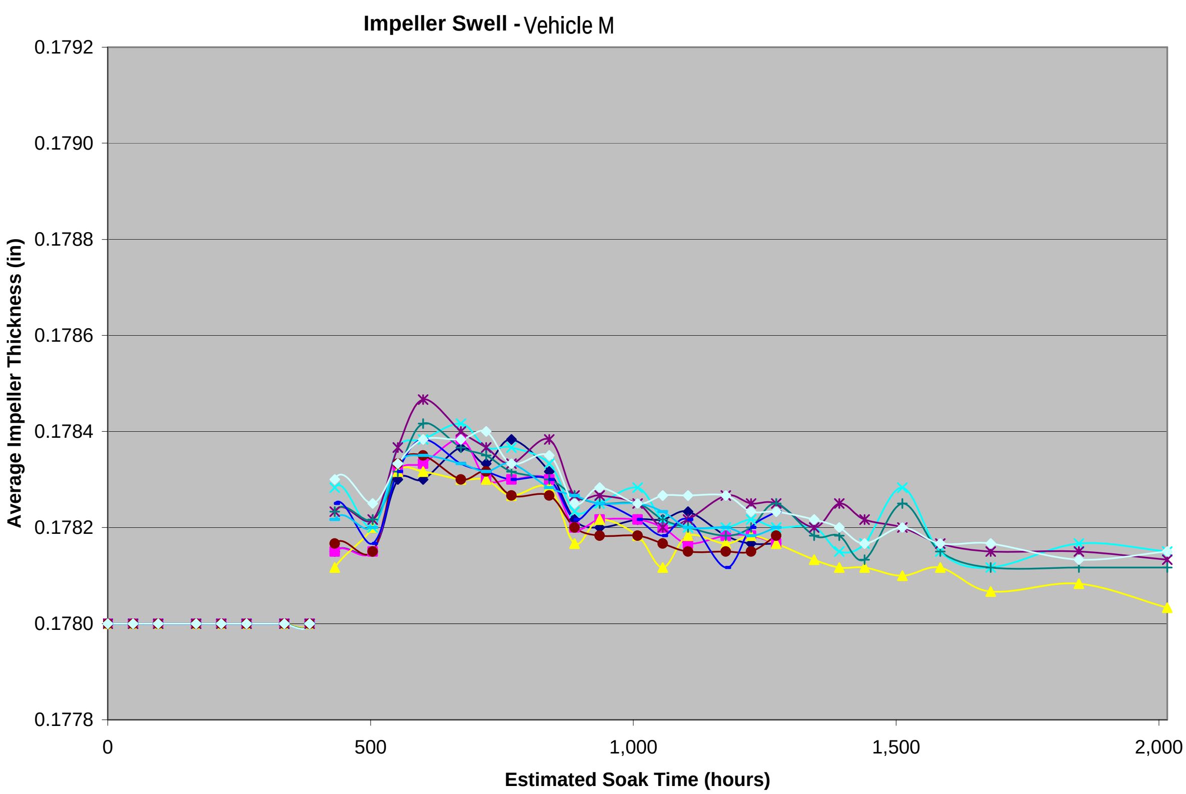
Impeller Swell - Vehicle L

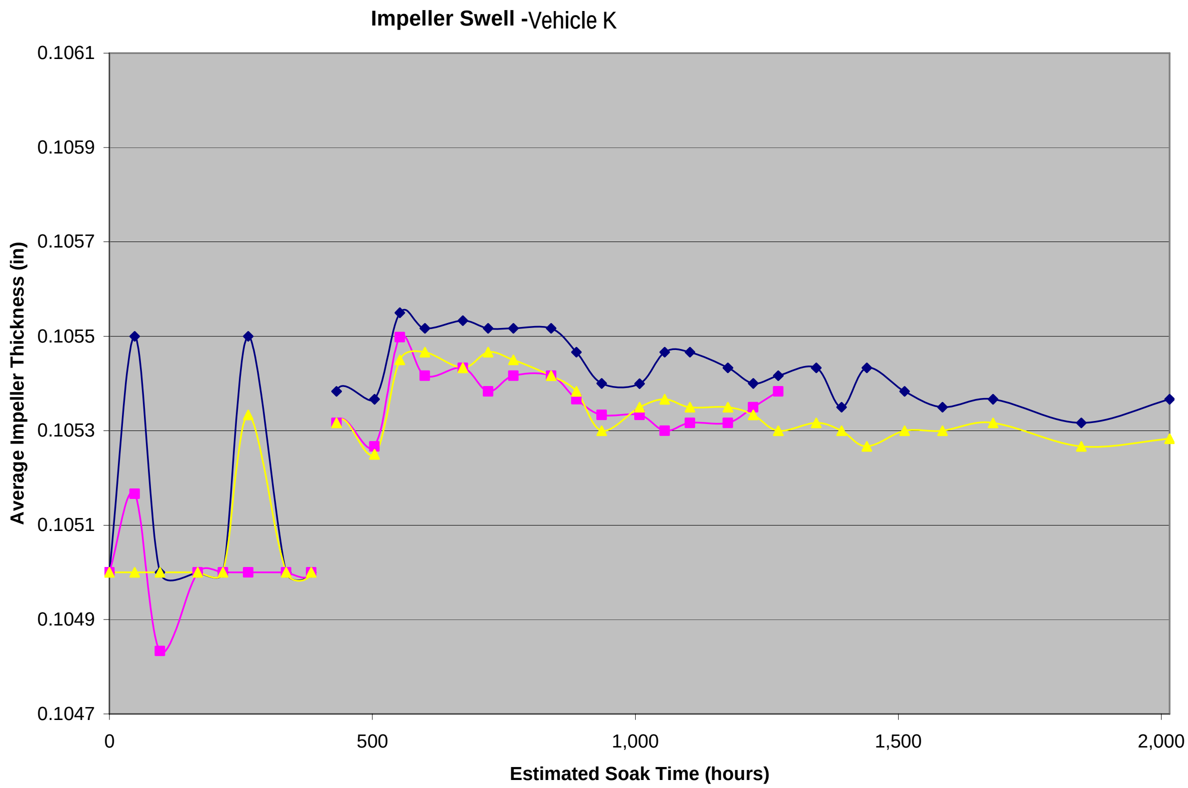


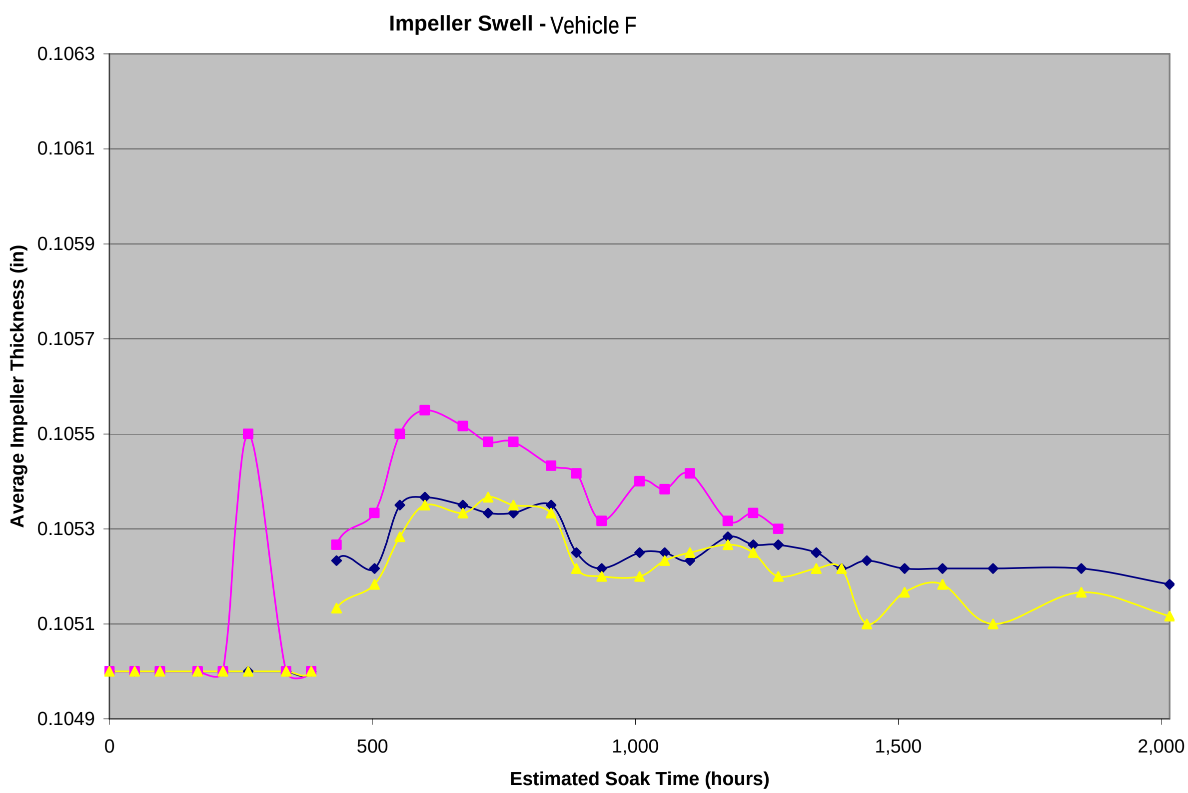
Impeller Swell - Vehicle H




Impeller Swell - Vehicle D
Average Impeller Thickness (in)
0.1063
0.1061
0.1059
0.1057
0.1055
0.1053
0.1051
0.1049
0
500
1,000
1,500
2,000
Estimated Soak Time (hours)


Impeller Swell - Vehicle M
Average Impeller Thickness (in)
0.1792
0.1790
0.1788
0.1786
0.1784
0.1782
0.1780
0.1778
0
500
1,000
1,500
2,000
Estimated Soak Time (hours)


Impeller Swell -Vehicle K
Average Impeller Thickness (in)
0.1061
0.1059
0.1057
0.1055
0.1053
0.1051
0.1049
0.1047
0
500
1,000
1,500
2,000
Estimated Soak Time (hours)


Impeller Swell - Vehicle F
Average Impeller Thickness (in)
0.1063
0.1061
0.1059
0.1057
0.1055
0.1053
0.1051
0.1049
0
500
1,000
1,500
2,000
Estimated Soak Time (hours)

APPENDIX C
FUEL PUMPS: MAIN PROGRAM

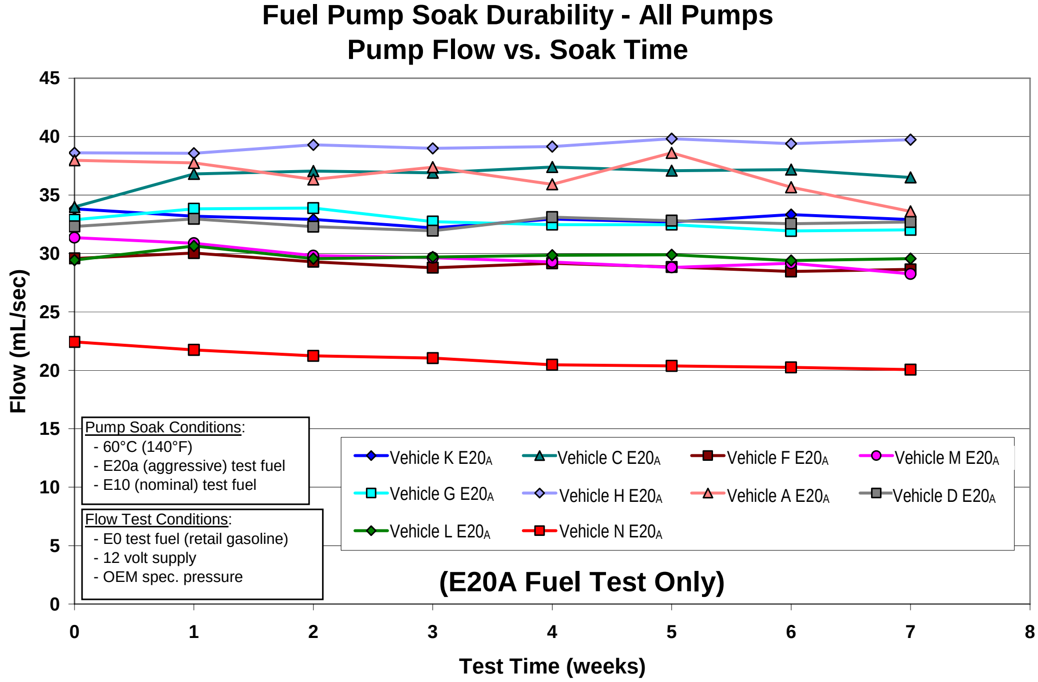
FUEL PUMP TESTING
DETAILED CHARTS AND DATA REVIEW

Fuel Pump Soak Durability

Phase 1: All Pumps Evaluated Using $E20_A$ Test Fuel

Figures C-1 and C-2 show all ten pumps tested using the soak durability test protocol with $E20_A$ test fuel over the seven week interval. Figure C-1 uses pump flow as the metric while Figure C-2 shows pump performance as a percent change in flow from the first test point. Pump performance was highly variable. Some pumps showed a flow increase while other showed a flow decline. The Vehicle N and Vehicle M pumps both showed the highest and most continuous flow decline among the group. The Vehicle A pump also showed a high flow decline over the test interval, but with high variability.

Figure C-1



Phase 2: Selected pumps evaluated using E10 test fuel

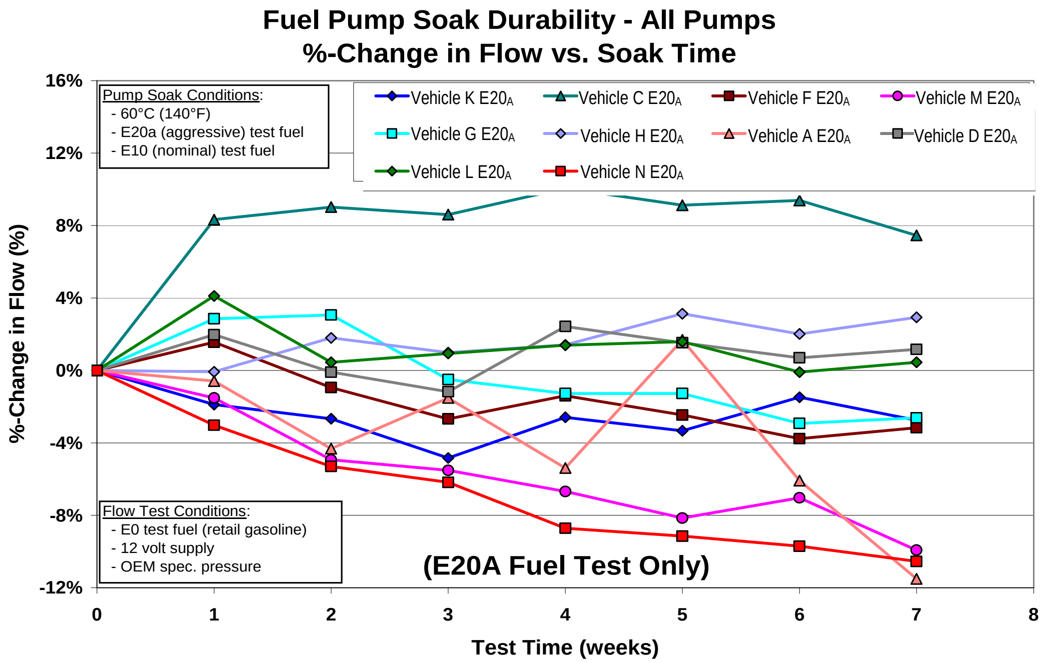
Three pumps were selected for follow-on testing with E10 fuel to provide a baseline comparison to the $E20_A$ test results.

