

CRC AVFL-15 Project
E20 Durability of Fuel System Components

*Project Co-leads: Dominic DiCicco, Ford Motor Company
Sean Torres, Ford Motor Company
Mike Foster, BP
Keith Knoll, NREL*

CRC AVFL-15a Project
E15 Durability and Effect of Aggressive Ethanol

*Project Co-leads: Scott Jorgensen, GM
Mike Foster, BP*

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AVFL-15 Project Summary

Scope

- Initial investigation to evaluate the durability impacts of wetted fuel components when exposed to E20.
- Program limited to one piece evaluations due to resource constraints with some selected additional testing

Technical Approach

- Query OEM's for candidate fuel system applications relevant to the concern.
- Perform specific durability protocols to expose and age components using mid-level ethanol.
- Conduct component functionality testing using E0 as the test fluid baseline.

Status:

- Pilot phase completed December 2008
- Fuel Injector testing completed E20_A testing Dec. 2009
- Fuel System Rigs E20_A, E10 completed aging February 2010
 - Fuel sample analysis to complete by Q4 2011.
- Fuel Damper completed testing E20_A August 2010
- Fuel Pump E20_A, E10, E0 testing to complete in August 2011
- Fuel Level Sender E20_A, E10, E0 to complete in Q4 2011
- Post Mortem in progress or to be conducted for various components



Vehicle Design & Components

Vehicle Design Selection

- 1996-2007MY (*attempting to represent model years found in the fleet*)

Fuel-System Related Components Included in Program

- Fuel pump
- Fuel injector
- Fuel level senders
- Fuel damper
- Fuel system rig assembly (from fuel rail to fuel tank and components in between)



Test Fuels

- **Base Gasoline (E0)** – used for durability and functional testing
 - Conventional Fuel with 38-40% aromatics
 - Instead of isooctane-toluene blend
- **E10** – durability fuel
 - Blended from the base gasoline
- **Aggressive E20 (E20_A)** – durability fuel
 - SAE J1681 – with agreed modifications
 - Chlorides – 10ppm max from ASTM 4806 (2 ppm for E20)
 - Sulfates – 4ppm max on denatured ethanol (~1 ppm for E20)
 - pHe – unable to achieve using acetic acid; replaced sulfuric acid with nitric acid (~2.8 as found in SAE J1681)
- **Fuels pre-blended and stored at testing facility**



