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Committee D02 on PETROLEUM PRODUCTS AND LUBRICANTS

Issued: October 08, 2012

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These are the unapproved minutes of the 09.26.2012 Sequence VI Surveillance Panel meeting.

The meeting was called to order at 8:30 AM by Chairman Charlie Leverett.

Agenda

The Agenda is the included as Attachment 1.

1.0 Roll Call

The Attendance list Attachment 2.
The Motions and Actions will be Attachment 3. Thanks to Bill Buscher for writing those up.

2.0 Approval of minutes

2.1 Approval of the minutes of the 07.17.2012 Conference Call.

Motion – Accept the minutes of the 07.17.2012 VID SP CC.
Charlie Leverett, Jason Bowden, second. Unanimous.

3.0 Action Item Review

3.1 OHT to report VIx engine usage.
There are 39 2009 and 153 2012 engines in inventory. No 2012 engines have been purchased by labs as of this meeting.

3.2 A Task Force will be setup to review the current VID Standard with the Scope/Goal being to better standardize. Dave has agreed to chair the Task Force.
The Task Force Report and Scope and Objectives are included as Attachments 4 and 5.
Discussion and votes on the recommendations are included in New Business.

3.3 Identify a list of ancillary components needed to last the life of the Sequence VID test with both the MY2009 and MY2012 engines and provide to GM. **This comes from the 03-27-2012 meeting and I am not sure who recommended this Action Item? Looking for someone to take this on?**
Jerry Brys will work on this list with representatives from other test labs.

Action Item – Jerry Brys to lead a task force that will generate a list of GM hardware from the MY2009 engine that will need to be carried over and used on the MY2012 engine.

Jason Bowden noted that there was a large demand for the knock sensor and there was no inventory and no currently available replacement part. The GM part number has been discontinued. IAR had tried remote mounting without success, so a resistor may be the best solution as the ECM still detects the knock sensor and Lubrizol has a presentation that a failure in this area will affect ignition timing. Their wiring harness failed, rather than the sensor itself. A heat insulator boot will help with this problem.

4.0 Old Business

4.1 None

5.0 New Business

5.1 Update from TMC on the next batch of BL & FO oils and 541-1 – Rich

The 541-1 results presentation is included as Attachment 6. 541 and 541-1 compare to existing targets with little difference. The sigmas are identical. A recommendation was made to use existing targets.

Motion – Accept RO 541-1 as a replacement for RO 541 using the current RO 541 targets to judge test acceptability, and review and fix targets at 30 data points.

Dave Glaenzer / Rich Grundza / Passed Unanimously

New BL and FO blends are in process based on a survey of the needs of the labs.

Action Item – Labs that have not already done so, issue purchase orders to the TMC ASAP for the next batch of BL & FO.

5.2 Recommendations from the TF - Dave.
A decision was made to vote on each recommendation and have discussion.

5.2.1 The first recommendation was to convert to a 50/50 mixture of Dexcool and water.
There were questions on why 100% Dexcool was selected. It was decided to blame it on Sid. There was also discussion on why 100 kPa was selected, but this is close to the 15 psi radiator caps used on many current vehicles and recommended by GM. SwRI asked, but no data was presented on changes to heat transfer or fuel dilution on the new engine.

Motion – With OHT6E-001-1 engine, change Engine Coolant to 50/50 mixture of Dexcool®/Demineralized or Distilled Water pressurized to 100 ± 10 kPa.

Dave Glaenzer / Mark Mosher / Passed Unanimously

5.2.2 The next recommendation was to use the same filter screen as the VG and other test types.

Motion – With OHT6E-001-1 engine, change Oil Filter Screen size to 60µm for FIL-1 & FIL-2.

Dave Glaenzer / Jason Bowden / Passed Unanimously

5.2.3 One minute data was recommended as snapshot logging for all stages including flushes and retain the data for 2 years.
SwRI recommended only requiring this for the Precision Matrix.

Motion – With OHT6E-001-1 engine, require one minute snapshot logging of data for all stages, including flushing and retain data for 2 years. Section 11.6.5 which specifies logging during BSFC routine remains unchanged.

Dave Glaenzer / Jason Bowden / Passed Unanimously

5.2.4 Next was a recommendation to change to 90 minute stabilization for each of the 6 stages in all test conditions [BLB, Candidate 1 and 2 and BLA].
Some labs have problems with temperature transitions, especially from the low temperature of Stage 5 to the high temperature of Stage 6. Afton is not stable in the current time and presented data that the CV [coefficient of variation] was more stable. See Attachment 7. SwRI felt this change did not improve test precision and only increased test price and reduced engine life. Guy recommended a review of oil heater conditions and hardware at affected labs to improve temperature control.

Motion – With OHT6E-001-1 engine, change Stabilization Times before BSFC from 60 minutes to 90 minutes.

Dave Glaenzer / Jason Bowden / Passed with 1 waive and 1 against

5.2.5 The Task Force felt the engine hour correction and BLB Delta limits should be reviewed for the new engine.

Motion – Matrix data generated with OHT6E-001-1 engine should be examined for appropriateness and potential update of engine hour correction factor as well as BLB1/BLB2 acceptance criteria.

Dave Glaenzer / Jason Bowden / Passed Unanimously

5.2.6 The Task Force also had concerns that calcium from the Flush Oil was retained and raised the value in the BLA oil.
SwRI had presented data that the calcium levels were stable by 4 flushes and identical at 5 flushes, so 6 were not needed. The comments were that other labs flush equipment might well be less effective and more flushes would be necessary.

Motion – With OHT6E-001-1 engine, modify Section 11.6.17 of procedure to incorporate additional flushing to BLA. Six BL oil changes; the first five followed by 30 minutes of flush conditions, the last followed by switch to BLA Stage 1.

Dave Glaenzer / Jason Bowden / Passed with 2 waives

5.2.7 There was a concern that using either the #8 or #10 hose size for the suction portion of the oil system restricted oil circulation.
Afton did some work with #12 line and a newer Burkert valve along with a specification of 0.5 inch minimum diameter internal diameter for those hoses.

They showed a photo of an oil pan with a recommended plumbing method. See Attachment 8.There was discussion on how to standardize plumbing between labs. Rich Grundza stated that D7589 was a test standard and all labs should be consistent to that procedure. However, Guy recommended defining line lengths and number of connector fittings and this was rejected. GM suggested a flow specification rather than a pressure range. Angela will try to provide a GM recommendation. SwRI has agreed to install a flow meter and work on meeting this specification.

Action Item – GM to provide oil flow data from LY7 to surveillance panel, if available.

Motion – With OHT6E-001-1 engine, FCV-150C is to be Burkert Type 2000 with 13 mm orifice and 50 mm actuator. Additionally, flexible hoses to and from FCV-150C are to be size #12 and the internal diameter of all fittings on the suction side of the engine driven oil pump shall be equal to or greater than 0.50 inches. Hose lines to and from FIL-2 are to be size #10.

Dave Glaenzer / Jason Bowden / Passed with 1 waive

5.2.8 The Task Force had also run a Round Robin to compare coolant flow results between labs.

The consensus was that the calibration procedure needed to be defined. It was also felt this change should be implemented on current VID test stands. This was covered with two motions.

Motion – With OHT6E-001-1 engine, Section 10.2.3 change to: *Coolant Flow Measurement System* – Calibrate the flow measurement device as installed in the system at the test stand, every 6 months. Calibrate the stand flow measurement device with a suitable flow measurement device using 100% water as the calibration media. Calibrate the flow measurement device used for calibration of the stand flow measurement device every 12 months using 100% water as the calibration media and shall be NIST traceable.

Dave Glaenzer / Jason Bowden / Passed Unanimously

Motion – Modify Sequence VID Procedure (D7589) Section 10.2.3 as follows: *Coolant Flow Measurement System* – Calibrate the flow measurement device as installed in the system at the test stand, every 6 months. Calibrate the stand flow measurement device with a suitable flow measurement device using 100% water as the calibration media. Calibrate the flow measurement device used for calibration of the stand flow measurement device every 12 months using 100% water as the calibration

media and shall be NIST traceable. Effective immediately and to be completed 1/1/2013.

Dave Glaenzer / Jason Bowden / Passed Unanimously

5.3 Aging study ran at IAR on 2012 engines - Charlie.

The IAR Aging data is included as Attachment 9. Afton also presented a slide with additional chemical analysis and oil consumption with 500 ml increased oil charge. This is Attachment 10. There was some indication aging length would need to be increased with the 2012 engine. The consensus there was not enough data to evaluate this change. TMC will check on the quantity of the original oil C, and the Statistical group will be asked to design an aging matrix.