- Vehicle M
- Vehicle G
- Vehicle N

Performance comparisons of these pumps were made on both $E20_A$ and E10 fuel over a test interval of 12 weeks. Metrics used for comparison were

- Measured pump flow
- %-Change in measured pump flow

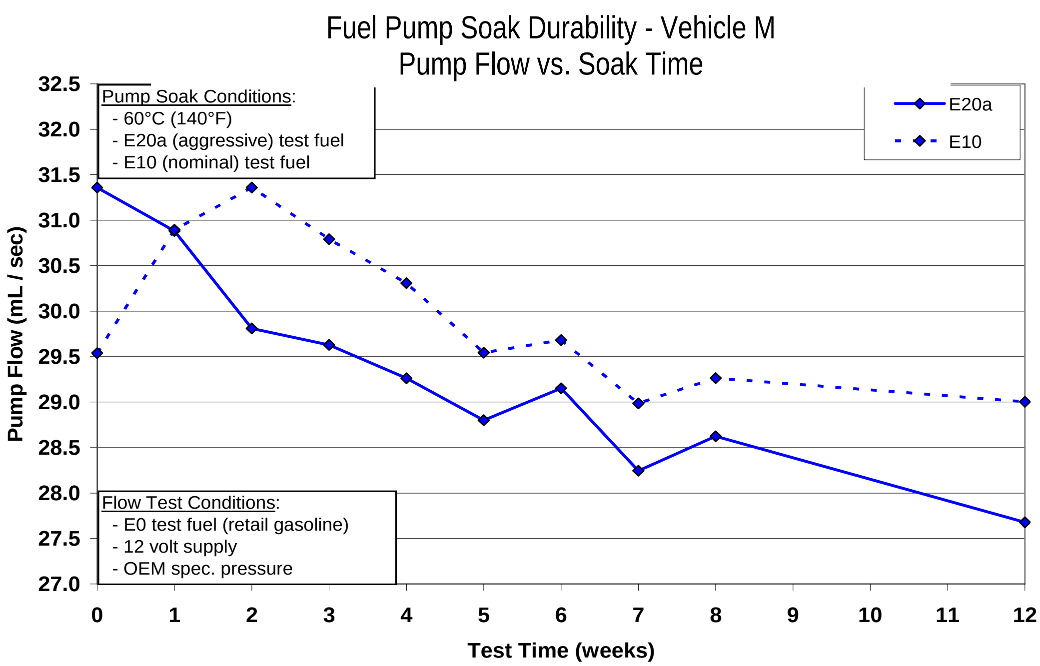
Figure C-2



Model M:

$E20_A$ and E10 pump test data for Model M are shown in Figures C-3 and C-4.

Figure C-3

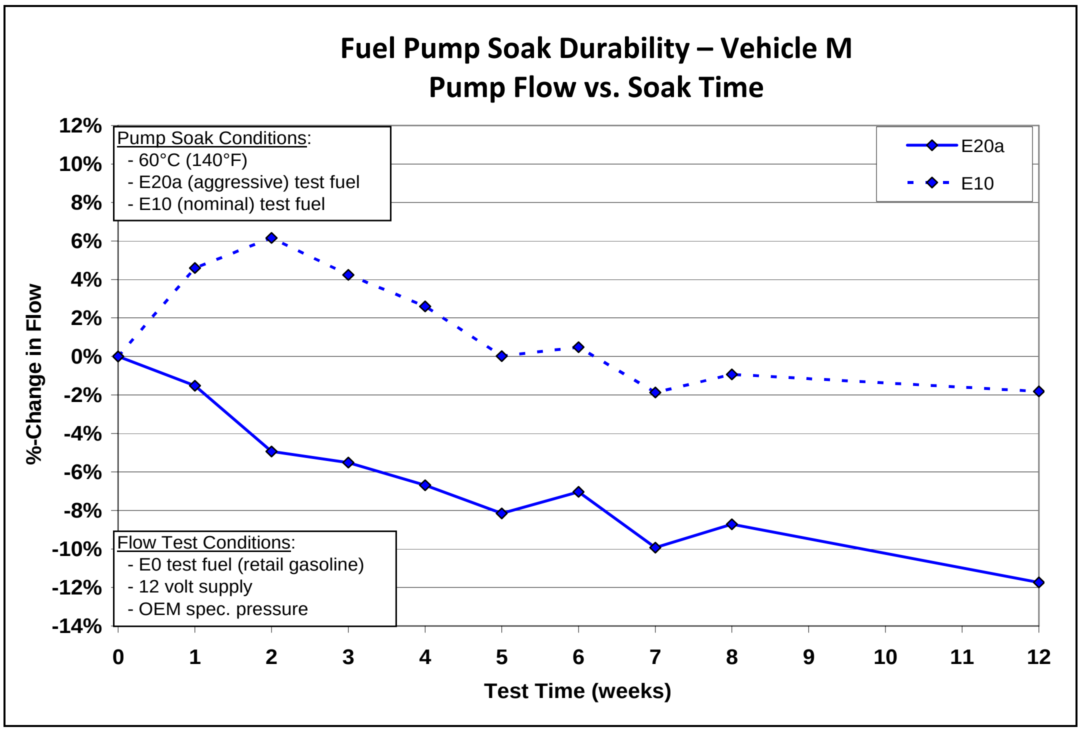


In Figure C-3, pump flow measurements for Model M show a flow decline over the test interval for both test fuels. The $E20_A$ test article exhibited continual decline from an initial flow of about 31.5 mL/sec to a final flow of about 27.5 mL/sec at 12 weeks, a total flow loss of about 3.5 mL/sec. The E10 test article exhibited an initial flow increase from start of test from about 29.5

mL/sec to about 31.5 mL/sec. At 12 weeks, the E10 pump exhibited an overall flow loss with a final flow measurement at 29.0 mL/sec, 0.5 mL/sec below its initial flow value. Overall, the $E20_A$ test article showed a greater flow loss than did the E10 test article.

Similarly, when considering %-change in flow (Figure C-4), the Model M pump showed a continual flow decline with $E20_A$ test fuel in comparison to an initial flow rise and then steady decline with E10 test fuel. Final values of flow loss were about 2% for E10 fuel and 12% for $E20_A$ test fuel. Flow losses from maximum observed flow, however, were closer; about 7% for E10 compared with 12% for $E20_A$.

Figure C-4



Vehicle G:

Pump flow measurements for the Vehicle G [Figure C-5] showed a relatively constant flow value for each of the test fuels over the duration of the 12 week test. The test article soaked in $E20_A$ fuel began the test with a flow value of about 33 mL/sec, showed a slight increase after the start of test, then a slight decrease but remained nearly constant for the second half of the test interval. Final flow value for the $E20_A$ test article was about 32 mL/sec, about 1 mL/sec below its initial flow value.

The test article soaked in E10 fuel began test at a flow value of about 30 mL/sec, 3 mL/sec below the starting value for the $E20_A$ test article. Flow for the E10 test article showed an initial decline to about 28.5 mL/sec, then a recovery to its original flow value for most of the remaining test points. Final flow value for the E10 article was about 29.5 mL/sec, about 0.2 mL/sec below its initial flow value.

Figure C-5

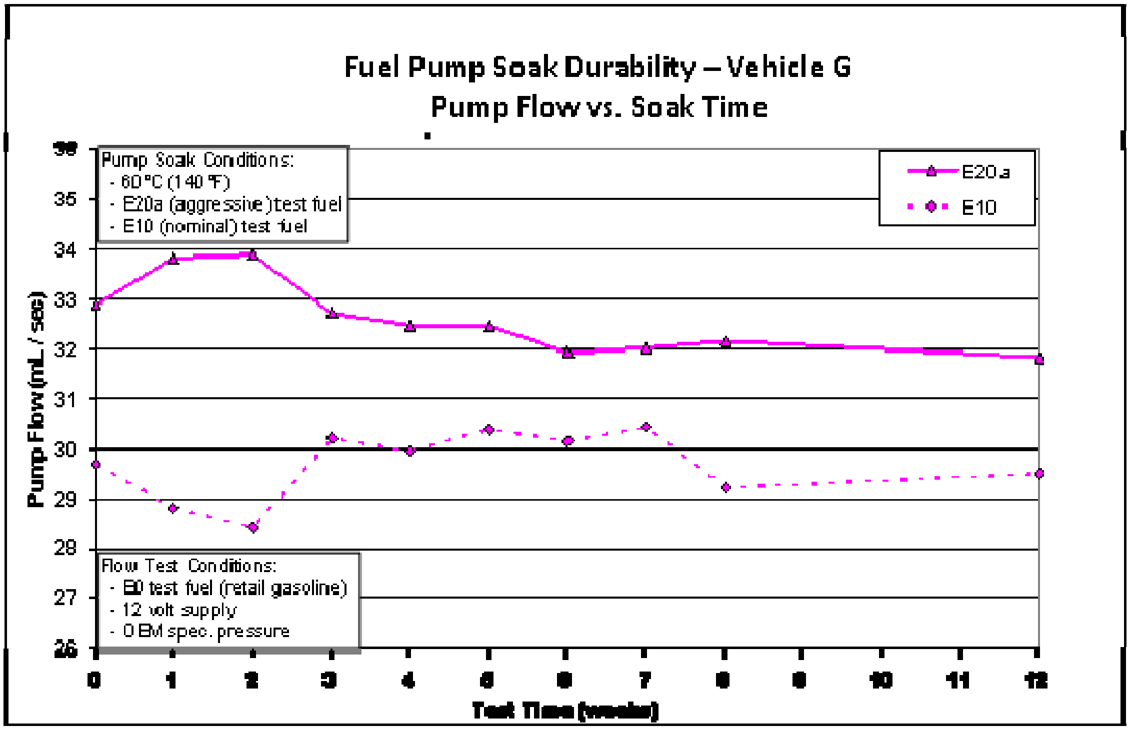
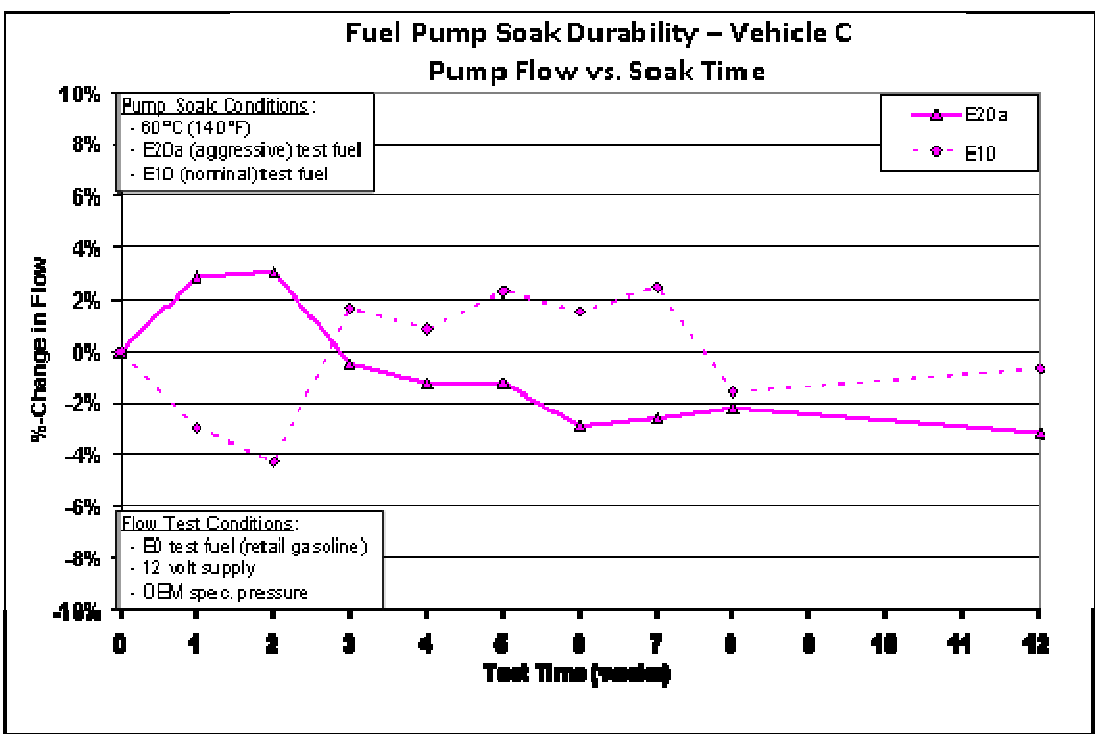


Figure C-6

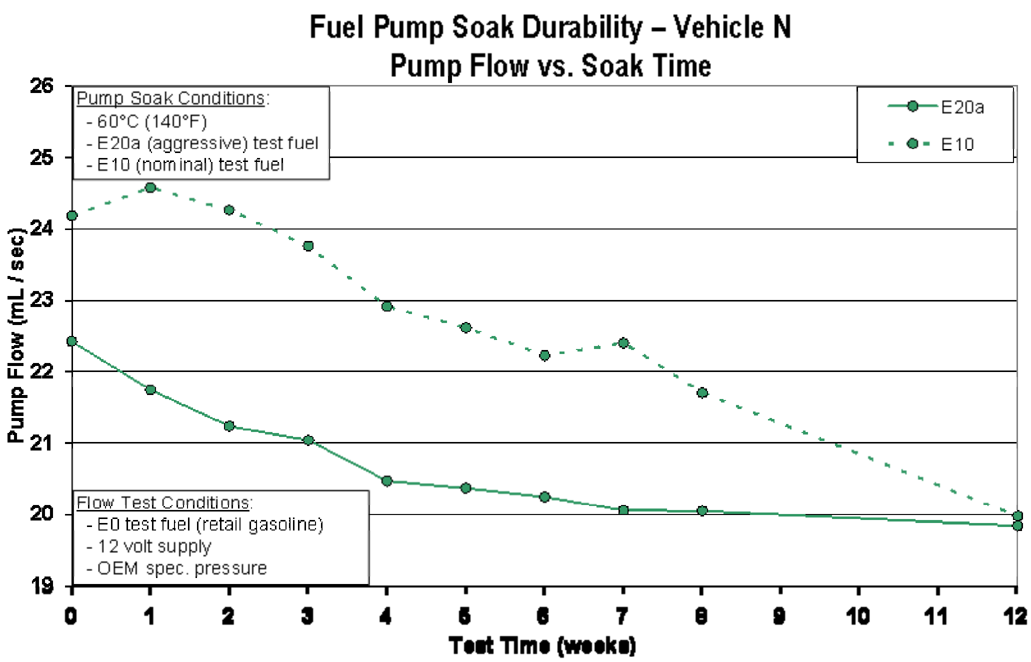


Similar trends were observed for %-change in flow for the two Vehicle G pumps as shown in Figure C-6. The E10 soak article finished the 12 week test with just over a 0.5% flow loss while the $E20_A$ soak article exhibited about 3% flow loss from start of test. Overall there was little differentiation between these two pumps over the two test fuels.

Vehicle N:

Pump flow measurements for Vehicle N showed notable decline for both test fuels over the 12 week test interval as shown in Figure C-7.