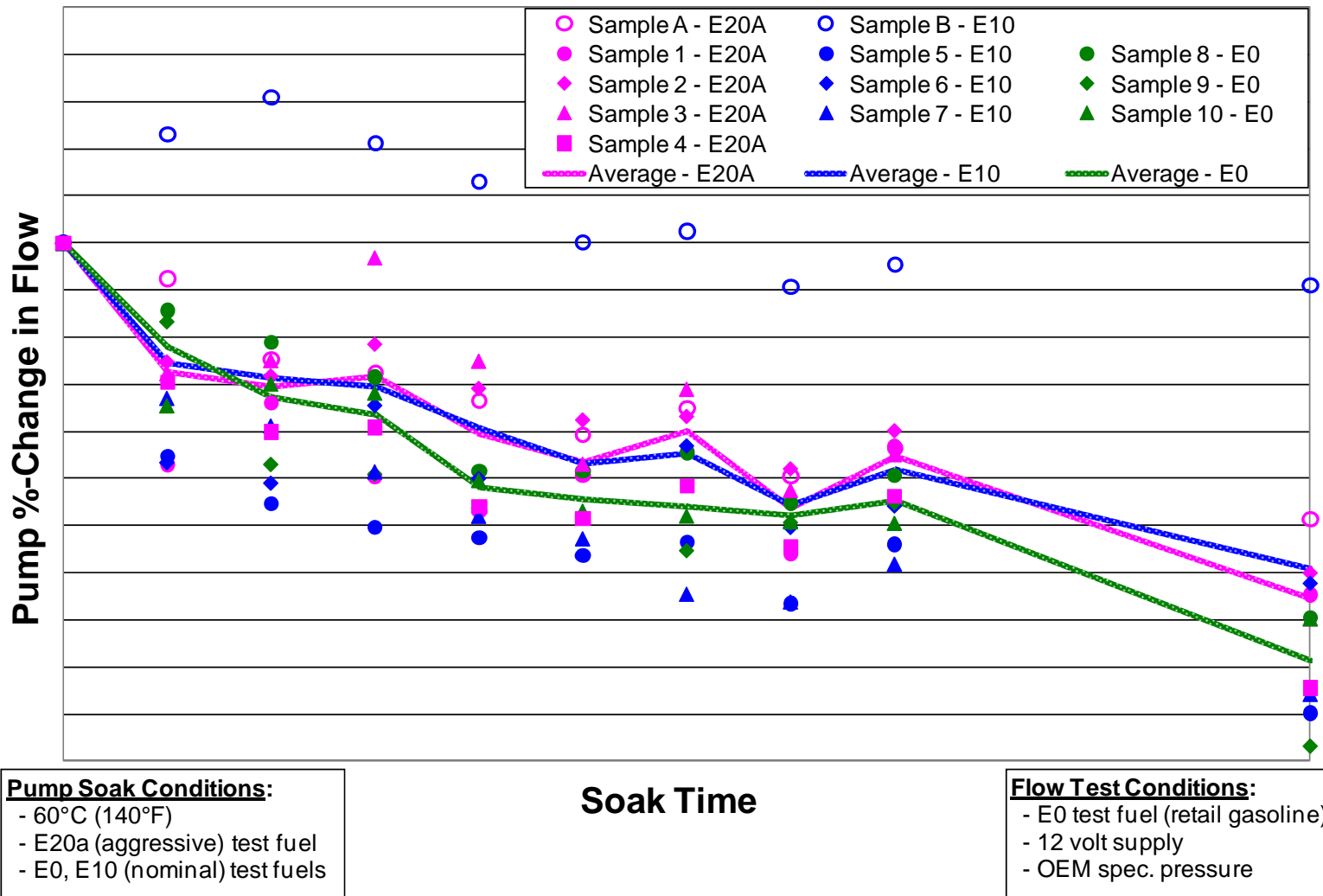
Fuel Pump: Soak Durability Test

- Soak fuel pumps in E20_A to determine change in pump performance
 - Soak aging of 10 designs (up to 12 weeks)
 - Soak pump in E20_A at 60° C (140° F), non-vented container
 - Pump on time using 13.5 VDC, pump flow and pressure per specifications
 - Fuel changed weekly for first 8 weeks, then changed at week 10 and week 12
 - Flow testing
 - Weekly using SAE/USCAR-13 for first 8 weeks, then final test at week 12
 - E0 used for all flow testing
 - Follow-up testing
 - Selected Pump designs impacted by E20_A repeated with E10 and E0
 - Pumps completing testing are to undergo tear down analysis
- Status:
- E20_A (10 designs) and E10 (3 designs) testing complete, tear down in progress
 - Additional testing (design with largest differentiation between fuels, multiple samples, E20_A, E10, E0) expected to complete by end of August 2011



Fuel Pump Soak Durability

%-Change in Pump Flow vs. Soak Time



Fuel Pump: Endurance Testing

- Operate fuel pumps in E20_A to determine change in pump performance from nearly continuous operation
- 8 designs tested with E20_A initially; repeat with E10 as necessary
- Endurance aging:
 - 3,000 hours (10 minutes on, 6 seconds off)
 - Aging temperatures included 105° F and 140° F
 - Fuel pressure is specific to design
 - Fuel change twice per week
- Test stand functionality as defined in SAE/USCAR-13
 - Test every 1,000 hours (and before/after hot temp operation)
- Status:
 - ☑ E20_A (8 designs) and E10 (4 designs) testing complete
 - Mixed fuel flow loss results, no direct fuel-related pump failures observed
 - Additional testing (designs with greatest flow loss, multiple samples, E20_A, E10, E0) expected completion by August 2011



Fuel Injector Testing

- Operate fuel injectors with E20_A to determine change in spray pattern, dynamic flow, static flow, and if leakage occurs due to operation in E20_A
- 3 designs tested with E20_A initially; repeat with E10 as necessary
- Aging
 - 600 MM cycles (approx. 6 weeks), Test every 100 MM cycles
 - Pulse Width of 2.5 ms with Period of 5.0 ms
 - Fuel change at Test points
 - Use aftermarket fuel pump and pressure regulator; pressure set per application
- Injector testing (SAE J1832)
 - Static and Dynamic Flow
 - Spray quality degradation (via photograph)
 - Leakage
- Status
 - Completed E20_A testing Dec. 2009
 - No further testing on E10 was warranted.