Action Item – Industry statistical group to make a recommendation on a matrix to obtain additional data for aging with an additional 500ml of oil added to the test oil charge. The goal is to match original VID aging, which is correlated to the FTP data, using the OHT6E-001-1 engine and the changes incorporated along with it.

5.4 Lambda Meter Discussion - Nathan

The Lambda Meter presentation is included as Attachment 11. Lubrizol has a meter with a different range than defined in the procedure. The AFM 1000 version is more accurate but over a more narrow range. Discussion was that AFR is a read only and that the tighter specification should be removed.

Motion – Modify Section 6.10.1 of the Sequence VID Procedure (D7589) to remove the AFR measurement range specification. Include reference to both the Horiba and ECM analyzers as acceptable devices in the procedure. Effective immediately.

Nathan Moles / Dave Glaenzer / Passed Unanimously

5.5 Afton Presentation – Greg Guither

At the request of several members the Afton presentation on changing the test specifications to better detect different viscosities was moved forward. See Attachment 12. The intent was to improve fuel economy correlation with real world values. A 5W-30, 5W-20 and 0W-16 were used for comparison. Their data was based on the Artemis European driving cycle with 7 vehicles. This is more robust than the FTP cycle. The recommendation was to reduce oil and coolant temperatures during Stages 1, 3, 4 and 6. C1 and C2 Aging would also have reduced temperatures to lower oil consumption and provide less stress on the oil. Later data indicated that only Stages 1 and 3 have the lower temperature as they represent the majority of the FEI effects on the VID test. All of these changes would be considered for the 2012 engine. The consensus is that more direction from the OEM's is needed on where to proceed with this information. The big concern is this would move the test away from the FTP results that were the basis of VID development.

Action Item – Surveillance panel chairman is to contact the OEMs to see if there is any interest in pursuing Afton's recommendations included in their presentation "Recommendations for Improving Discrimination of Test Oils in the Sequence VI Fuel Economy Test". A summary of the OEM responses will be distributed to the surveillance panel members.

5.5 Flow Meter Discussion – Nathan

The Flow Meter presentation is included as Attachment 13. His comments were that the Micro Motion device reads at the lower end of the scale in idle conditions. Cube Mass makes a unit with a better range for the VID and Micro Motion plans to release a similar version. Most labs calibrate Micro Motion flow in the lower end of the range to improve response. Lubrizol is willing to purchase a new unit and place it in series so the VID reading is not affected to compare results.

5.6 Knock Sensors - Nathan

The Lubrizol Presentation is Attachment 14. They had a case where it appeared the knock sensor failed and was replaced. However it was actually damage to the wiring harness, and this can shift ignition timing. A couple of suggestions were a thermal boot and to relocate the sensor or replace it with a resistor and move that away from the exhaust manifold.

Action Item – Lubrizol, and other test labs if interested, to further investigate solutions to issues observed with the knock sensor, so that a motion can be considered.

5.7 Current Retired VID Engines

There was discussion on whether the retired 2006-2009 engines can be disposed of by the labs. Consensus was the labs can take that action.

5.8 Burkert Valves – Dave Glaenzer

Section 6.6.5.3 (5) states that all valves should be of the same type. As they serve different operating conditions, this is not necessary.

Motion – Modify Section 6.6.5.3 (5) of the Sequence VID Procedure (D7589) to remove the wording "only one type" of Burkert valve. Effective immediately.

Dave Glaenzer /Jason Bowden / Passed Unanimously

5.9 VIB Oils – Rich Grundza

Rich noted that there have not been any VIB tests run recently. As part of their audit process, TMC would like to dispose of BC-6 and reference oil 539.

Motion –Approve disposal of the VIB BC-6 baseline and reference oil 539. Effective immediately.

Rich Grundza / Dave Glaenzer / Passed Unanimously

6.0 Next Meeting

At the call of the chairman.

7.0 Meeting Adjourned

The meeting adjourned at 1:55 PM.

Charlie Leverett, Rich Grundza, second. Unanimous.

Sequence VI Surveillance Panel conference Call
September 26, 2012 @ Intertek AR
8:30 – 4:00 CDT
Call in #: 800-391-9177
Pass Code: 4875645502

Agenda

1.0) Roll Call

2.0) Approval of minutes

2.1) Approve the minutes from the July 17, 2012 Sequence VI Surveillance Panel conference call.

3.0) Action Item Review

3.1 OHT to report VID engine usage and expected depletion date at all Surveillance Panel meetings. **44 as-of 02/06/12**

3.2 A Task Force will be setup to review the current VID Standard with the Scope/Goal being to better standardize, Dave has agreed to chair the task force. **Dave will present the TF recommendations today.**

3.3 Identify a list ancillary components needed to last the life of the Sequence VID test with both the MY2009 and MY2012 engines and provide to GM. **This comes from the 03-27-2012 meeting and I am not sure who recommended this Action Item? Looking for someone to take this on?**

4.) Old Business

None

5.) New Business

5.1 Update from TMC on the next batch of BL & FO and 541-1 - Rich

5.2 Recommendations from the TF - Dave

5.3 Aging study ran at IAR on 2012 engines – Charlie

5.4 Lambda meter discussion – Nathan

5.5 Flow meter discussion - Nathan

5.6 CPD report – OHT

5.7 Can we dispose of the current used VID engines in our inventory?

5.8 VID Mods - Afton

6.) Next Meeting

Call of the chairman

7.) Meeting Adjourned

ASTM SEQUENCE VI

Name	Address	Phone/Fax/Email	Attendance
Jason Bowden Voting Member	OH Technologies, Inc. P.O. Box 5039 Mentor, OH 44061-5039	Phone: 440-354-7007 Fax: 440-354-7080 jhbowden@ohtech.com	✓
Timothy Caudill Voting Member	Ashland, Inc. 21st and Front Streets Ashland, KY 41101	Phone: 606-329-5708 Fax: 606-329-3009 Tlcaudill@ashland.com	
David Glaenzer Voting Member	Afton Research Center 500 Spring Street Richmond, VA 23218	Phone: 804-788-5214 Fax: 804-788-6358 Dave.Glaenzer@aftonchemical.com	✓
Rich Grundza Voting Member	ASTM TMC 6555 Penn Ave. Pittsburgh, PA 15206-4489	Phone: 412-365-1034 Fax: 412-365-1047 reg@astmtmc.cmu.edu	✓
Charlie Leverett Voting Member	Intertek Automotive Research 5404 Bandera Road San Antonio, TX 78238	Phone: 210-647-9422 Fax: 210-523-4607 charlie.leverett@intertek.com	✓
Jim Linden Voting Member	Toyota	lindenjim@hotmail.com	✓
Bruce Matthews Voting Member	GM Powertrain Engine Oil Group Mail Code: 483-730-472 823 Joslyn Rd	Pontiac, MI 48340 Phone: 248-830-9197 bruce.matthews@gm.com	
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ASTM SEQUENCE VI

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Mark Sutherland Voting Member	Chevron Oronite Company LLC 4502 Centerview Ste. 210 San Antonio, TX 78228	Phone: 210.731.5605 Fax: 210.731.5621 msut@chevrontexaco.com	✓
Haiying Tang Voting Member	Chrysler	HT146@Chrysler.com Tel: 248-512-0593	
Dan Worcester Voting Member	Southwest Research Institute (SwRI) 6220 Culebra Road San Antonio, TX 78228	Phone: 210.522.2405 dan.worcester@swri.org	✓

Guests

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ASTM SEQUENCE VI

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Teri Kowalski	teri.kowalski@tema.toyota.com	Toyota	✓

Sequence VID Surveillance Panel
September 26, 2012
8:30AM – 4:00PM
Intertek AR
San Antonio, TX

Motions and Action Items
As Recorded at the Meeting by Bill Buscher

1. Action Item – Jerry Brys to lead a task force that will generate a list of GM hardware from the MY2009 engine that will need to be carried over and used on the MY2012 engine.

2. Action Item – Labs that have not already done so, to issue purchase orders to the TMC ASAP for the next batch of BL & FO.