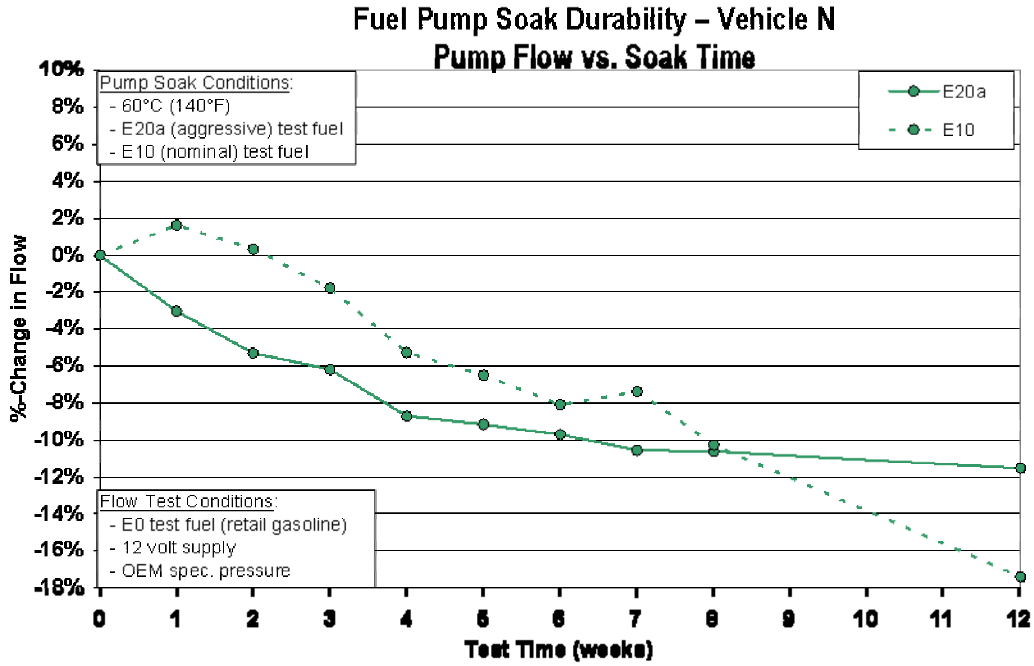
Figure C-7



The $E20_A$ test article began test at about 22.5 mL/sec flow while the E10 article began test with just over 24 mL/sec flow. The $E20_A$ test article show an initial decline and then stabilized somewhat for the second half of the test interval, finishing the 12 week test at just below 20 mL/sec flow. The E10 test pump showed an initial flow increase but then declined steadily through end of test with a final value of about 20 mL/sec. Overall flow loss for the E10 test pump was about 4.2 mL/sec while the $E20_A$ test pump exhibited a 2.6 mL/sec loss in flow.

Similar trends were observed for %-change in flow for the two Vehicle N pumps as shown in Figure C-8. The E10 soak article finished with a nearly 18% flow loss while the $E20_A$ soak article exhibited just under 12% flow loss.

Figure C-8

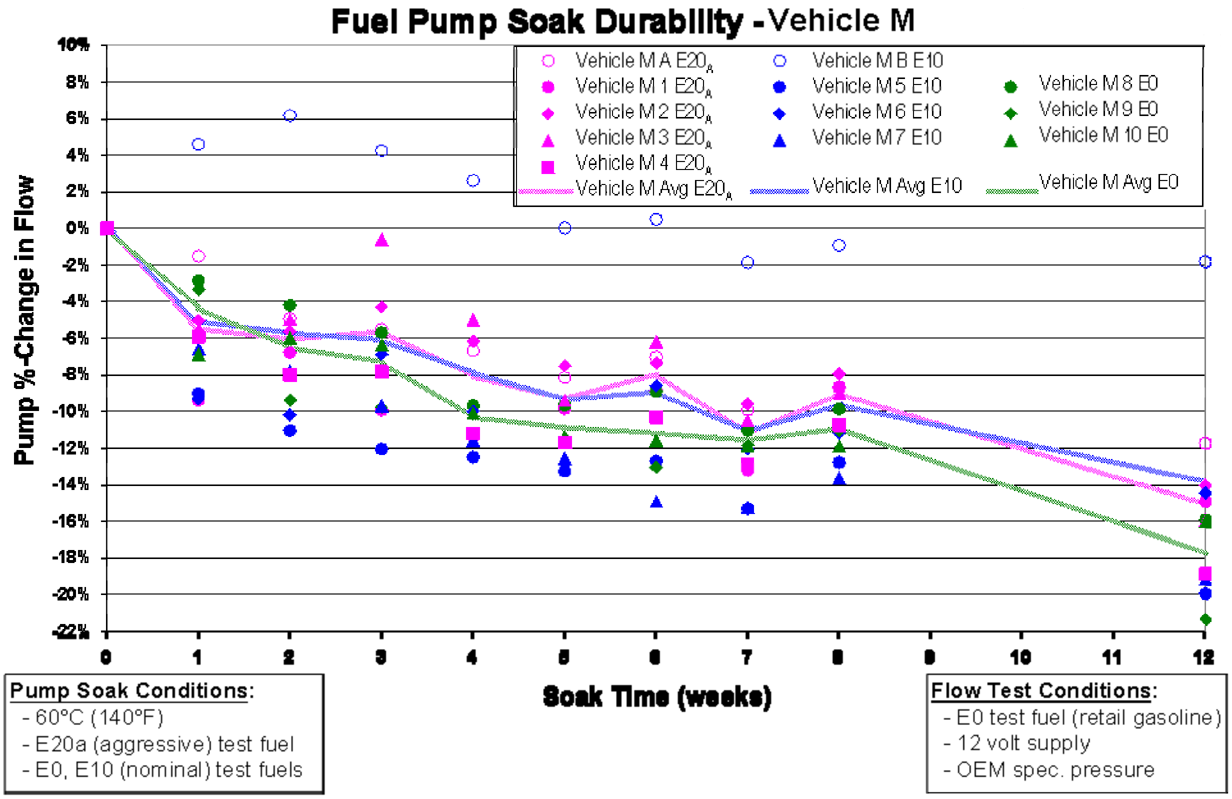


Phase 3: One pump selected for evaluation using $E20_A$, E10 and E0 test fuels

In Phase 3 testing, ten additional 2001 Vehicle M pumps were tested. Four were soaked in $E20_A$, three were soaked in E10 and three soaked in E0. Results of these tests are shown in Figures C-9 and C-10.

As the figure shows, there was considerable scatter in the data. However, on average there was little differentiation in pump aging performance among the test fuels. The four pumps soaked in $E20_A$ test fuel completed the 12 week test with an average flow loss of about 15%, while the three E0 and three E10 test articles finished with average flow losses of about 18% and 14%, respectively.

Figure C-9

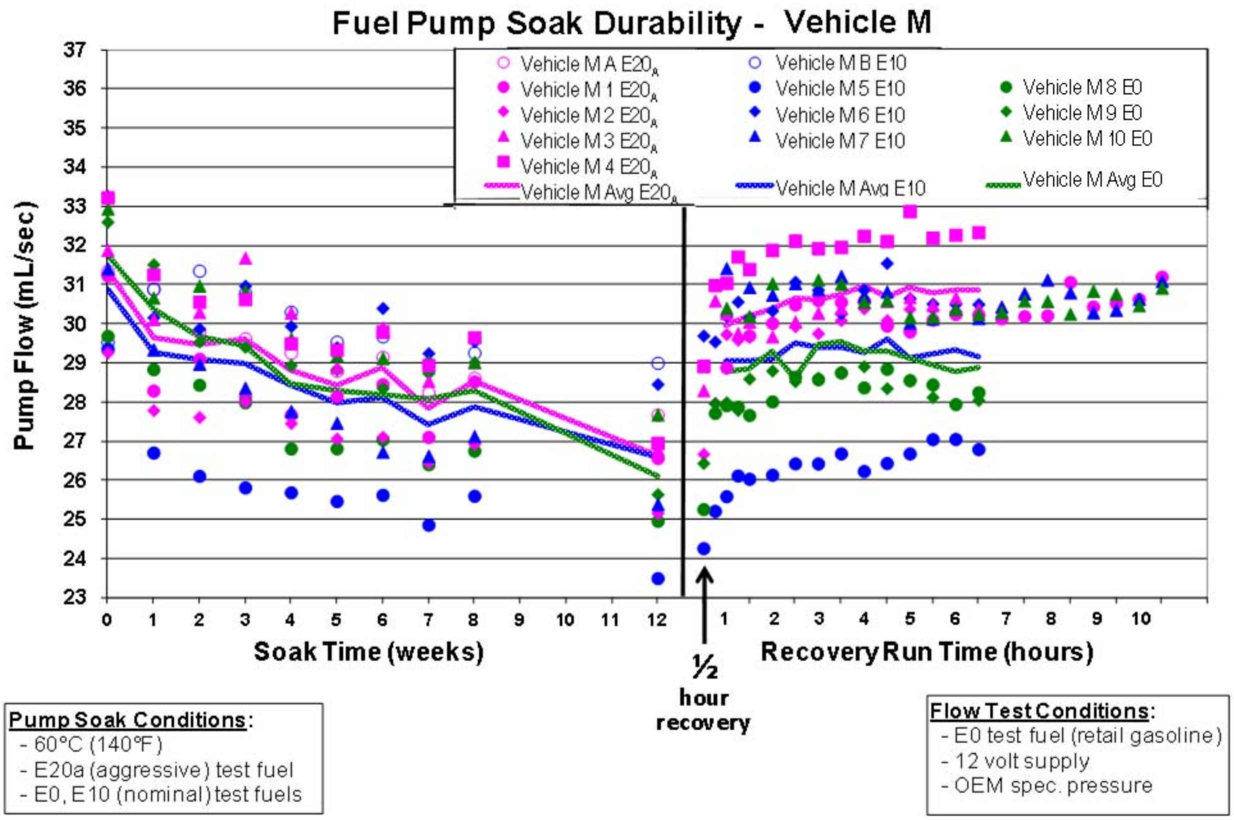


The soak durability protocol was designed to specifically investigate effects of long term static soak on fuel pump flow performance. Brush/commutator film build-up was believed to be one of the more likely causes of the flow degradations observed in Figure C-9. To further evaluate this potential failure mechanism – and to further differentiate among fuels – it was decided to additionally test each pump under continuous operation to determine if the observed flow losses were permanent or could be recovered. Test pumps were removed from their post-test storage containers[2] and immersed in E0 test fuel. Each pump was then connected to the flow test stand and energized. Flow was recorded after ½ hour of operation and then periodically thereafter for between 6 and 10 hours of continuous operation using E0 test fuel. Results of these flow tests are shown in Figure C-10.

On the left side of Figure C-10, flow data from the ten Vehicle M pumps tested in Phase 3 are included. Similar to the percent-change data of Figure C-9, considerable scatter was apparent in measured flow among the ten pumps. Flow data at the beginning of test varied between about 29 mL/sec and 33 mL/sec. End-of-test flow values varied from a low of about 23.5 mL/sec up to 29 mL/sec. It should be noted again, however, that these pumps did not experience a typical break-in procedure to stabilize flow.

[2] Following their last flow test on E0 (at week 12), pumps were stored in sealed plastic bags in a fuel-wet condition and placed in room temperature storage. Pumps remained in storage for one week before being flow tested as described.

Figure C-10



On the right side of Figure C-10, continuous flow data are shown for the same pumps tested after removal from storage. Flow for all pumps increased markedly within the first 1 hour of operation and appeared to stabilize by about 6 hours of continuous operation. It is assumed that continuous operation provided the needed pump break-in and cleaned the residual film build-up at the brush/commutator interface for all fuels. With the exception of the Vehicle M 5 E10 fuel pump, final flow values for all pumps were within 3 mL/sec of the flow measured at the start of the soak durability protocol. The Vehicle M 5 E10 fuel pump ended the continuous operation test at about 4.5 mL/sec below its initial flow value. On average, there was no significant differentiation among test pumps across fuels.

Fuel Pump Endurance Aging

Phase 1: All Pumps Evaluated Using $E20_A$ Test Fuel

Figures C-11 and C-12 show all eight pumps tested using the endurance test protocol on $E20_A$ fuel over the 3000 hour interval. Flow test results are shown directly in Figure C-11 while percent change in flow is shown in Figure C-12. In all charts below, endurance test conditions and flow test conditions are described in text boxes. Endurance aging temperatures over the test period are shown just above the x-axis.

All pumps included in the $E20_A$ endurance test exhibited some decline in performance over the 3000 hour interval. The Vehicle A and Vehicle G test articles both showed the greatest percent-decline in flow, with the Vehicle A pump completing the test about 35% below its initial flow value and the Vehicle G pump failing before the end of test during the last elevated temperature test cycle. All other pumps remained within 20% of their initial flow values with four of the pumps finishing the test protocol within 10% of their initial flow value. The Vehicle L and Vehicle N pumps both finished at just over 10% flow loss with a nearly 13% drop in flow.

Figure C-11

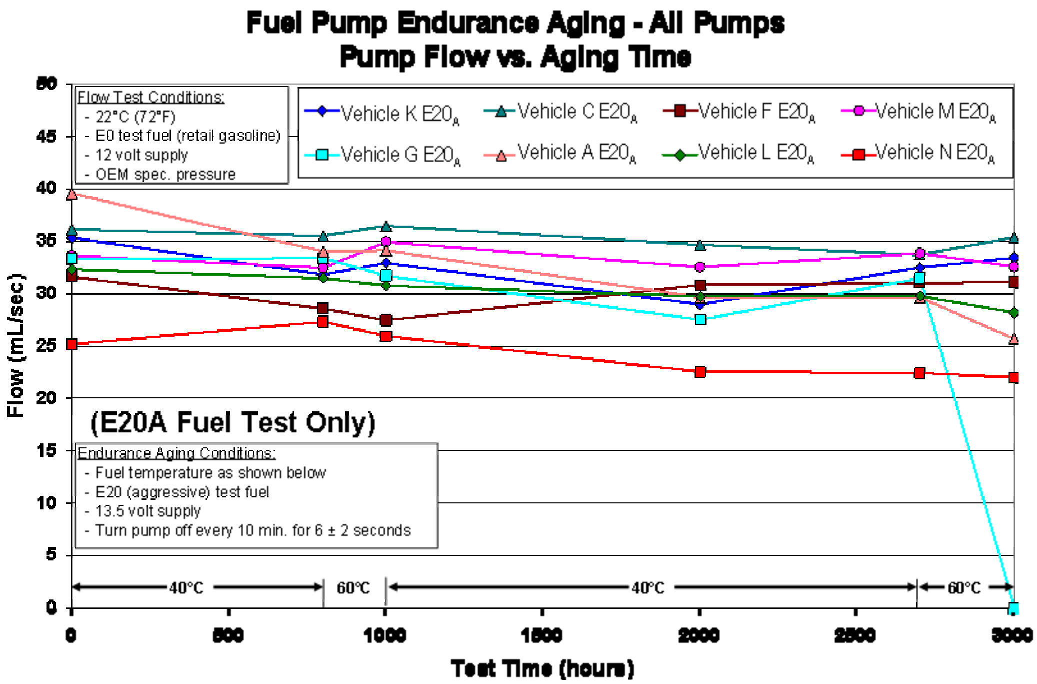
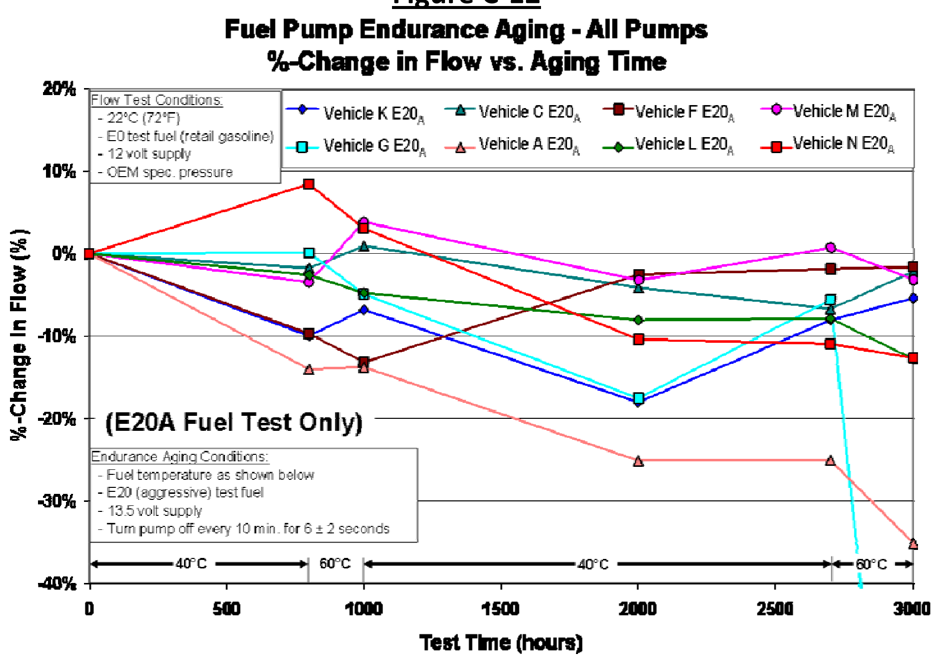


Figure C-12



Phase 2: Selected pumps evaluated using E10 test fuel
Four of the eight pumps were selected for baseline comparison testing using E10 test fuel.