Fuel Level Sender

- Operate fuel level sender in E20_A to determine performance
- Fuel Resistance (1000 hr test, 8 designs)
 - 250,000 cycles (powered), 1 week soak (no power) for 1 million cycles
 - Total duration at 1 Hz: Approximately 40 days
- Full Sweep (8 designs)
 - 5,000,000 cycles (58 days at 1 Hz)
- Evaluation to consist of:
 - Sensor Accuracy
 - Continuity and Noise
 - Resistance Stability
 - Visual Inspection

Note: In addition to the customer interface, Fuel Level Senders are used by On-Board Diagnostic systems.

□ Status:

☑ Fuel Resistance:

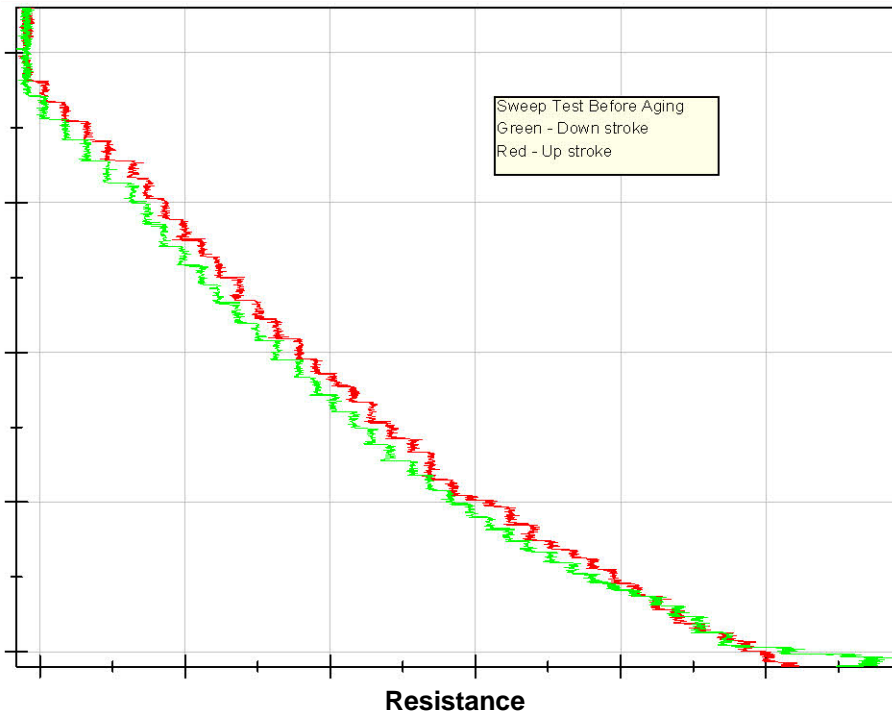
- ☑ E20_A initial testing completed. Complete open circuit (1 design), some partial open circuits, spikes in signals & hysteresis.
- ☑ E10 testing on four designs completed. Two designs showing noise not as extensive as found with E20_A.

□ Full Sweep on E20_A, E10, E0 testing for 2 designs to complete in Q4 2011.

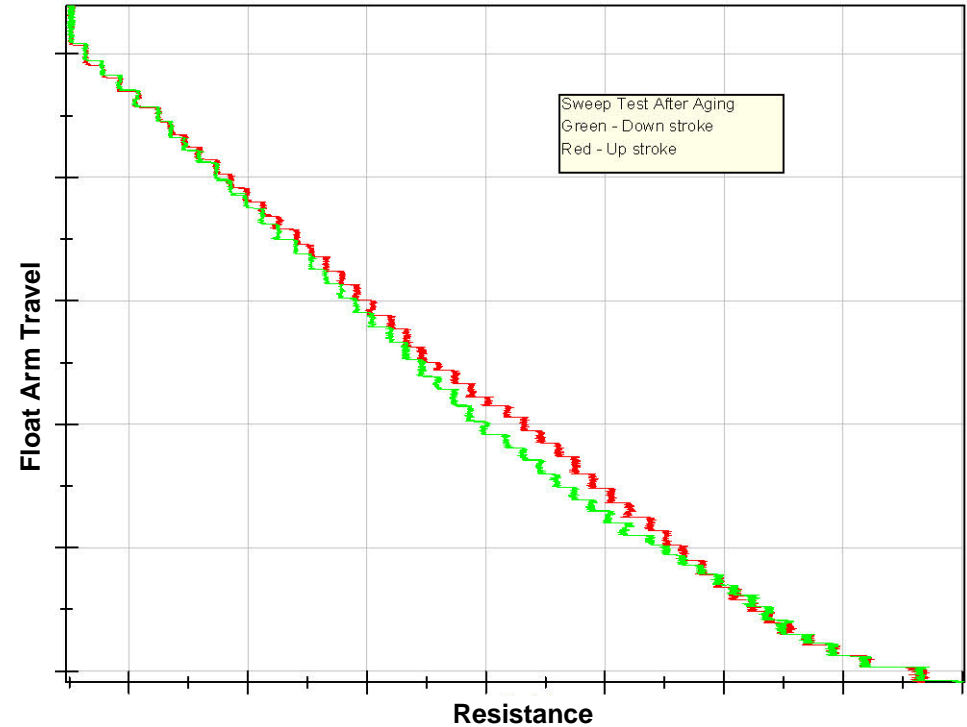
□ Teardowns to complete Q4 2011.