3. Motion – Accept RO 541-1 as a replacement for RO 541 using the current RO 541 targets to judge test acceptability, and review and fix targets at 30 data points

   Dave Glaenzer / Rich Grundza / Passed Unanimously

4. Action Item – GM to provide oil flow data from LY7 to surveillance panel, if available.

5. Motion – With OHT6E-001-1 engine, change Engine Coolant to 50/50 mixture of Dexcool®/Demineralized or Distilled Water pressurized to 100 ± 10 kPa.

   Dave Glaenzer / Mark Mosher / Passed Unanimously

6. Motion – With OHT6E-001-1 engine, change Oil Filter Screen size to 60μm for FIL-1 & FIL-2.

   Dave Glaenzer / Jason Bowden / Passed Unanimously

7. Motion – With OHT6E-001-1 engine, require one minute snapshot logging of data for all stages, including flushing and retain data for 2

years. Section 11.6.5 which specifies logging during BSFC routine remains unchanged.

Dave Glaenzer / Jason Bowden / Passed Unanimously

8. Motion – With OHT6E-001-1 engine, change Stabilization Times before BSFC from 60 minutes to 90 minutes.

   Dave Glaenzer / Jason Bowden / Passed with 1 waive and 1 against

9. Motion – Matrix data generated with OHT6E-001-1 engine should be examined for appropriateness and potential update of engine hour correction factor as well as BLB1/BLB2 acceptance criteria.

   Dave Glaenzer / Jason Bowden / Passed Unanimously

10. Motion – With OHT6E-001-1 engine, modify Section 11.6.17 of procedure to incorporate additional flushing to BLA. Six BL oil changes; the first five followed by 30 minutes of flush conditions, the last followed by switch to BLA Stage 1.

    Dave Glaenzer / Jason Bowden / Passed with 2 waives

11. Motion – With OHT6E-001-1 engine, FCV-150C is to be Burkert Type 2000 with 13 mm orifice and 50 mm actuator. Additionally, flexible hoses to and from FCV-150C are to be size #12 and the internal diameter of all fittings on the suction side of the engine driven oil pump shall be equal to or greater than 0.50 inches. Hose lines to and from FIL-2 are to be size #10.

    Dave Glaenzer / Jason Bowden / Passed with 1 waive

12. Motion – With OHT6E-001-1 engine, Section 10.2.3 change to: *Coolant Flow Measurement System* – Calibrate the flow measurement device as installed in the system at the test stand, every 6 months. Calibrate the stand flow measurement device with a suitable flow measurement device using 100% water as the calibration media. Calibrate the flow measurement device used for calibration of the stand flow measurement device every 12 months using 100% water as the calibration media and shall be NIST traceable.

Dave Glaenzer / Jason Bowden / Passed Unanimously

13. Motion – Modify Sequence VID Procedure (D7589) Section 10.2.3 as follows: *Coolant Flow Measurement System* – Calibrate the flow measurement device as installed in the system at the test stand, every 6 months. Calibrate the stand flow measurement device with a suitable flow measurement device using 100% water as the calibration media. Calibrate the flow measurement device used for calibration of the stand flow measurement device every 12 months using 100% water as the calibration media and shall be NIST traceable. Effective immediately and to be completed 1/1/2013.

    Dave Glaenzer / Jason Bowden / Passed Unanimously

14. Action Item – Industry statistical group to make a recommendation on a matrix to obtain additional data for aging with an additional 500ml of oil added to the test oil charge. The goal is to match original VID aging, which is correlated to the FTP data, using the OHT6E-001-1 engine and the changes incorporated along with it.

15. Motion – Modify Section 6.10.1 of the Sequence VID Procedure (D7589) to remove the AFR measurement range specification. Include reference to both the Horiba and ECM analyzers as acceptable devices in the procedure. Effective immediately.

    Nathan Moles / Dave Glaenzer / Passed Unanimously

16. Action Item – Surveillance panel chairman to contact the OEMs to see if there is any interest in pursuing Afton's recommendations included in their presentation "Recommendations for Improving Discrimination of Test Oils in the Sequence VI Fuel Economy Test". A summary of the OEM responses will be distributed to the surveillance panel members.

17. Action Item – Lubrizol, and other test labs if interested, to further investigate solutions to issues observed with the knock sensor, so that a motion can be considered.

18. Action Item – OHT to investigate if the knock sensor that comes with the MY2012 engine can be used with the MY2009 electronics if the connector is changed out.

19. Action Item – OHT to investigate what resistor would be needed to mimic the resistance of the currently used knock sensor.

20. Action Item – Lubrizol to install a Cubemass 83A flow meter in series with the Micro Motion CMFS010M flow meter to generate data simultaneously on both flow meters and see if there is an improvement in measurement using the Cubemass 83A flow meter.

21. Motion – Remove 6.6.5.3 (5) from the Sequence VID Procedure (D7589). Effective immediately.

    Dave Glaenzer / Mark Mosher / Passed Unanimously

22. Motion – Allow TMC to dump remaining inventories of Sequence VIB BC-6 and RO 539 oils.

    Rich Grundza / Dave Glaenzer / Passed Unanimously

Sequence VI Test Quality Task Force

Report to Sequence VI Surveillance Panel

September 20, 2012

David L. Glaenzer, TF Chairman

Introduction

At a Sequence VI teleconference on 01/23/2012, the Surveillance Panel reviewed operational data from RO 542 runs utilizing the MY 2012 engine at IAR and SRI. Differences were noted in oil circulation temperature, coolant delta temperature and engine oil pressure. Subsequently, additional data was presented from a RO 542 run at LZ. Afton made a few observations on the data, providing some insight as to potential areas where the test procedure may require a tightening of specification. Chairman Leverett asked and David Glaenzer agreed to head a Task Force to look at test stand/procedural improvements.

Prior to soliciting membership in the Task Force, TF Chairman Glaenzer spoke with SP Chairman Leverett as well as Matt Snider and Bruce Matthews as Test Sponsor to help define a Scope and Objectives for the Group. Following discussions with SP Chairman Leverett and GM, the following was drafted to present to the initial TF meeting.

Draft Scope and Objectives

1. Examine ASTM D7589 for ambiguities in and opportunities for improvement to stand set-up and operation of the procedure.
2. Define experiments where necessary to understand optimum conditions for potential changes.
3. Conduct experiments to verify potential changes are producing desired output.
4. Report to Surveillance Panel monthly with final report due before November, 2012.

On February 20, 2012 the Sequence VI Surveillance Panel was solicited for interested members to participate in the Task Force.

Meetings

March 13, 2012 Teleconference

An initial Teleconference of the Task Force was held with 22 individuals participating. At the initial meeting, the Scope and Objectives was reviewed and accepted. A draft of potential areas of interest was distributed with members encouraged to review and add to

the list to be prioritized and reviewed at a face-to-face meeting scheduled for March 27 in Corpus Christi, TX.

March 27, 2012 Meeting

At a face-to-face meeting in Corpus Christi, TX the new engine break-in procedure was reviewed. It was felt that the potential for improvement was possible with modification of engine oil and oil gallery temperatures. Afton agreed to run a modified procure, following Sequence VIA protocol in their 2012 GM engine as they had not yet been able to provide data on calibration oils. IAR volunteered to review variability of VID data to determine a stage to use for determining break-in stability.

The subject of stability at test conditions prior to the critical BSFC measurement routine was discussed. Several labs indicated that their processes are marginally stable at the beginning of the BSFC routine, especially on those stages where large temperature changes are required. SwRI volunteered to run comparison data by completing the BLB1/BLB2 segment of the VID test using 60 minute stage stabilization followed by a second BLB1/BLB2 evaluation using 90 minute stage stabilization. Data logging frequency would be 1 minute snapshot data during stabilization and 1 second snapshot data during data logging.

External engine oil system plumbing, especially on the suction side of the engine oil pump as well as to and from the engine oil filter was discussed. Variations in line size as well as line length and pipe fitting selection may contribute to differences in engine oil pressure noted in the initial data generated by IAR, SwRI and LZ with the 2012 engine. The TMC was asked to evaluate operational data from different labs using different engines over time for oil pressure trends on BLB2, all six stages. GM provided oil pressure data on a similar green engine with 5W-30 oil.

The use of 100% Dexcool® for engine coolant was discussed. It is unclear how the procedure came about the use 100% rather than a mix. Charlie Leverett of IAR volunteered to share data they had generated on different coolant mixtures to be evaluated for consideration to switch to 50/50 Dexcool®/water mixture. Differences in coolant delta temperatures observed in the 2012 engine data prompted a discussion of coolant flow rate calibration. Ed Altman of Afton volunteered to loan a calibrated flow meter to be circulated among the labs to measure their observed flow.