- Vehicle K
- Vehicle G
- Vehicle A
- Vehicle L

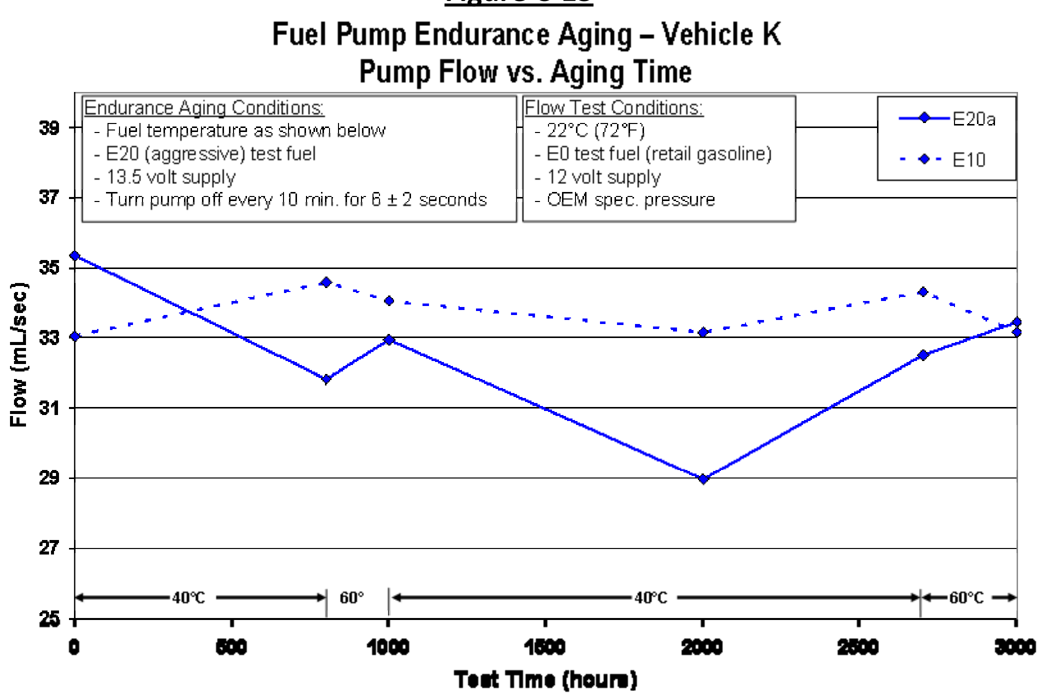
The following metrics were used to evaluate performance of these pumps using the endurance test protocol over a 3000 hour interval.

- Measured pump flow
- % Change in Flow

Each pump is considered individually in the charts below.

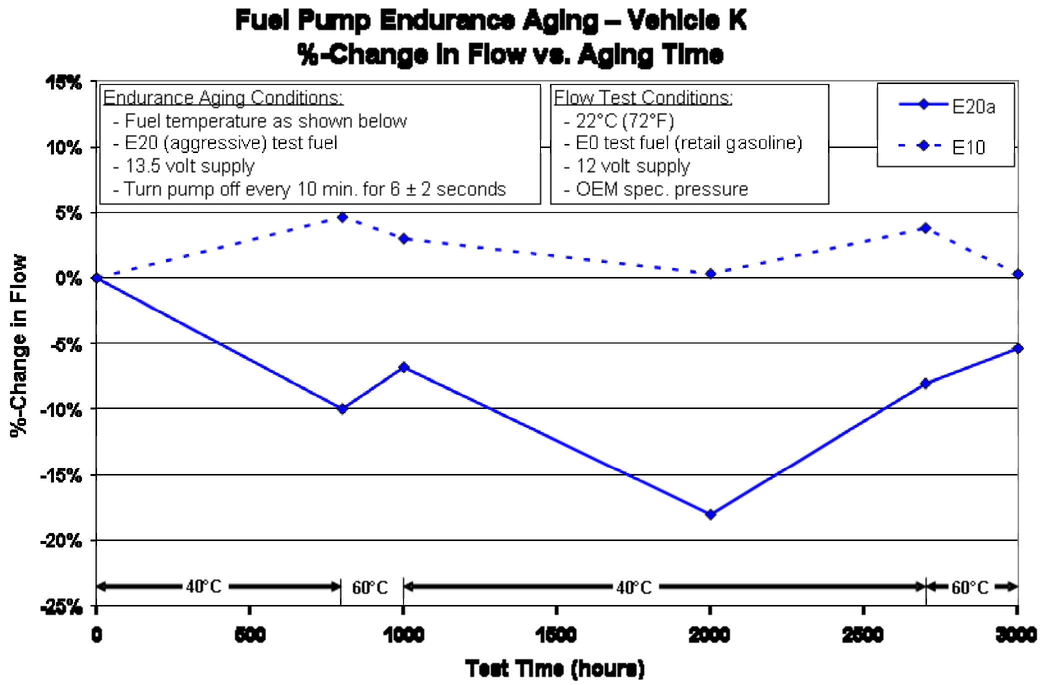
Vehicle K:
$E20_A$ and E10 endurance test data for Vehicle K are shown in Figures C-13 and C-14. Measured flow data in Figure C-13 show that for $E20_A$ test fuel, this pump exhibited an initial decline in performance but then recovered during the last 1000 hours of testing. Initial flow was just over 35 mL/sec while flow at end of test was just over 33 mL/sec; a loss of about 2 mL/sec. Flow for the E10 test pump varied considerably less than flow for the $E20_A$ test pump. Initial and final flow values were nearly identical at about 33 mL/sec.

Figure C-13



Percent change in flow for the Vehicle K pump are shown in Figure C-14. This chart shows that the $E20_A$ aging pump exhibited about a 5% loss in flow over the test interval while the E10 pump experienced rough a 0% decline. Maximum measured flow loss for the $E20_A$ aging pump was 18% and occurred at the 2000 hour test point.

Figure C-14



Vehicle G:

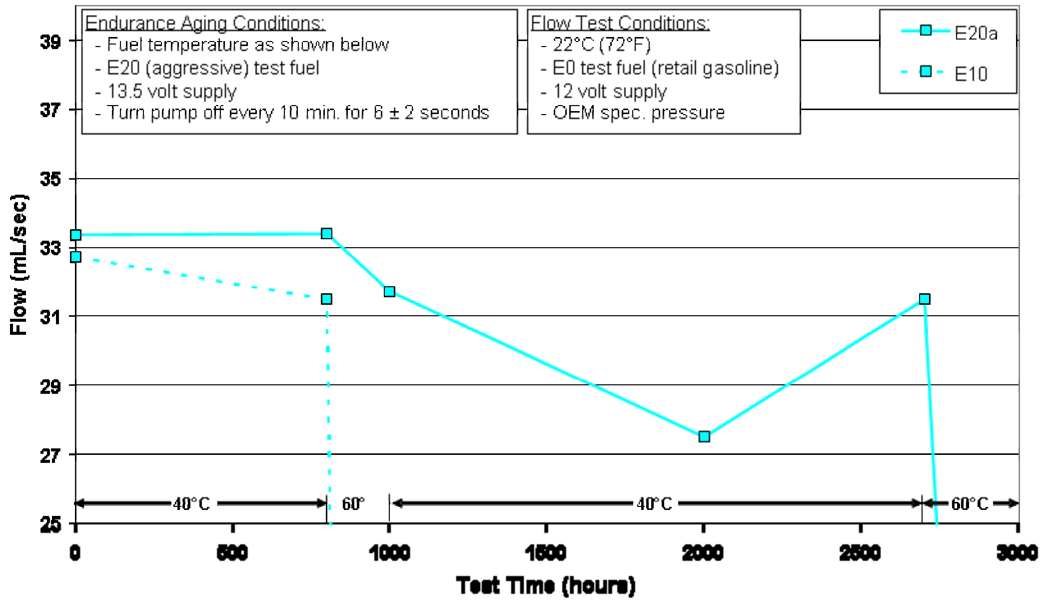
Endurance test results for Vehicle G on $E20_A$ and E10 test fuels are shown in Figures C-15 and C-16. Both Vehicle G pumps failed prior to test completion. The $E20_A$ endurance pump failed at 2890 hours, just prior to finishing the full 3000 hours of test and nearly 200 hours into the second of two 60°C elevated temperature phases of the test. The E10 endurance pump failed at 850 hours; immediately after the first flow test at 800 hours, 50 hours into the first 60°C elevated temperature phase.

Flow data for both the $E20_A$ and E10 endurance pumps are shown in Figure C-15. The $E20_A$ aging pump began test with a slightly higher flow than the E10 aging pump; 33.4 mL/sec compared with 33.7 mL/sec. The $E20_A$ aging pump finished the first 800 hours of test with stable flow. Flow for this pump then declined through the 2000 hour test point and then recovered somewhat at the 2700 hour test point – just before failure. The E10 aging pump showed just over a 1 mL/sec flow decline at the 800 hour test point, just before failure.

Similar observations are made from Figure C-16 which shows %-change in flow for the two Vehicle G pumps.

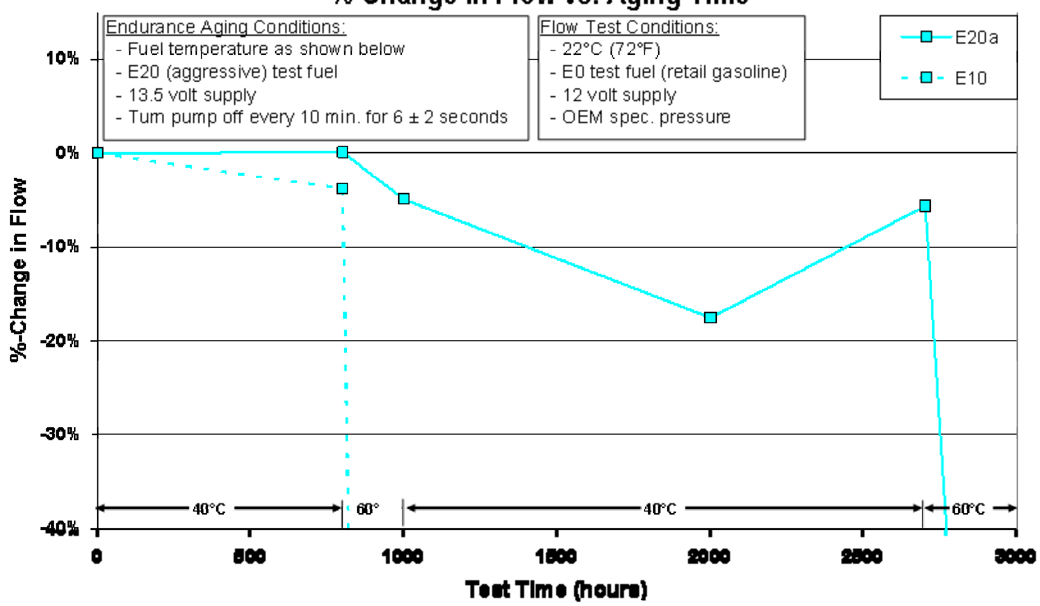
<u>**Figure C-15**</u>

Fuel Pump Endurance Aging – Vehicle G
Pump Flow vs. Aging Time



<u>**Figure C-16**</u>

Fuel Pump Endurance Aging – Vehicle G
% Change in Flow vs. Aging Time



<u>Vehicle A:</u>

$E20_A$ and E10 endurance test data for the Vehicle A are shown in Figures C-17 and A-18. Both pumps experienced a significant decline in flow over the test interval as shown in Figure C-17. The $E20_A$ pump began test just below 40 mL/sec and declined steadily to just over 25 mL/sec at 3000 hours; a decline of about 14 mL/sec. The E10 aging pump began test at about 37 mL/sec and declined steadily over the 3000 hour test interval to finish at 19 mL/sec; an 18 mL/sec flow loss.