Sample 1: Resistance Data



Pre-Test Sweep
(first sweep only)

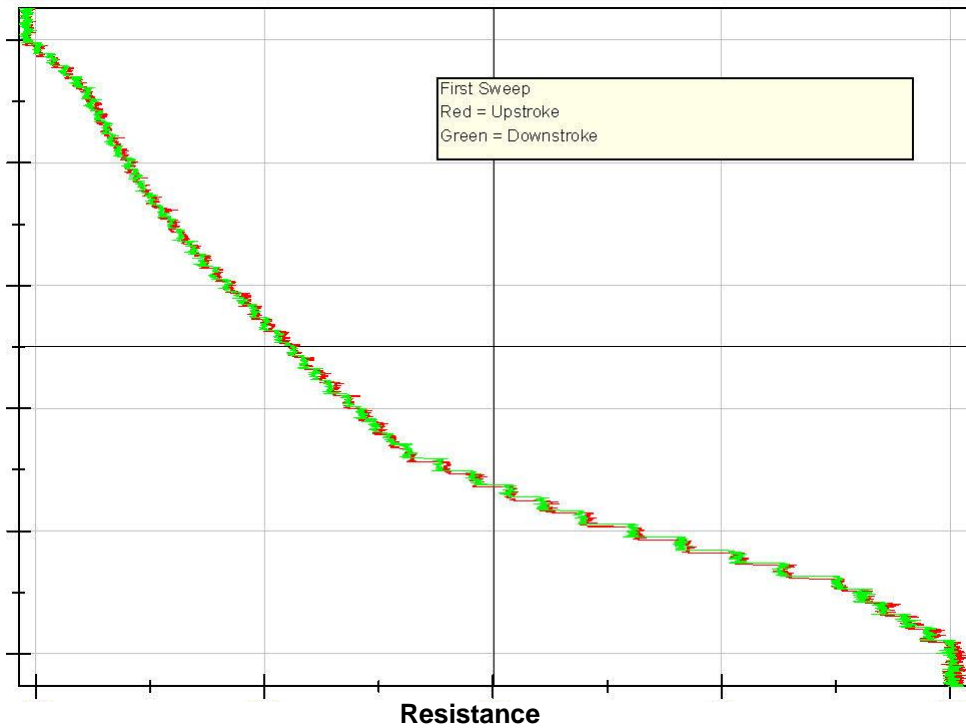


Post-Test Sweep
(first sweep only)