Afton presented data indicating that the high detergent level present in FO, flushing oil, is not being fully removed from the engine. Elevated levels of calcium in BLA oil samples were noted. Similar elevated levels were noted by SwRI as well as IAR. Jerry Brys of

Lubrizol agreed to run additional flushes, taking several samples to see what level of flushing is needed to bring calcium to the expected level.

Mark Mosher of ExxonMobil was curious as to what data the ECU monitors during test operation and offered to create a data collection table.

April 26, 2012 Teleconference

Action Item Review from March 27, 2012 Meeting

The TF accepted the recommendation of Martin Chadwick of IAR to monitor stability of new engine break by stabilizing at Sequence VID Stage 3 conditions. Furthermore, Afton reported that the new engine break-in following a Sequence VIA "type" protocol was underway.

SRI data comparing BLB1/BLB2 evaluation using 60 minute and 90 minute stabilization times has been circulated. Dan Worcester commented that the BLB1/BLB2 shift for the 60 minute stabilization was +0.26% and for the 90 minute stabilization it was +0.08%. TF members were encouraged to review the data for discussion at the next teleconference.

Richard Grundza is working on his study of engine oil pressure across different engines/labs/hours. Matt Snider of GM provided typical oil pressures for the 2012 engine operated at our stage conditions. Chairman Glaenzer volunteered to create a listing of pipe fitting, hoses and lines on the suction side of the engine oil pump as well as to the external engine oil filter for use in defining some standardized way of providing similar restriction on the suction side of the pump and thusly similar operating oil pressures.

Charlie Leverett of IAR presented his information on engine coolant mixtures. The safety of using 100% Dexcool® is the concern. The TF is recommending to the Sequence VI Surveillance Panel the test procedure be changed to use 50/50 mixture of Dexcool®/distilled water with a system pressure of 100 ±10 kPa.

Ed Altman of Afton Chemical is preparing a calibrated flow meter and procedure for a round robin study of coolant flow calibration variation.

The filter screen size used in the external oil circulation as well as the external engine oil filter system was discussed and the TF is recommending to the Sequence VI Surveillance Panel the test procedure be changed to make filter size for both applications 60 micron.

Jerry Brys of Lubrizol presented information on the effectiveness of additional flushing to return BLA calcium levels to the expected range. It had been noted that with the

current procedure BLA exhibits approximately 10% more calcium in the used oil as measured by ICP analysis. It is believed the additional calcium is for FO flushing oil which has very high detergent level. Charlie Leverett has some additional data generated on additional flushing. This will remain an open item.

New Business

Data logging requirements in ASTM D7589 has very few specifics which leads to the inability to make meaningful comparisons of test data. Discussion centered about what was required and what is needed. It was decided that the 30 minute logging for BSFC values as spelled out in Section 11.6.5 should remain unchanged; however the TF is recommending to the Sequence VI Surveillance Panel the test procedure be changed to include one minute snapshot data for all stages, including flushes and retain the data for two years. Section 11.6.5 would remain unchanged. An additional motion, to move to one second snapshot data for all stages was tabled following discussion of the ability of some labs to manage the quantity of data.

<u>May 22, 2012 Teleconference</u>

Action Item Review from March 27, 2012 Meeting and April 26, 2012 Teleconference

Chairman Glaenzer presented the information for the modified (VIA type) break-in run at Afton Chemical on engine GM5 along with their subsequent RO 542 test data. The program run at Afton did not impact RO 542 results. Charlie Leverett of IAR commented on work they had done with standard VID break-in and subsequence RO runs using a dealer purchased engine. The TF is recommending to the Sequence VI Surveillance Panel the break-in procedure not be changed and remain as stated in ASTM D7589.

The Task force reviewed data presented by Dan Worcester of SwRI pertaining to 60 minute verses 90 minute stabilization times prior to the BSFC data gathering routine. The TF is recommending to the Sequence VI Surveillance Panel the test procedure be modified to 90 minute stabilization.

Richard Grundza of the ASTM Test Monitoring Center presented his final report evaluating oil pressure trends.

The subject of engine coolant flow round robin testing is still ongoing. Afton will use the calibrated meter on one of their stands and ship to the next lab. Ed Altman is writing a procedure to follow. The TF is recommending to the Sequence VI Surveillance Panel the engine coolant flow calibration be done with 50/50 Dexcool®/deionized water.

The survey to evaluate external engine oil filter and suction side of engine oil pump lines and fittings is still underway with responses anticipated prior to the next teleconference. No changes were made to the data request form.

The Lubrizol flush effectiveness study to reduce calcium levels in BLA was once again reviewed. There is some conflicting data due to variations in the way labs made their evaluations and took samples. Charlie Leverett of IAR will repeat the study following the Lubrizol protocol for review at the next teleconference.

New Business

The Task Force reviewed RO 542 results generated at Afton chemical as stated above.

Dan Worcester of SwRI reviewed a list of recommendations for quality improvement. SwRI recommended the concept of a golden stand that others would duplicate. Other items included review of the BLB1/BLB2 delta limits in light of the change from 60 to 90 minute stabilization as well as the appropriateness of the engine hour correction with the MY2012 engine. The TF is recommending to the Sequence VI Surveillance Panel that future matrix data generated using the MY2012 engine be examined for the appropriateness of the BLB1/BLB2 acceptance criteria as well as the engine hour correction factor.

June 19, 2012 Teleconference

Open Action Item Review from March 27, April 26 and May 22

Coolant flow calibration round robin is underway. Labs will hook up one of their stands to calibrated standard provided by Afton Chemical, set flow to ~80 L/m using 100% Dexcool® and report observed flow from their data system as well as from standard meter to Rich Grundza at TMC. Information will be used to determine if a specific procedure is required.

Task Force reviewed additional data on BLA flushing provided by IAR. Intent is to remove residual calcium from FO oil that is carried over into BLA. The TF is recommending to the Sequence VI Surveillance Panel that ASTM D7589 be changed to incorporate additional flushes to BLA. Five oil changes to BL, each followed by 30 minutes of operation at flush conditions before a final oil change to BL and continuation with Stage 1 BLA.

The oil line survey was discussed and reviewed. Matt Snider of GM will talk people at GM to verify the "normal" engine oil operating pressure at Sequence VID conditions. That

information will be distributed with the intent on standardizing plumbing to minimize differences in operating oil pressures amongst stands/labs.

July 31, 2012 Teleconference

Open Action Item Review from March 27, April 26, May 22 and June 19

Coolant flow round robin calibration nears completion with 5 of 6 labs having reported data to the ASTM-TMC. The TF recommends a standard procedure be developed for use with 100% water. After discussion, Charlie Leverett of IAR graciously volunteered to write a motion detailing how calibrations are to be made for future tests. This may be implemented by the Sequence VI Surveillance Panel prior to the issuance of a VIE procedure. If not, the TF will recommend changes to ASTM D7589.

Mark Mosher continues to work on a list of parameters that may be monitored from the engine ECM. Again, this may continue outside the TF scope.

Chairman Glaenzer reviewed his work on lines that supply oil to the suction side of the engine driven oil pump through Flow Control Valve 150C (FCV-150C). The TF discussed a configuration tested at Afton Chemical using the Burkert Type 2000 valve as well as data generated using a MY2012 engine with OEM oil pan pick-up for engine oil pump. Chairman Glaenzer moved, Mathews seconded a motion for change. A roll call vote was taken. The TF is recommending to the Sequence VI Surveillance Panel that with OHT6E-001-1 engine, FCV-150C is to be Burkert Type 2000 with 13 mm orifice and 50 mm actuator. Additionally, flexible hoses to and from FCV-150C are to be size #12 and the internal diameter of all fittings on the suction side of the engine driven oil pump shall be equal to or greater than 0.50 inches. Hose lines to and from FIL-2 are to be size #10.

August 23, 2012 Teleconference

Open Action Item Review

Coolant flow round robin calibration is complete. Charlie Leverett drafted a change to Section 10.2.3 of ASTM D7589 which the TF reviewed. The TF is recommending to the Sequence VI Surveillance Panel that that with OHT6E-001-1 engine, Section 10.2.3 be changed to: *Coolant Flow Measurement System*—Calibrate the flow measurement device as installed in the system at the test stand, every 6 months. Calibrate the stand flow measurement device with a suitable flow measurement device using 100% water as the calibration media. Calibrate the flow measurement device used for calibration of the stand

flow measurement device every 12 months using 100% water as the calibration media and shall be NIST traceable.