Figure C-17

Fuel Pump Endurance Aging – Vehicle A
Pump Flow vs. Aging Time

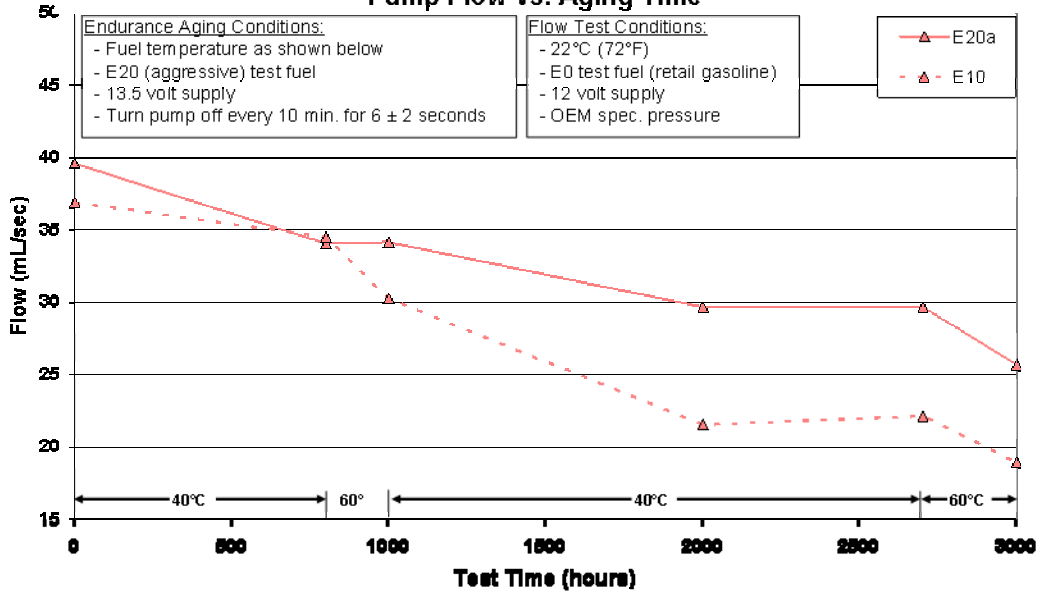
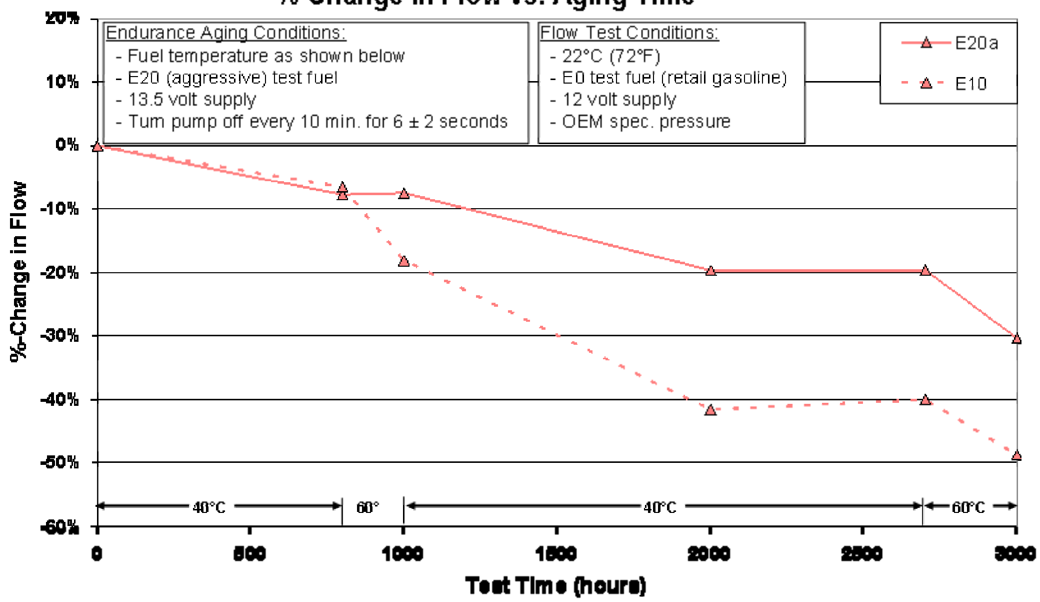


Figure C-18

Fuel Pump Endurance Aging – Vehicle A
% Change in Flow vs. Aging Time



Similar observations are made from Figure C-18 which shows that the $E20_A$ pump finished test with a 30% loss in flow and the E10 pump finished with a nearly 50% loss in flow. Overall the

Vehicle A pump aged using E10 fuel showed a greater performance decline than did the pump aged using $E20_A$ test fuel.

Vehicle L:

The E10 Vehicle L aging pump failed about one-third of the way through the 3000 hour test interval, so limited comparison data is available.

Data for the two Vehicle L test pumps are summarized in Figures C-19 and C-20. The $E20_A$ aging pump exhibited a 2 mL/sec loss in flow over the 3000 hour test. This corresponds to roughly 13% loss in flow and an efficiency drop of just over 1%. The flow loss and drop in efficiency exhibited by the $E20_A$ test pump are less than differences observed between the two pumps at the start of test.

Figure C-19

Fuel Pump Endurance Aging – Vehicle L
Pump Flow vs. Aging Time

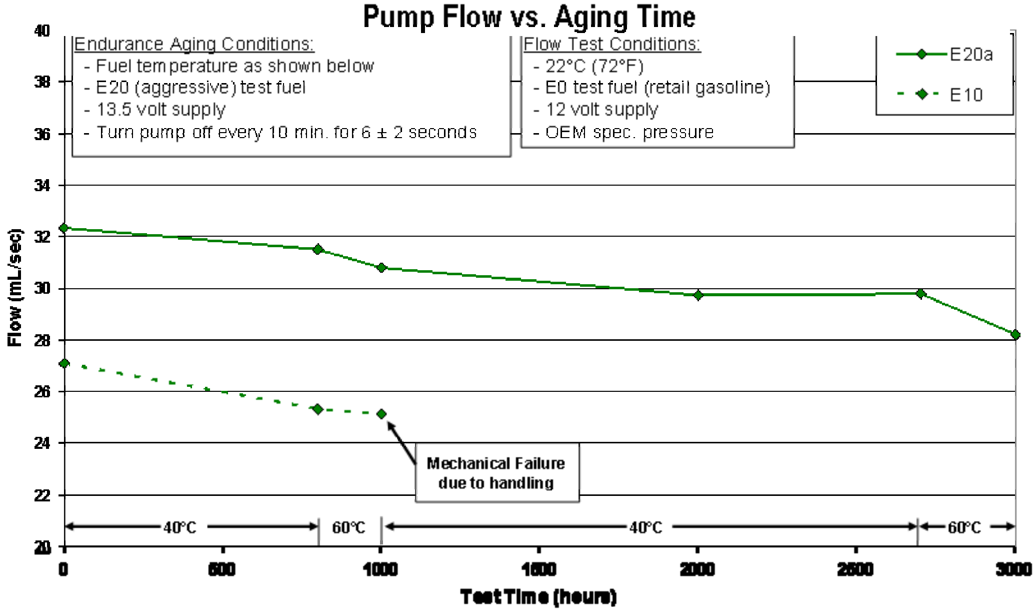
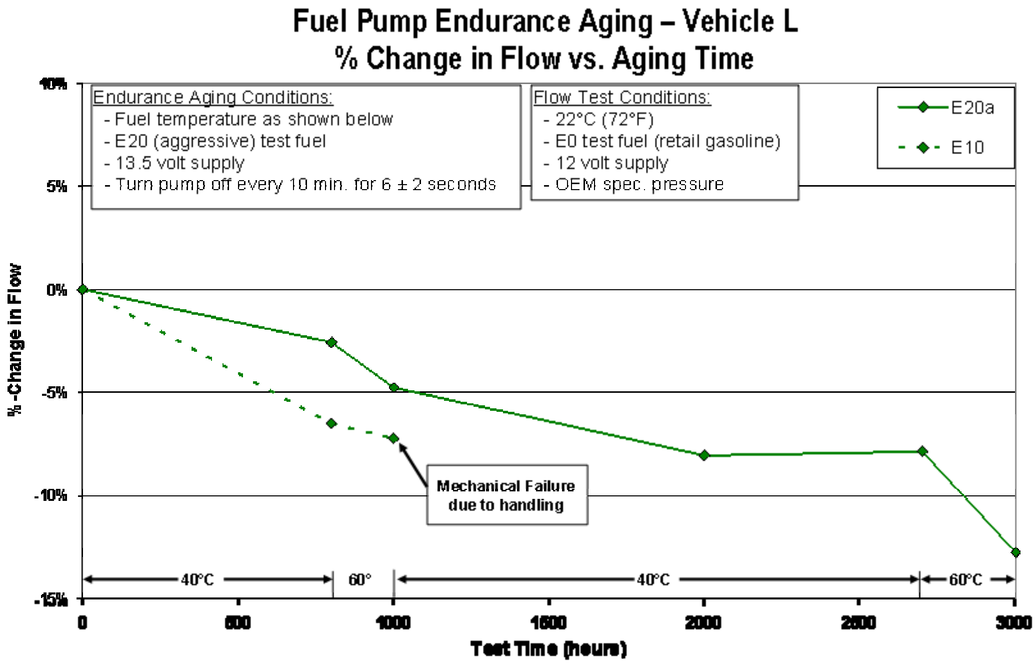


Figure C-20



<u>Phase 3: Two pumps selected for evaluation using $E20_A$, E10 and E0 test fuels</u>

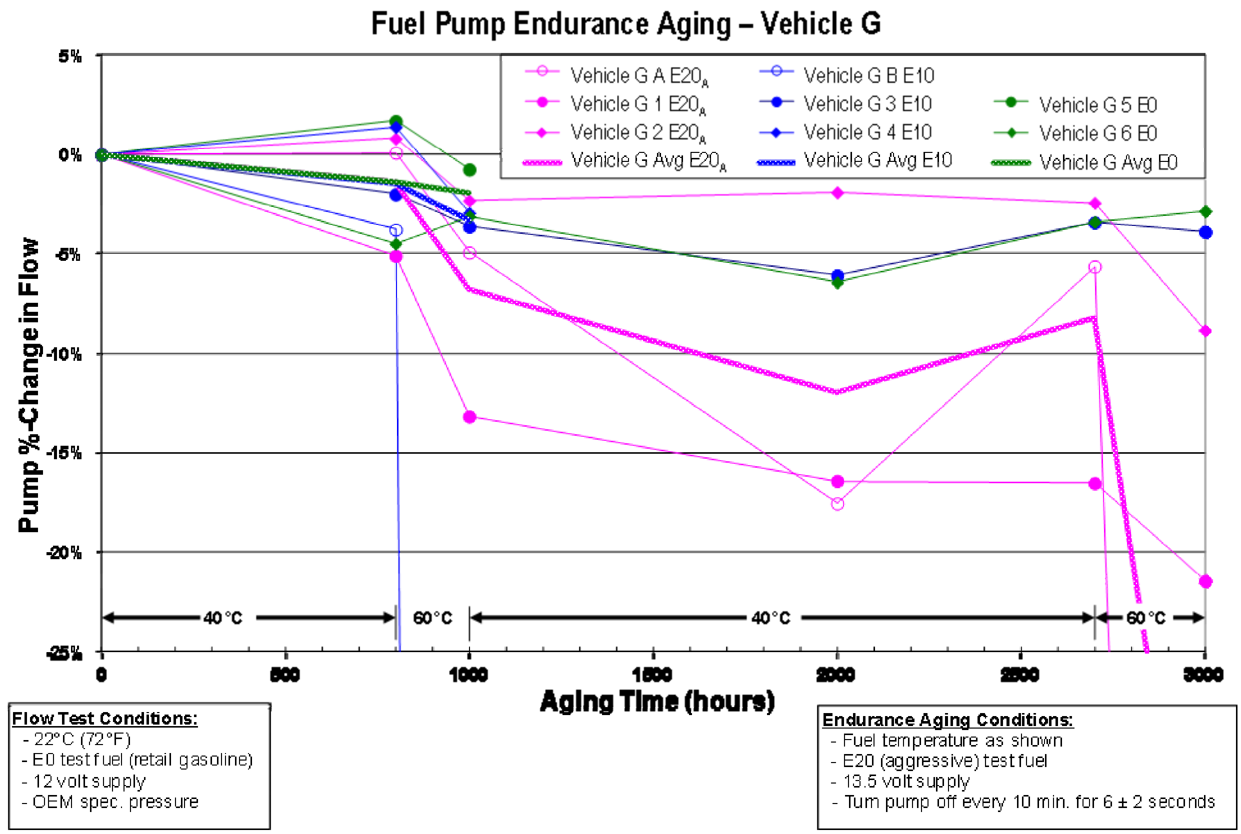
In Phase 3 testing, the two pump models which showed the greatest decline in performance from Phases 1 and 2 were selected for further evaluation using $E20_A$, E10 and E0 test fuels.

Both 2000 Vehicle G pumps tested in Phases 1 and 2 failed prior to completion of the endurance test protocol. The $E20_A$ Vehicle G pump (Phase 1) failed after 2890 hours of endurance aging while the E10 Vehicle G pump (Phase 2) failed after 850 hours. Because these results were initially considered to suggest sensitivity to ethanol in gasoline, this pump was selected for Phase 3 evaluation.

Both Vehicle A pumps tested in Phases 1 and 2 showed significant decline in flow during endurance aging. The Vehicle A pump operated in $E20_A$ test fuel (Phase 1) exhibited a roughly 30% flow decline (~ 14 mL/sec loss) at the 3000 hour test point while the pump operated in E10 test fuel (Phase 2) exhibited about a 50% flow decline (~ 18 mL/sec loss in flow) at 3000 hours of aging. Because the Vehicle A pumps tested here were electronically controlled variable speed pumps, the observed flow losses may not be indicative of in-field degradation. Fuel comparison effects, however, are still considered valid.

Combined results from Phases 1, 2 and 3 for the Vehicle G pump are shown in Figure C-21. Pumps labeled A and B were those pumps tested in Phases 1 and 2, while pumps labeled 1 thru 6 were the additional pumps tested in Phase 3.

Figure C-21

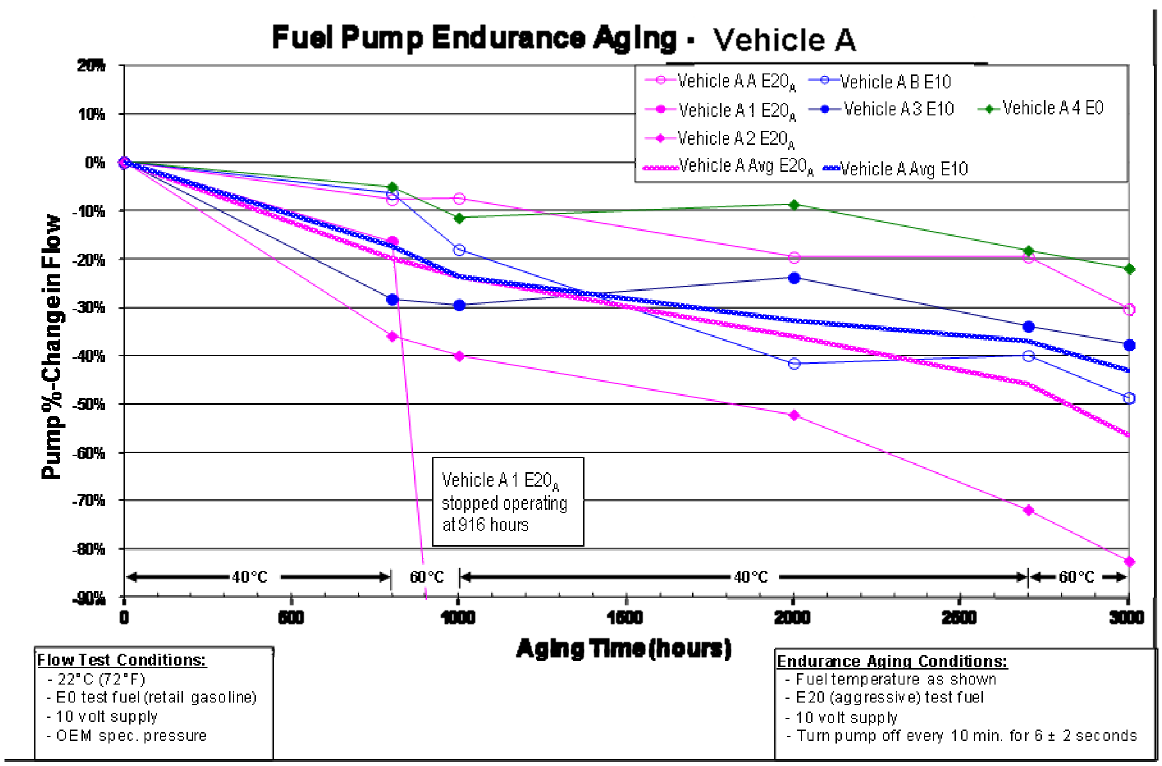


While Phase 3 testing was being conducted, a teardown analysis report on the Phase 1 and 2 pumps was completed by the pump supplier. This report suggested that neither of the two failures was related to a fuel-effect, so there was no indication of heightened ethanol sensitivity for this pump. The supplier's report suggested that test procedure was the likely root cause of each pump failure. For the $E20_A$ pump, the impeller was found to be melted, and there was evidence of charring from a flame. From this, it was believed that the pump must have been run dry. For the E10 pump, melting occurred in the brush/commutator section. The most likely root cause was diagnosed as a clogged intake filter; probably a result of no filtration in the pump test bench. Filtration was subsequently added to all of the endurance aging benches to provide a more prototypic environment for pump evaluation.