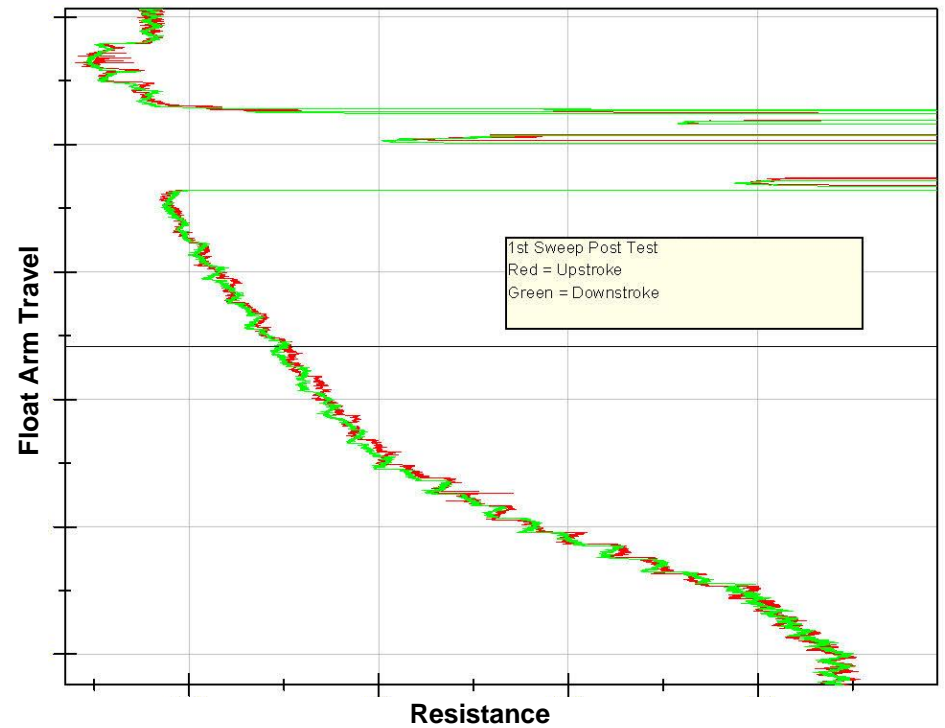
NOTE: This is an example of a fuel level sender which experienced very little change from baseline to post test.



Sample 2: Resistance Data



Pre-Test Sweep
(first sweep only)



Post-Test Sweep
(first sweep only)

NOTE: This is an example of a fuel level sender which experienced a significant open near the full/top position in the post test.



Fuel Damper

- Soak fuel dampers in E20_A to assess damping change
- High Temperature Soak / Permeation Test
 - 100 psig fluid pressure @ 120° C for 120 hrs
- Pulse Attenuation (“water hammer” setup) using fast acting valve
 - 10 Hz to 200 Hz injector frequency at 20° C
- External Leakage
 - 72 psig air test while submerged in test fluid
- ☑ **Status:**
 - ☑ Testing completed on E20_A August 2010
 - ☑ No further testing on E10 was warranted.



Fuel System Rig Testing

- Expose fuel system components to E20_A and E10
- 13 rigs: 6 designs (1 rig for each fuel) & one additional rig from
- CRC Project E-65 (on E20_A)
 - Rigs to mimic vehicle fuel system (using new parts)
- 14 month soak at 105° F (40.6° C)
- Fuel circulation for 10 min every weekday to wet components
- Fuel replaced weekly, then every 2nd week, then every 3rd week during each subsequent 14 week period
- Conduct Tear Down and Post Mortem Analysis
 - Capture fuel samples to assess material degradation
 - Analyze fuel system materials at the end of the soak
- Status
 - Aging completed February 2010
 - Rig teardown and component analysis complete
 - Fuel sample analysis to complete by Q4 2011



Fuel System Rig Example



Post-Mortem Testing

- **Fuel Pump**
 - Flow Test
 - Teardown (e.g. brush, commutator, impeller)
 - Status: ongoing / as needed
- **Fuel System Rig**
 - Leak Test
 - Disassemble
 - Component teardowns (e.g. corrosion, contamination, seal degradation)
 - Status: complete
- **Fuel Level Sender**
 - Teardown (e.g. visual inspections of wiper assembly / printed circuit card)
 - Status: ongoing / as needed
- **Fuel Damper**
 - Post-mortem testing not required.
- **Fuel Injector: Post Mortem Testing Not Required**
 - Post-mortem testing not required.



AVFL-15a Project Summary

Scope:

Evaluate durability impacts of wetted fuel components when exposed to E15 and E15_A

Technical Approach:

- Follow same general technical approach used for AVFL-15 project
- Perform specific durability protocols to expose and age fuel pumps and fuel level sender components using mid-level ethanol
- Conduct component functionality testing using two E15 test fuel formulations

Status:

- Project started in February 2011; planned duration is 10 months
- Fuels designed and contracted
- Test setups designed and approved
- Test components selected and obtained
selected based on best information from AVFL-15 available in early March
- Endurance pump testing active 7/14
- Test vessel and electronics build up of sender test vessels active
- Testing plan complete 11/28
- Data gathering complete 12/12
- Program should complete at end of 2011