Discussion of the running test full oil level ensued. Section A8.2.7 of ASTM D7589 calls for test full to be 77±5 mm below an oil pan tab. Labs reported full levels of 83, 85, 89 and 95 mm below the oil pan tab with #12 lines. One lab reported full level of 80 mm below the oil pan tab with #8 lines. Potential fixes could be the redesign of the oil pan displacement block or an addition of test oil charge. Bruce Matthews shared information that with the 2012 engine, the service oil fill is increased by 0.5 qt. Jim Linden reminded the TF that in order to achieve oxidation levels at aging the oil level was reduced by 0.6L during test development. TF Chairman Glaenzer asked OHT to look into a redesign of the oil pan displacement block. Charlie Leverett of IAR volunteered to run an evaluation with the 2012 engine supplied by GM with #12 lines and an addition of 500 ml of test oil charge. Charlie will run oil that was run during VID development for comparison and he should complete by the second week of September.

<u>September 19, 2012 Teleconference</u>

Open Action Item Review

Charlie Leverett of IAR reported on experimental runs completed with Development Oil "C" using standard oil charge and +500 ml oil charge. Engines used were GM supplied engine and locally purchased MY 2012 engine. The aging was extended to 150 hours to generate equivalent oxidation to test development data as measured by DIR 5.8. The data generated indicated that the 2012 engine did not age oil "C" as severely as the engines used during the test development work. The discussion of this subject was deemed a Surveillance Panel item and will be reviewed at a SP meeting on September 26, 2012.

Task Force Chairman Glaenzer reviewed Scope and Objectives (March 13, 2012) and noted that the TF had completed its work. After thanking the participants, Chairman Glaenzer called for a disbanding of the Task Force.

<u>Summary</u>

I would like to thank all the participants in the Task Force. I believe we have taken steps to substantial improve the quality of the test. The Task Force would like ask the Sequence VI Surveillance Panel give consideration to the following recommended changes to ASTM D7589 for tests conducted with the OHT6E-001-1 engine.

1. Change Section 7.3 of D7589 to "The engine coolant shall equal parts of demineralized or distilled water and GM Dexcool®".

2. Change Section 6.6.5.7 of D7589 to "….with a stainless steel screen having a rating of 60 μm, Part No. OHT6A-0013-3.
3. Change procedure to require one minute snapshot data logging for all stages, including flushing and retain data for a minimum of two years. Section 11.6.5 of D7589 which specifies data logging for BSFC is to remain unchanged.
4. Change Section 11.6.4 and Table 5 of D7589 stabilization time to 90 minutes.
5. Change Section 10.2.3 of D7589 to require engine coolant flow calibration with 100% water.
6. Future matrix data generated using the OHT6E-001-112 engine be examined for the appropriateness and potential update of the BLB1/BLB2 acceptance criteria and the engine hour correction factor.
7. Modify Section 11.6.17 of D7589 to incorporate additional flushing to BLA. Following FO flushes, BL is charged to the engine on six occasions; the first five of which are followed by 30 minutes of operation at steady state flush conditions. Following the sixth oil charge, the test proceeds to stabilize at BLA Stage 1 conditions.
8. With OHT6E-001-1 engine, FCV-150C is to be Burkert Type 2000 with 13 mm orifice and 50 mm actuator. Additionally, flexible hoses to and from FCV-150C are to be size #12 and the internal diameter of all fittings on the suction side of the engine driven oil pump shall be equal to or greater than 0.50 inches. Hose lines to and from FIL-2 are to be size #10.
9. With OHT6E-001-1 engine, Section 10.2.3 change to: *Coolant Flow Measurement System*—Calibrate the flow measurement device as installed in the system at the test stand, every 6 months. Calibrate the stand flow measurement device with a suitable flow measurement device using 100% water as the calibration media. Calibrate the flow measurement device used for calibration of the stand flow measurement device every 12 months using 100% water as the calibration media and shall be NIST traceable.

Respectfully submitted,

David L. Glaenzer

Chairman, Sequence VI Test Quality Task Force

Sequence VI Test Quality Task Force
Scope and Objectives

1. Examine ASTM D7589 for ambiguities in and opportunities for improvement to stand set-up and operation of the procedure.
2. Define experiments where necessary to understand optimum conditions for potential changes.
3. Conduct experiments to verify potential changes are producing desired output.
4. Report to Surveillance Panel with final report due before November, 2012.