Because the Vehicle G pump was no longer suspected of exhibiting heightened ethanol sensitivity, two of the six pumps being evaluated in Phase 3 were removed following the 1000 hour test point to allow room for testing of alternate pumps. Pumps retained for completion of the 3000 hour test were Vehicle G 1 and Vehicle G 2 (both $E20_A$ test articles), Vehicle G 3 (E10 test article) and Vehicle G 6 (E0 test article). As Figure 5 shows, there remained wide variation in pump performance. One of the $E20_A$ test articles exhibited about 21% flow loss at 3000 hours, while the other test articles in $E20_A$, E10 and E0 test fuels remained within 10% flow loss throughout the test. While the 21% flow loss exhibited by the Vehicle G 1 pump might suggest a concern, there was no indication from post-test teardown analysis that any fuel-related issue existed with this pump.

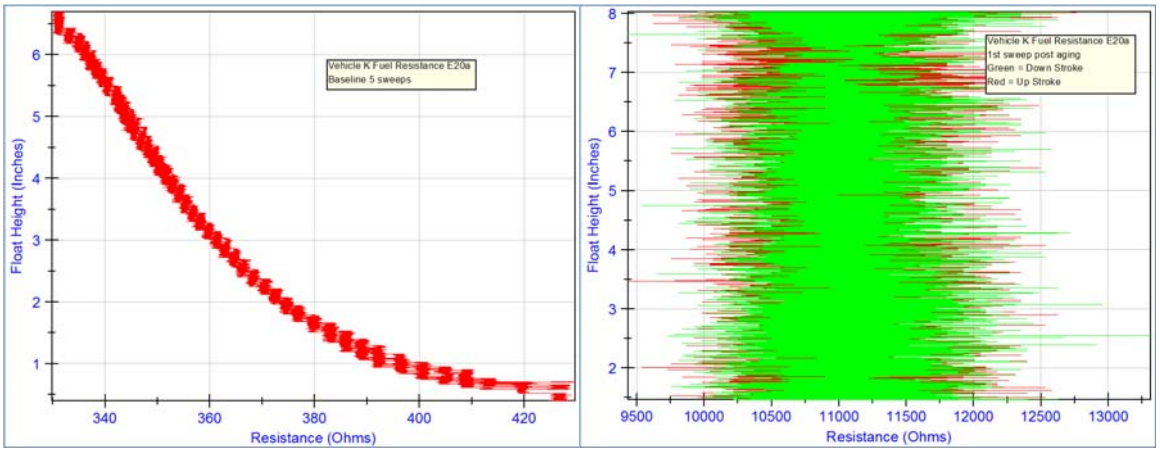
Combined results from Phases 1, 2 and 3 for the Vehicle A pumps are shown in Figure C-22. Pumps labeled A and B were those pumps tested in Phases 1 and 2, while pumps labeled 1 through 4 were the additional pumps tested in Phase 3. As the figure shows, one of the Vehicle A pumps tested in $E20_A$ failed to complete the test protocol, ceasing operation at 916 hours. Post-test teardown analysis for this pump found high resistance at the brush-commutator interface. This failure was believed to have been caused by excessive deposits on the brush contact face. The observed deposits, believed to be either chloride or sulfate, are consistent with experience from similar pumps exposed to higher levels of ethanol blends in gasoline (e.g., E85, which is expected to contain higher levels of chlorides and sulfates). Based on analysis by the vehicle manufacturer's fuel pump lab, this failure was believed to be fuel-related and caused by the higher ethanol content in the $E20_A$ test fuel. The two Vehicle A pumps which completed the test in $E20_A$ showed greater average flow loss compared with the E10 and E0 test pumps; however, individual data for the two $E20_A$ pumps overlapped with data from the E10 test pumps. The single E0 Vehicle A pump tested exhibited the least flow loss among the three test fuels. End of test flow loss values for all pumps were 82.5% and 35.1% for $E20_A$, 48.7% and 37.8% for E10, and 21.9% for E0.

Figure C-22

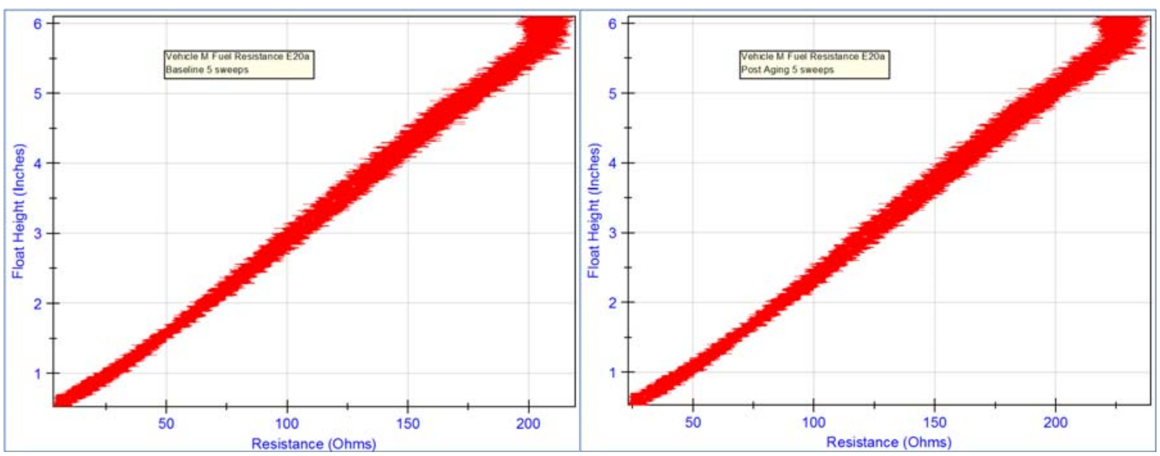


APPENDIX D
FUEL LEVEL SENDERS

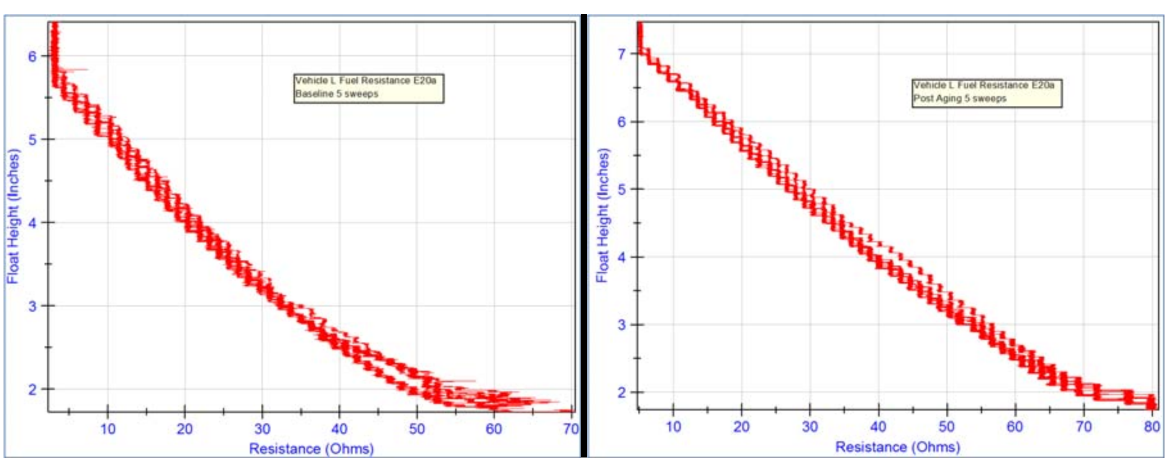
Test Results



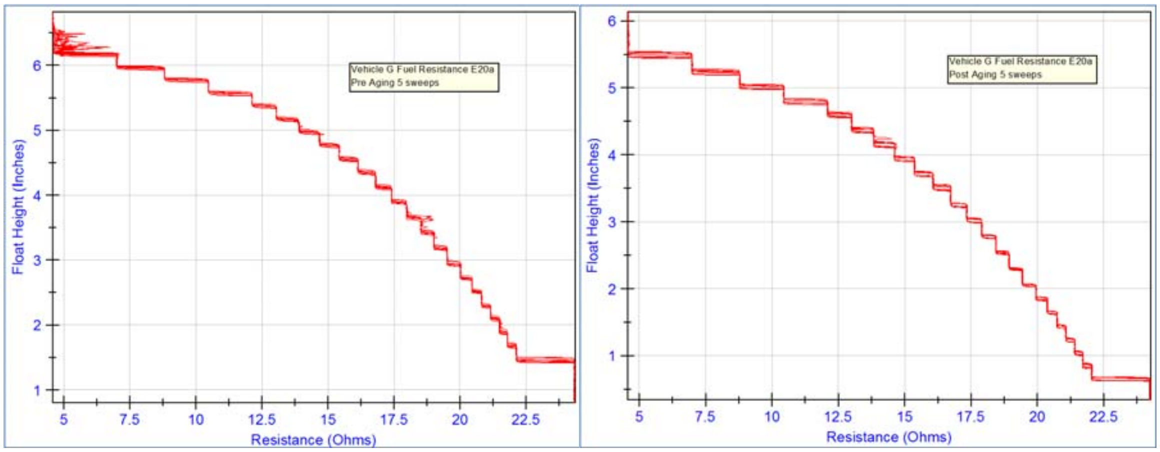
Vehicle K Level Sender $E20_A$ Fuel Resistance pre- and post-aging (sensor became an open circuit)



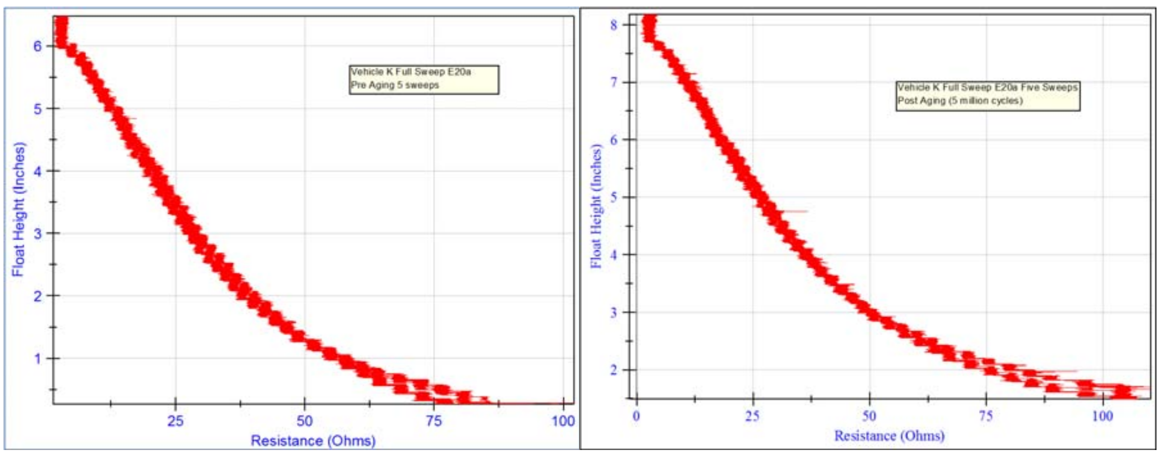
Vehicle M Level Sender $E20_A$ Fuel Resistance pre- and post-aging



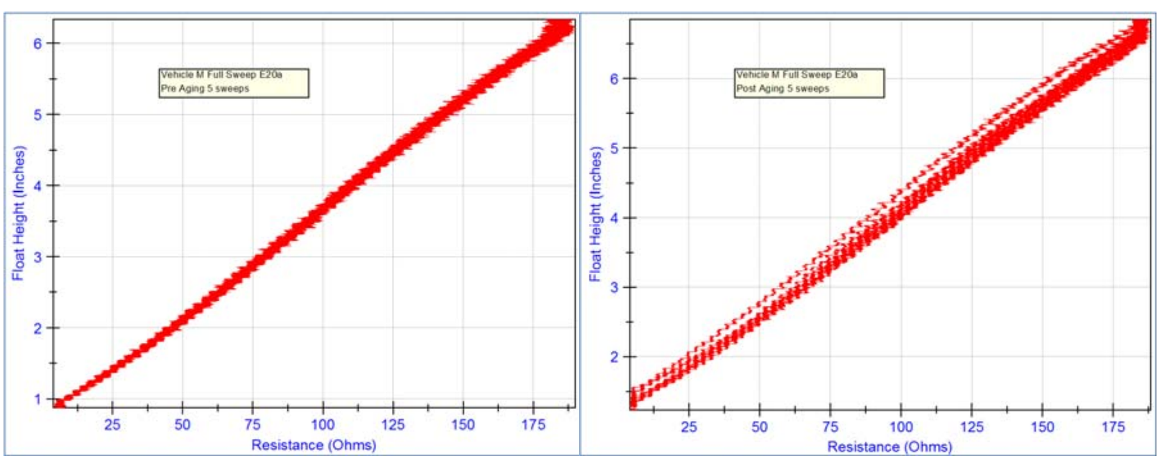
Vehicle L Level Sender $E20_A$ Fuel Resistance pre- and post-aging



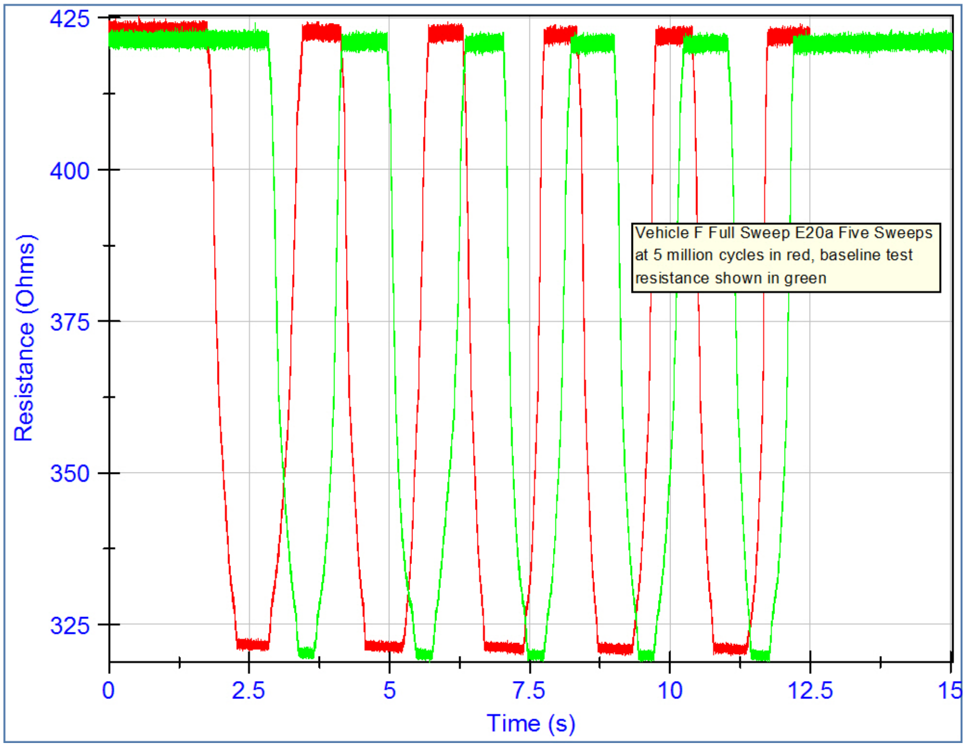
Vehicle G Level Sender $E20_A$ Fuel Resistance pre- and post-aging



Vehicle K Level Sender $E20_A$ Full Sweep pre- and post-aging



Vehicle M Level Sender $E20_A$ Full Sweep pre- and post-aging



Vehicle F Level Sender $E20_A$ Full Sweep pre- (green) and post- (red) aging (float arm failed just prior to test at 5 million cycles)

CRC AVFL-15 Fuel Level Sender Testing Procedure

I. Fuel Resistance Test
   a. Fuel sensors shall be tested using the cycle/soak test described below except as noted. Senders shall be kept wet and contacts held stationary after durability test (no cycling) until electrical tests are complete.
      i. Cycle 250,000 cycles in test fuel at a cycle rate between 1 and 2 cycles/sec. Sender powered.
      ii. Soak in test fuel for 1 week. Sender not powered.
      iii. Repeat steps (i) and (ii) for a total of 1,000,000 cycles and 4 weeks of static soaks, ending with the fourth static soak.
   b. Notes:
      i. Senders not powered unless otherwise specified.
      ii. Fuels shall be changed (not refreshed). Duration between fuel changes shall be no greater than 168 hours.
      iii. When soaking, assemblies shall be completely covered in test fuel.
      iv. Cycle senders through full range by dipping unit with float assembly in test fuel. Alternatively, mechanically cycle sender with assembly completely covered in test fuel.

II. Full Sweep Test
   a. The fuel sensor shall withstand 5 million full sweep cycles at +25°C to +30°C.
   b. The recommended sweep rate is 1 cycle per second.
   c. The level senders should be powered by the standard level sender circuit.
   d. Notes:
      i. Senders not powered unless otherwise specified.
      ii. Fuels shall be changed (not refreshed). Duration between fuel changes shall be no greater than 168 hours.
      iii. When soaking, assemblies shall be completely covered in test fuel.
      iv. Cycle senders through full range by dipping unit with float assembly in test fuel. Alternatively, mechanically cycle sender with assembly completely covered in test fuel.

III. Pass Criteria
   a. Pass criteria for each of these tests is no loss of function or service life, based on the following functional tests. These tests shall be performed both pre- and post durability.
   b. Sensor Accuracy
      i. Three slope Sensor Design
      ii.

Position (% of travel)	Resistance (ohms)	Tolerance (ohms)
Empty Stop	250	± 3.3
15% point	178	± 3.3
45% point	106	± 3.3
Full Stop	40	± 2.5

Note: Values may vary by design or OEM

      iii. Sensor calibration shall be linear between breakpoints.

iv. Accuracy, maintained throughout the entire range, shall be determined using the standard sender circuit and sweeping the complete sender from full to empty stop and back to comprehend system hysteresis. Record calculated resistance, float arm rotation, and buoyancy height from bottom of sender for both sweep directions.

c. Continuity & Noise
    i. Test Conditions:
        1. Digital sampling rate: at least 4 kHz
        2. Sweep cycle rate: 2 seconds or less
    ii. Acceptance Criteria:
        1. A cumulative total of 50 milliseconds open circuit is allowed during a sweep cycle with no single open greater than 10 milliseconds. No more than one open per pad is allowed during each sweep.
        2. Maximum RMS noise allowed for any 10% of a sweep cycle: 5 ohm.

d. Resistance Stability – 10s Dwell
    i. Acceptance criteria: Sender resistance shall be stable for any 10 second interval when set at the following points.
        1. Empty stop: Normal resistance -0 + 2.5 Ohms
        2. Mid range pad: Normal resistance -0 + 3.0 Ohms
        3. Full stop: Normal resistance -0 + 3.0 Ohms
    ii. Definition of normal resistance: Designed resistance for that pad (resistor + clean contact resistance).

Note: Values may vary by design or OEM

As a scoping study, only one sample per fuel level sender design is tested on $E20_A$. Initially, only the fuel resistance test is planned, step (I). Pending the results of the first set of designs tested on $E20_A$, any of the following may occur:

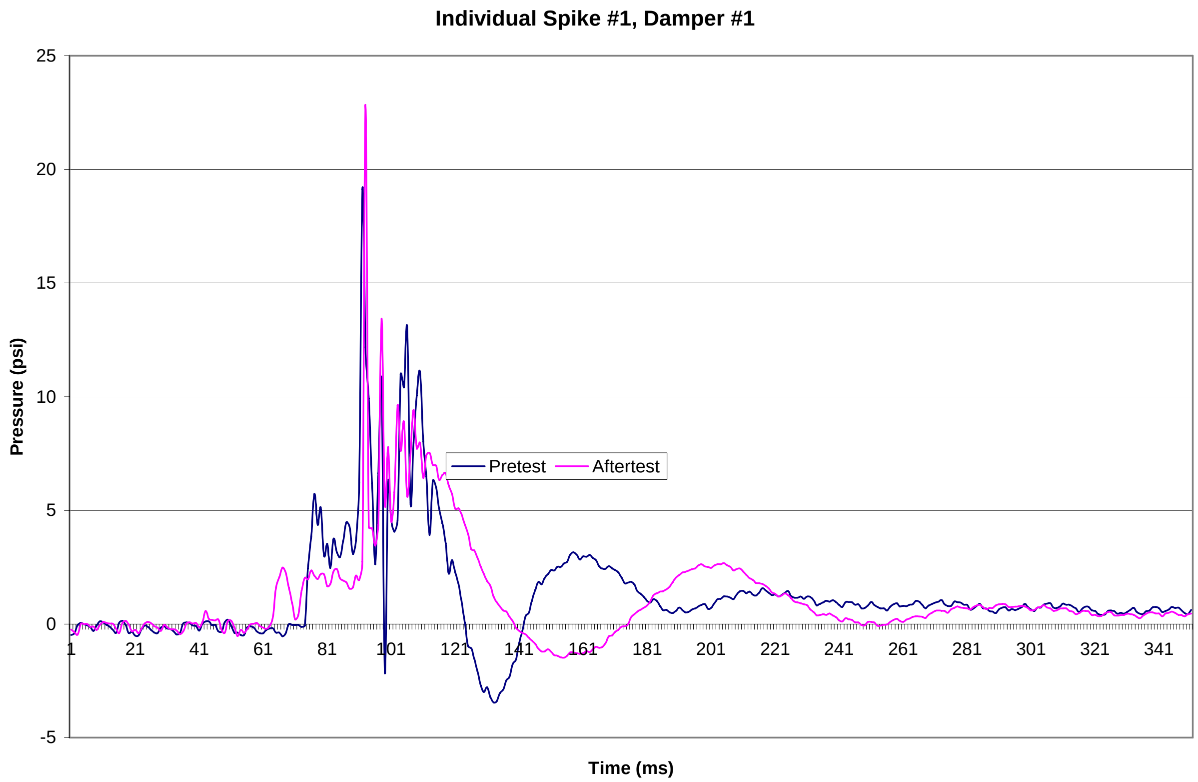
- ⇒ New samples perform the full sweep test on $E20_A$
- ⇒ New samples perform the fuel resistance test on E10
    - o New samples may also perform the full sweep test on E10

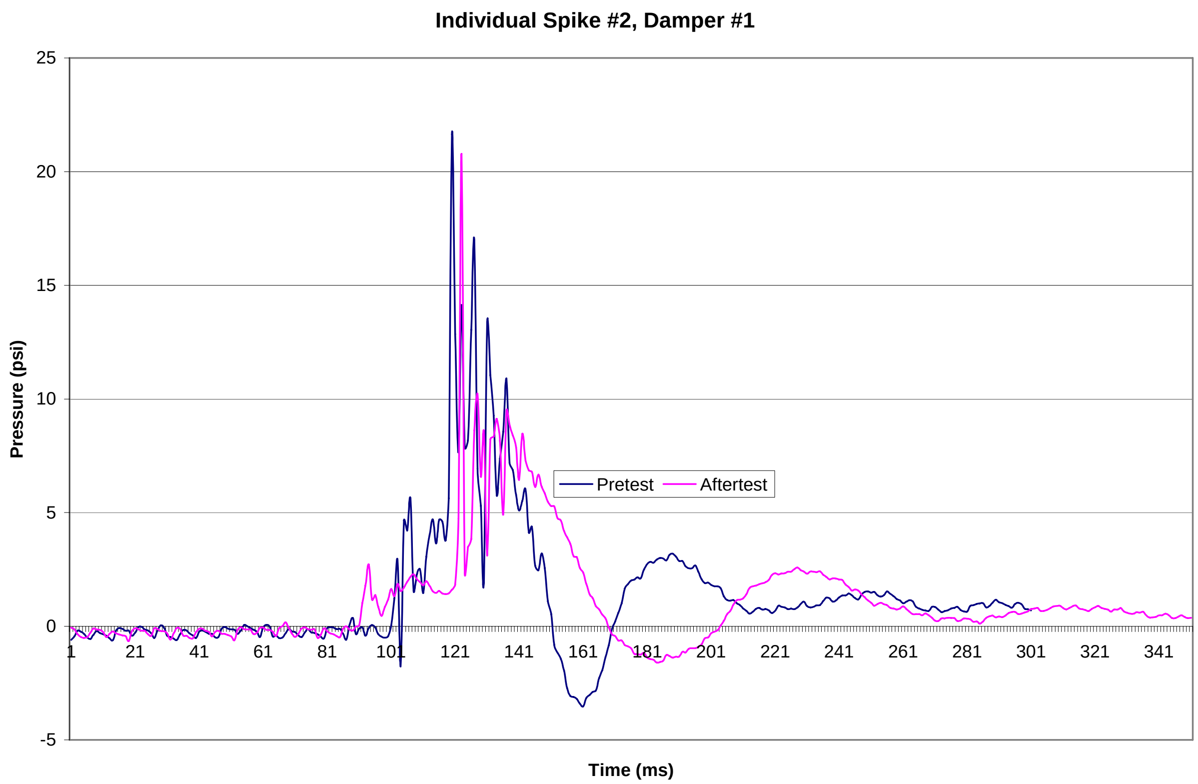
APPENDIX E
FUEL DAMPERS

CRC AVFL-15 Fuel Damper Testing Summary

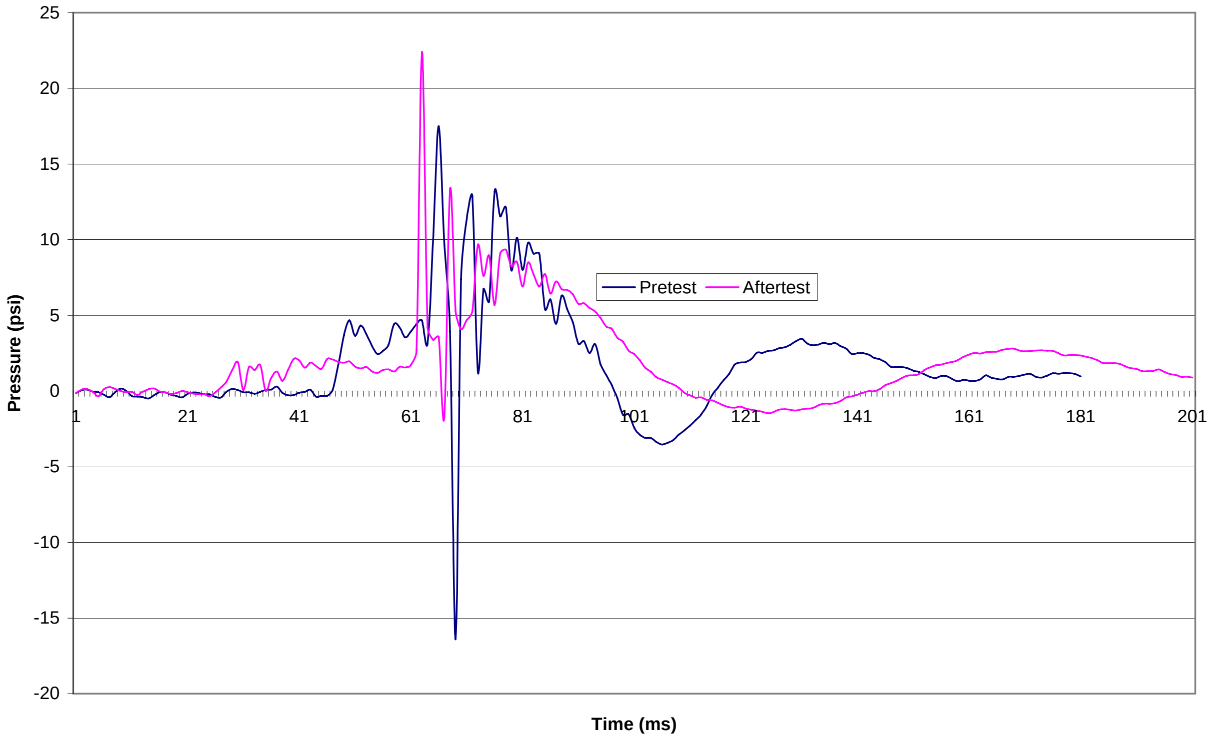
I. Fuel Damper Testing
   a. 10 or more samples per design required
   b. Damper performance test
      i. Stainless steel construction
      ii. High flow diaphragm fuel pump
      iii. Fuel flows into long tube that ends at a fast-acting solenoid valve
      iv. Mounted prior to the solenoid valve is a port for a damper and then a dynamic pressure transducer is mounted
      v. Pressure recorded on a data acquisition system at 30 Hertz (or faster)
      vi. Perform test five times without damper and five times with each damper to determine the damping ratio
   c. Damper leak test
      i. Pressurize damper with 72 psi of air and submerge in test fluid for 10 seconds and observe for any bubbles coming from the damper
   d. Fill damper with test fuel, seal damper, and then soak at 120ºC for 120 hours
   e. Perform Damper Performance Test before and after the fuel soak
   f. Perform the Damper Leak Test prior to any testing and before the fuel soak

As a scoping study, only two total samples are tested.