David L. Glaenzer
Approved 03/13/2012

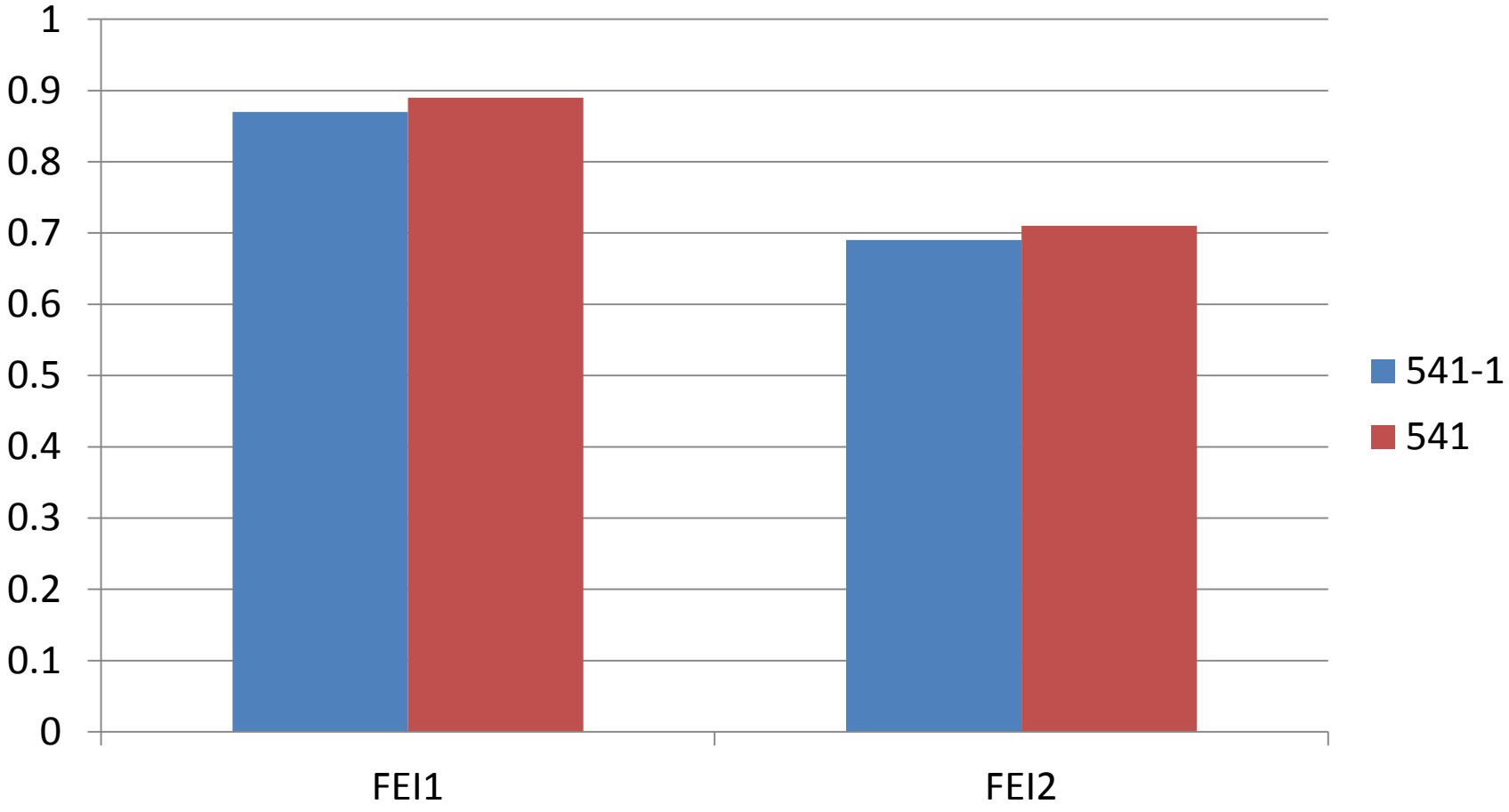
Update on 541-1 Results

Sequence VI Surveillance Panel

San Antonio, TX

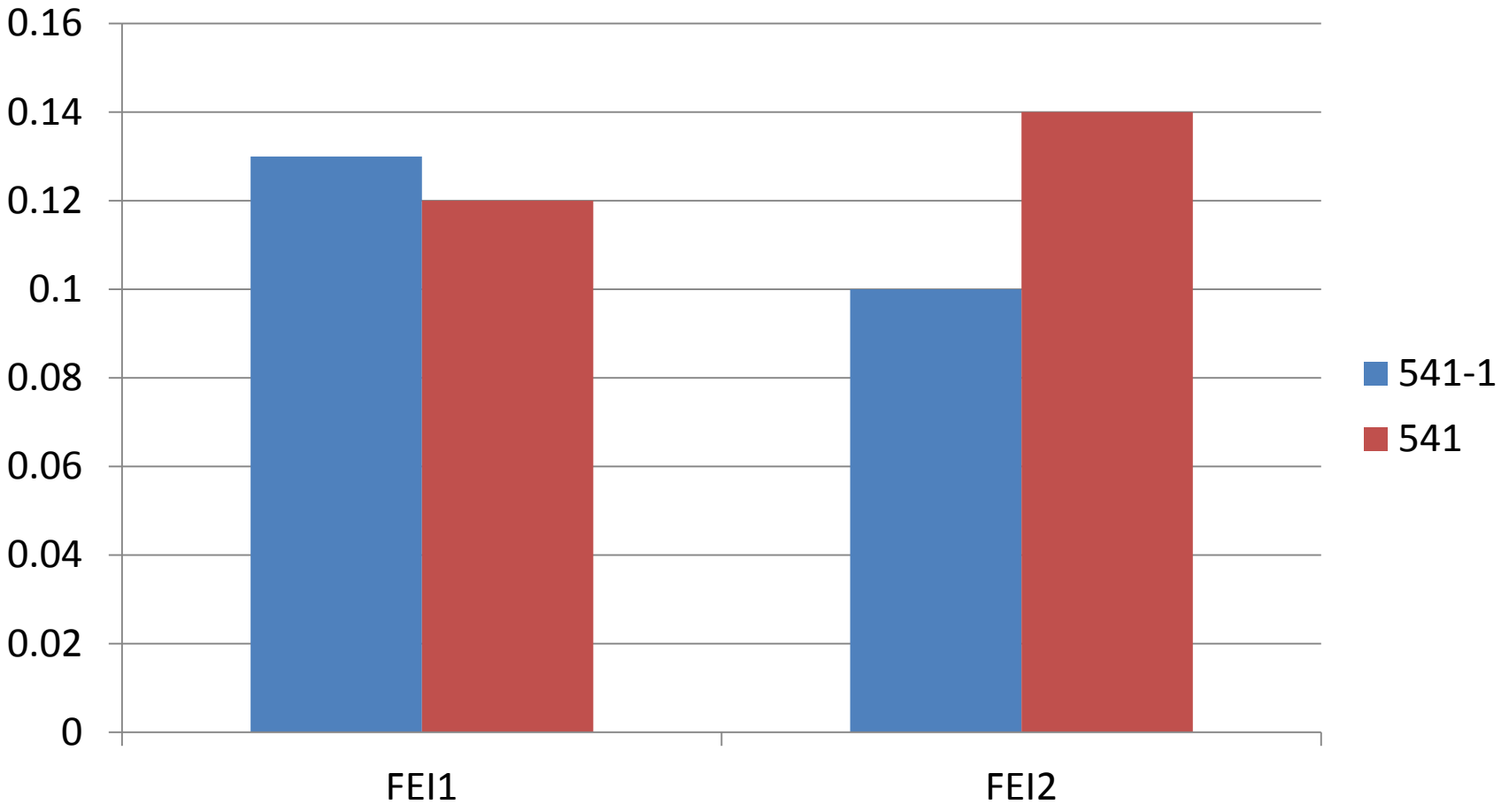
September 26, 2012

Comparison of Mean Performance of 541-1 (n= 10) with 541 targets



All 541-1 results severity adjusted using candidate model, where appropriate.
Results on new engines have not been severity adjusted.

Comparison of Standard Deviations of 541-1 (n= 10) with 541 targets



All 541-1 results severity adjusted using candidate model, where appropriate.
Results on new engines have not been severity adjusted.

Data Used to Generate Targets

Lab	Engine	FEI1	FEI1 SA	FEI1 Adj.	FEI2	FEI2 SA	FEI2 Adj.
A	47D*	0.78	0	0.78	0.57	0	0.57
B	42D*	0.86	0	0.86	0.59	0	0.59
G	26D*	1.03	0	1.03	0.67	0	0.67
A	30D	0.89	-0.10	0.79	0.77	-0.09	0.68
G	11D	0.71	0.01	0.72	0.60	0.01	0.61
D	39D	0.76	0.04	0.80	0.61	0.06	0.67
A	48D*	0.98	0	0.98	0.76	0	0.76
A	53D*	1.03	0	1.03	0.80	0	0.80
A	55D*	1.06	0	1.06	0.71	0	0.71
G	25D	0.84	-0.07	0.77	0.84	0.04	0.88

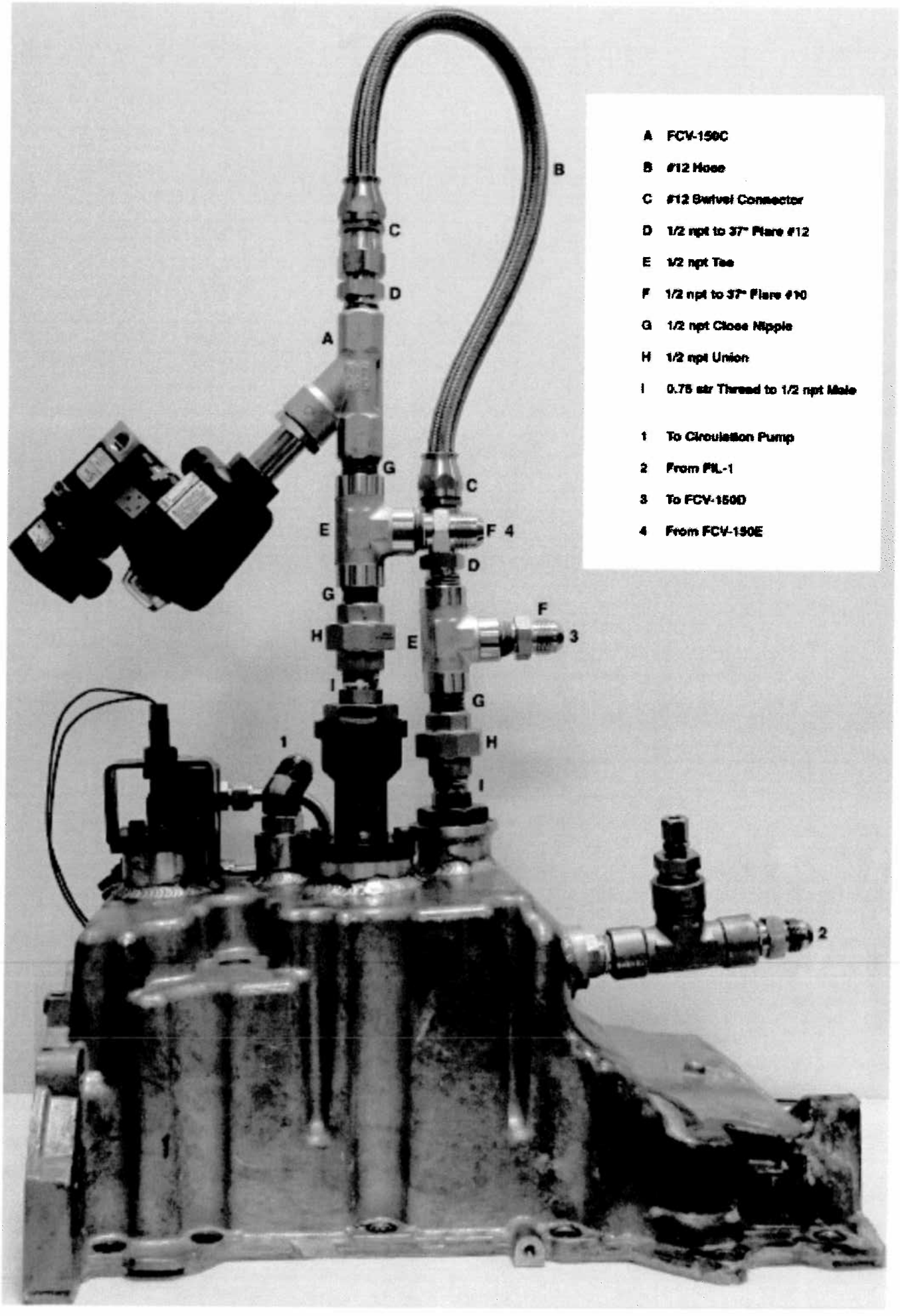
* New Engine

IAR VID Aging Experiment

9/14/2012

	Test Number	CMIR	DIR 5.8	DIR 6.1	KV40	KV100	OC
New							
Normal Oil Charge	3-131-2012A-4	89842	--	--	45.18	8.021	--
+500 ml Oil Charge	2-153-GM1-5	89841	--	--	44.75	7.944	--
75 Hours							
Normal Oil Charge	3-131-2012A-4	89842	6	6	43.50	7.694	500
+500 ml Oil Charge	2-153-GM1-5	89841	5	5	45.04	7.942	600
100 Hours							
Normal Oil Charge	3-131-2012A-4	89842	**7**	7	44.25	7.771	700
+500 ml Oil Charge	2-153-GM1-5	89841	**7**	7	45.90	8.026	800
125 Hours							
Normal Oil Charge	3-131-2012A-4	89842	9	9	45.09	7.905	700
+500 ml Oil Charge	2-153-GM1-5	89841	9	10	46.76	8.132	1200
150 Hours							
Normal Oil Charge	3-131-2012A-4	89842	11	12	46.23	8.002	800
+500 ml Oil Charge	2-153-GM1-5	89841	11	14	47.75	8.245	1300

Original GM Vehicle Oil C Averages							
2k Miles			5	--	42.52	7.67	--
6.5k Miles			**11**	--	45.26	7.89	--


A FCV-150C
B #12 Hose
C #12 Swivel Connector
D 1/2 npt to 37° Flare #12
E 1/2 npt Tee
F 1/2 npt to 37° Flare #10
G 1/2 npt Close Nipple
H 1/2 npt Union
I 0.75 str Thread to 1/2 npt Male
1 To Circulation Pump
2 From PIL-1
3 To FCV-150D
4 From FCV-150E

Recommendations for Improving Discrimination of Test Oils in the Sequence VI Fuel Economy Test

Afton Chemical Corporation

September 26, 2012

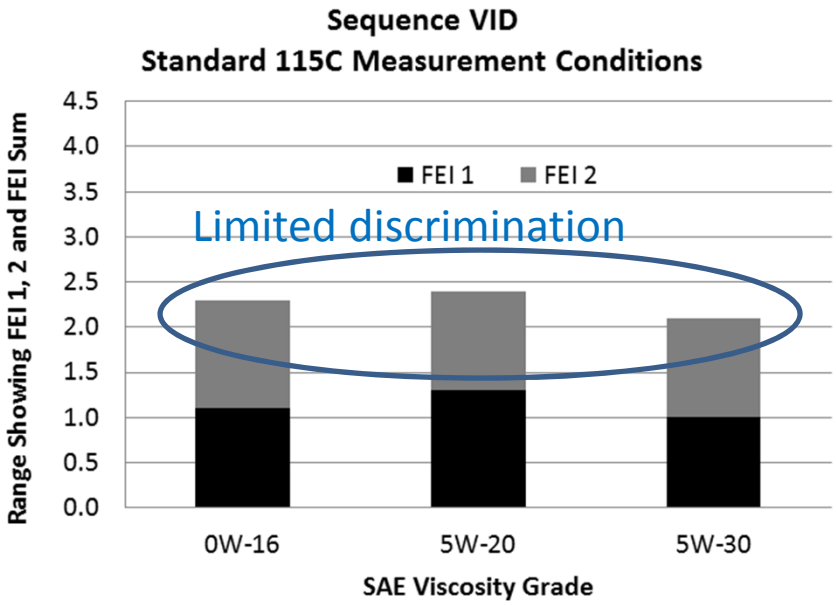
Passion for Solutions™

Agenda

- **Current State of Sequence VID Test Discrimination**
- **Background Information on VID Development**
- **Summary of Current VID Test Conditions**
  - Oil Aging
  - Fuel Economy Measurement
- **Real-World Vehicle Operating Conditions**
- **Afton Recommendations to Improve Sequence VID Correlation with the Real-World**
- **Data to Support the Recommendation**
- **Next Steps**

Current State of Test Discrimination in the Seq. VID Test

- **Afton has observed that the Sequence VID has a limited ability to discriminate oils based on viscometrics.**
- **Afton believes this is a result of the emphasis on high measurement temperatures during FEI1 and FEI 2**



Testing conducted in the same lab using the same DI package in three viscosity grades.

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Background – Sequence VID Development Highlights

- ✓ **In order to achieve correlation with the FTP & HwFET, the VID Consortium performed numerous and very thorough analyses of the Buick 3.6L vehicle, culminating in a preliminary set of 10 test conditions with good representation of the cycle.**

- ✓ **Subsequent test matrices reduced the number of conditions to 6, with an emphasis on high-temperature – more boundary-like operation.**

- ✓ **With respect to aging, there was a focus on achieving parity to oxidation in the vehicle.**

Sequence VID Measurement and Aging Conditions

- **The Sequence VID oil temperature is biased toward the upper limits of operation, with an emphasis on boundary lubrication**
  - 95% of VID weighted fuel economy is measured at 115°C
    - Higher temperatures reduce pumping, flow, and hydrodynamic energy losses, inhibiting the ability of the test to accurately assess the impact that viscosity plays on fuel economy in the real world. This is consistent with the "Stribeck ZN/P" information used in VID development in the Consortium report.

Stage #	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
Speed, rpm	2000	2000	1500	695	695	695
Power, kw	22	22	16.5	1.5	1.5	2.9
Oil Temp, C	115	65	115	115	35	115
Coolant In Temp, C	109	65	109	109	35	109
Stage Weight	0.300	0.032	0.310	0.174	0.011	0.172

>95%

- **Sequence VID ages oils at 120°C for 100 hours, producing excessive oil consumption and volatility-related losses inconsistent with the real-world.**

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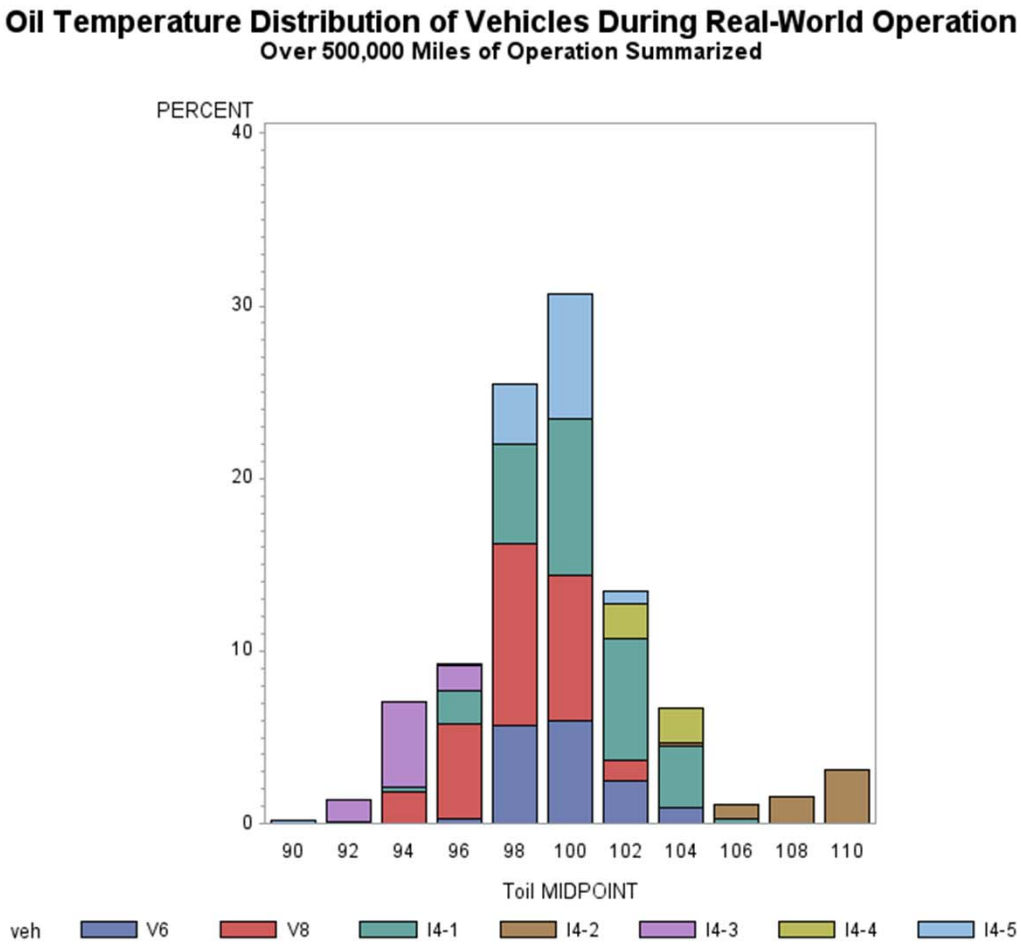
Vehicle Operation – Oil Temperature Studies

- **Normal Operating Oil Temperature is far below 115°C or 120°C**
  - Robust mean is 100°C.