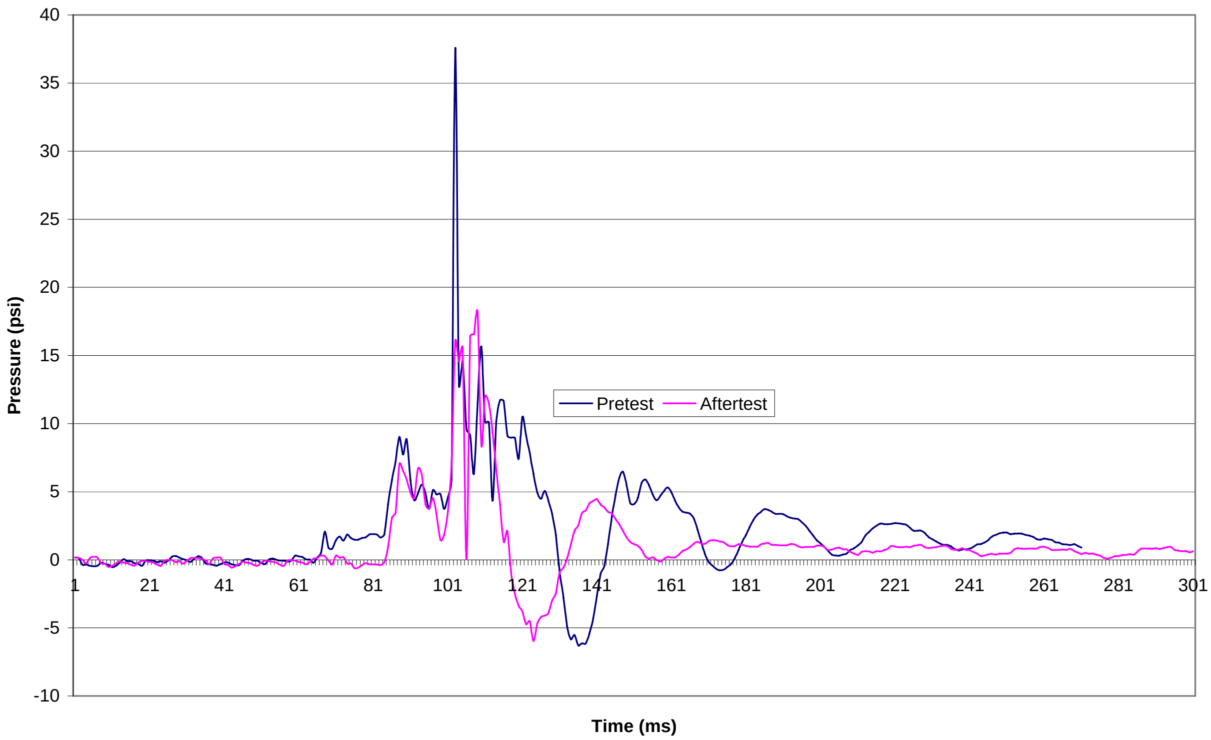

Individual Spike #1, Damper #1
Pressure (psi)
25
20
15
10
5
0
-5
1
21
41
61
81
101
121
141
161
181
201
221
241
261
281
301
321
341
Time (ms)
Pretest
Aftertest

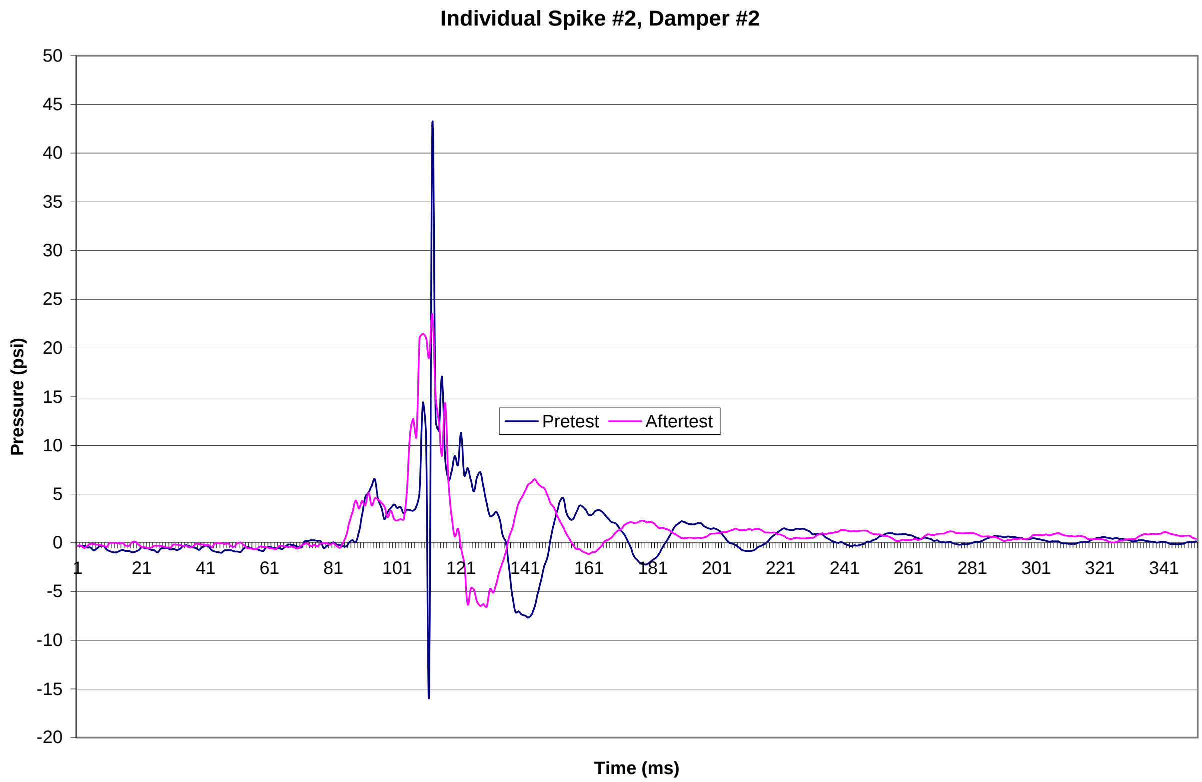

Individual Spike #2, Damper #1
Pressure (psi)
25
20
15
10
5
0
-5
1
21
41
61
81
101
121
141
161
181
201
221
241
261
281
301
321
341
Time (ms)
Pretest
Aftertest

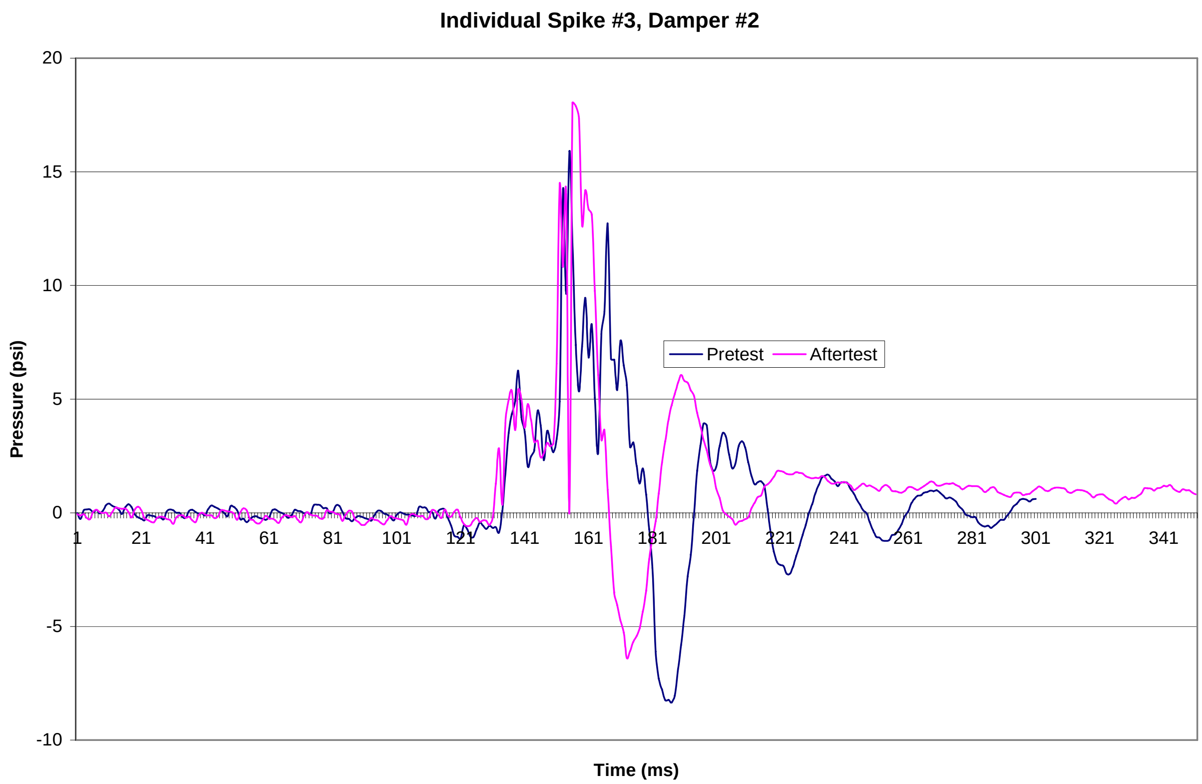
Individual Spike #3, Damper #1



Individual Spike #1, Damper #2




Individual Spike #2, Damper #2
Pressure (psi)
Time (ms)
Pretest
Aftertest
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
1
21
41
61
81
101
121
141
161
181
201
221
241
261
281
301
321
341


Individual Spike #3, Damper #2
Pressure (psi)
Time (ms)
Pretest
Aftertest
20
15
10
5
0
-5
-10
1
21
41
61
81
101
121
141
161
181
201
221
241
261
281
301
321
341

APPENDIX F
FUEL INJECTORS

Fuel Injector Test Procedure
CRC AVFL-15 Fuel Injector Testing Summary

I. Fuel Injector Aging
   a. Aging Fixture
      i. All components stainless steel or ethanol compatible (e.g. ethanol compatible fuel lines)
      ii. Capable of aging four injectors simultaneously
      iii. Simplified version of SAE J1832 Figure 32 utilizing factory fuel injector rail consisting of:
         1. Test fuel reservoir
         2. Heat exchanger to maintain fuel temperature
         3. Factory fuel filter
         4. Aftermarket pressure regulator
         5. Aftermarket fuel pump
         6. Pressure Transducer
         7. Thermocouple for fuel temperature
         8. Computer control and data acquisition
   b. Operate injectors at 14.0 Volts (or manufacturer's specified voltage)
   c. Rail pressure set to the specific vehicle application
   d. Cycle injectors with a Period of 5.0 milliseconds and pulse width of 2.5 milliseconds
   e. Record fuel temperature and pressure once per minute during aging
   f. Fuel temperature per SAE J1832 Bench Durability Procedure at 21ºC ±5ºC
   g. Test Points at 0, 25 million, 50 million, 75 million, 100 million and every 100 million cycles there after
   h. Change fuel every 100 million cycles
   i. Continue test to 600 million cycles

II. Fuel Injector Performance Testing
   a. All testing to be performed on E0
   b. Static Flow Test
      i. Flow each injector at 14.0 volts (or manufacturer's specified voltage) and specified pressure for set amount of time into a graduated cylinder
         1. This time will vary with each injector set to produce sufficient quantity of fuel for measurement
      ii. Weigh the graduated cylinder to determine the amount of fuel delivered
      iii. Repeat for a total of 5 static flow tests on each of the four injectors
   c. Dynamic Flow Test
      i. Flow each injector at 14.0 volts (or manufacturer's specified voltage) and specified pressure for set number of cycles into a graduated cylinder
         1. Period of 10 milliseconds and a pulse width of 2.5 milliseconds
         2. Number of pulses will vary with each injector set to produce sufficient quantity of fuel for measurement
      ii. Weigh the graduated cylinder to determine the amount of fuel delivered
      iii. Repeat for a total of 5 dynamic flow tests on each of the four injectors

As a scoping study, performance tests are conducted at 0 cycles and then every 100 million cycles. In addition, the ethanol content of the test fuel will be checked every 25 million cycles to insure that there is no ethanol loss. Pending the results of the first set of each design's injectors tested on $E20_A$, new samples may be evaluated on E10.

Vehicle A	Injector	Static Flow Rate (g/s)	% Change	Dynamic Flow Rate (g/s)	% Change
0 cycles	1	2.68		0.580	
100 MM cycles	1	2.67	-0.21%	0.574	-1.05%
200 MM cycles	1	2.68	-0.03%	0.554	-4.46%
300 MM cycles	1	2.71	1.34%	0.567	-2.20%
400 MM cycles	1	2.68	0.06%	0.572	-1.39%
500 MM cycles	1	2.68	0.24%	0.576	-0.68%
600 MM cycles	1	2.67	-0.11%	0.575	-0.77%
0 cycles	2	2.66		0.578	
100 MM cycles	2	2.70	1.45%	0.571	-1.17%
200 MM cycles	2	2.70	1.25%	0.573	-0.87%
300 MM cycles	2	2.72	2.04%	0.585	1.18%
400 MM cycles	2	2.70	1.49%	0.585	1.18%
500 MM cycles	2	2.70	1.32%	0.584	1.02%
600 MM cycles	2	2.69	1.09%	0.571	-1.27%
0 cycles	3	2.70		0.589	
100 MM cycles	3	2.73	1.09%	0.594	0.95%
200 MM cycles	3	2.72	0.86%	0.592	0.54%
300 MM cycles	3	2.74	1.53%	0.593	0.73%
400 MM cycles	3	2.73	1.09%	0.586	-0.50%
500 MM cycles	3	2.70	0.07%	0.592	0.64%
600 MM cycles	3	2.69	-0.19%	0.593	0.72%
0 cycles	4	2.71		0.567	
100 MM cycles	4	2.72	0.64%	0.569	0.50%
200 MM cycles	4	2.71	-0.04%	0.571	0.74%
300 MM cycles	4	2.75	1.45%	0.578	2.09%
400 MM cycles	4	2.71	0.16%	0.574	1.27%
500 MM cycles	4	2.68	-0.84%	0.575	1.40%
600 MM cycles	4	2.68	-0.86%	0.579	2.16%

Table F.1. Vehicle A Fuel Injector Test Results

Vehicle I	Injector	Static Flow Rate (g/s)	% Change	Dynamic Flow Rate (g/s)	% Change
0 cycles	1	3.61		0.778	
100 MM cycles	1	3.60	-0.41%	0.776	-0.28%
200 MM cycles	1	3.57	-1.19%	0.770	-1.02%
300 MM cycles	1	3.59	-0.65%	0.769	-1.25%
400 MM cycles	1	3.63	0.64%	0.780	0.28%
500 MM cycles	1	3.56	-1.28%	0.765	-1.68%
600 MM cycles	1	3.58	-0.74%	0.771	-0.98%
0 cycles	2	3.63		0.790	
100 MM cycles	2	3.60	-0.91%	0.803	1.74%
200 MM cycles	2	3.56	-1.83%	0.804	1.80%
300 MM cycles	2	3.61	-0.53%	0.798	0.99%
400 MM cycles	2	3.62	-0.13%	0.806	2.01%
500 MM cycles	2	3.57	-1.71%	0.788	-0.16%
600 MM cycles	2	3.61	-0.62%	0.801	1.37%
0 cycles	3	3.65		0.768	
100 MM cycles	3	3.60	-1.43%	0.754	-1.83%
200 MM cycles	3	3.58	-1.98%	0.757	-1.50%
300 MM cycles	3	3.57	-2.23%	0.754	-1.85%
400 MM cycles	3	3.61	-1.11%	0.762	-0.78%
500 MM cycles	3	3.58	-2.00%	0.751	-2.29%
600 MM cycles	3	3.60	-1.47%	0.756	-1.65%
0 cycles	4	3.65		0.764	
100 MM cycles	4	3.55	-2.56%	0.761	-0.31%
200 MM cycles	4	3.59	-1.69%	0.777	1.69%
300 MM cycles	4	3.60	-1.35%	0.762	-0.27%
400 MM cycles	4	3.63	-0.58%	0.778	1.90%
500 MM cycles	4	3.56	-2.45%	0.763	-0.04%
600 MM cycles	4	3.63	-0.61%	0.776	1.60%

Table F.2. Vehicle I Fuel Injector Test Results