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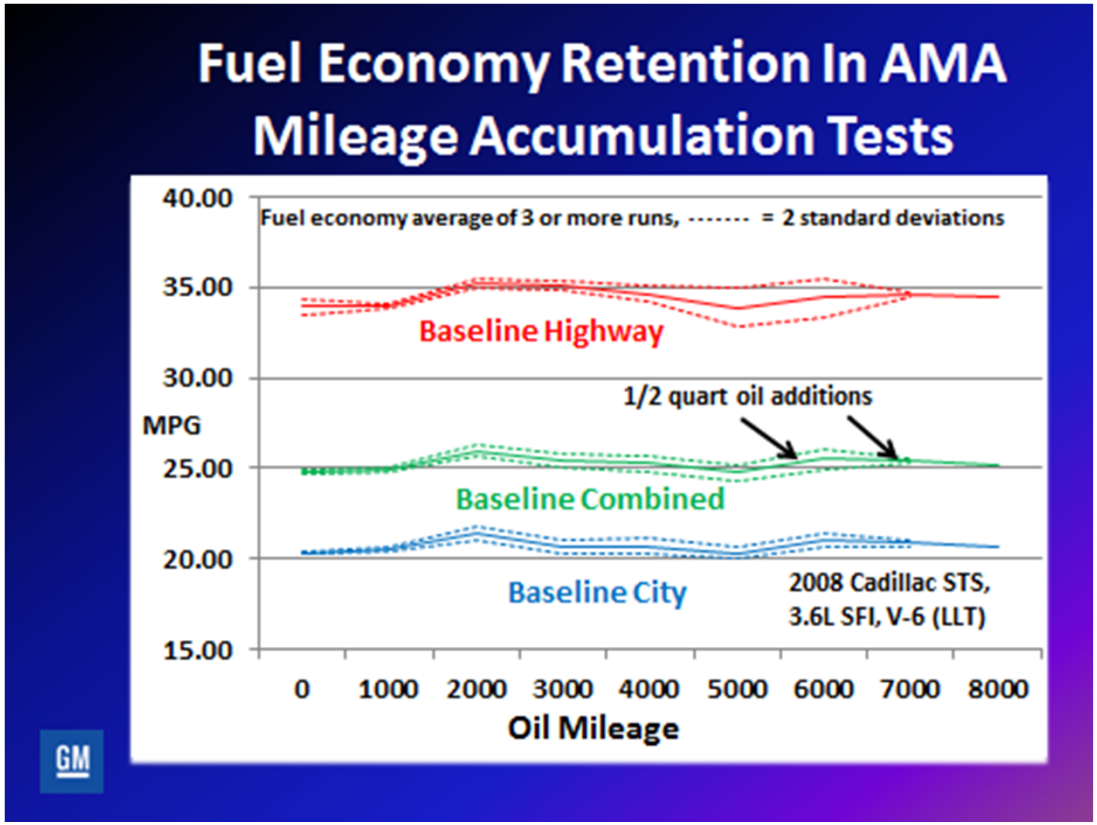
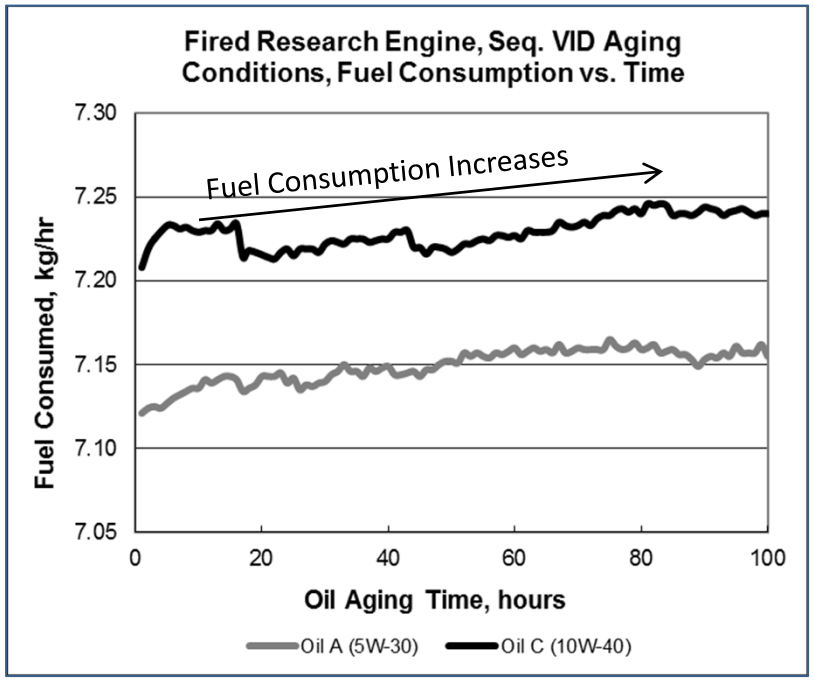
Oil Age and Fuel Economy

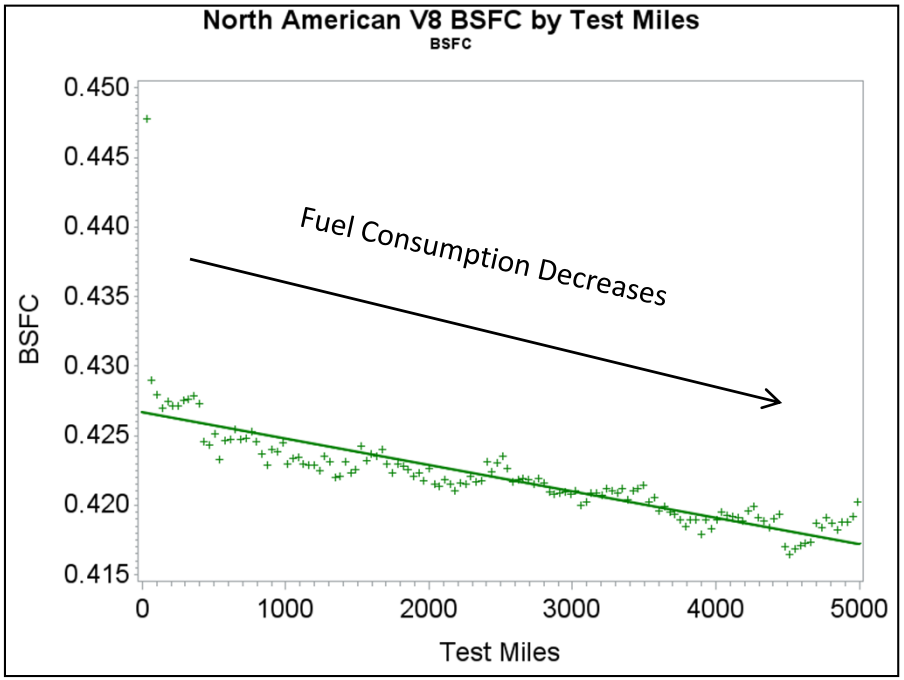
- **STLE, May 7, 2012 – Don Smolenski**
- **GM presentation highlighted data from Cadillac STS which shows no loss in FE with oil age**



Oil Age and Fuel Economy – Seq VID versus Vehicles

- **Seq VID aging stresses oil in ways not seen in vehicles producing increase in fuel consumption with oil age**
- **Vehicles always show an improvement with oil age**





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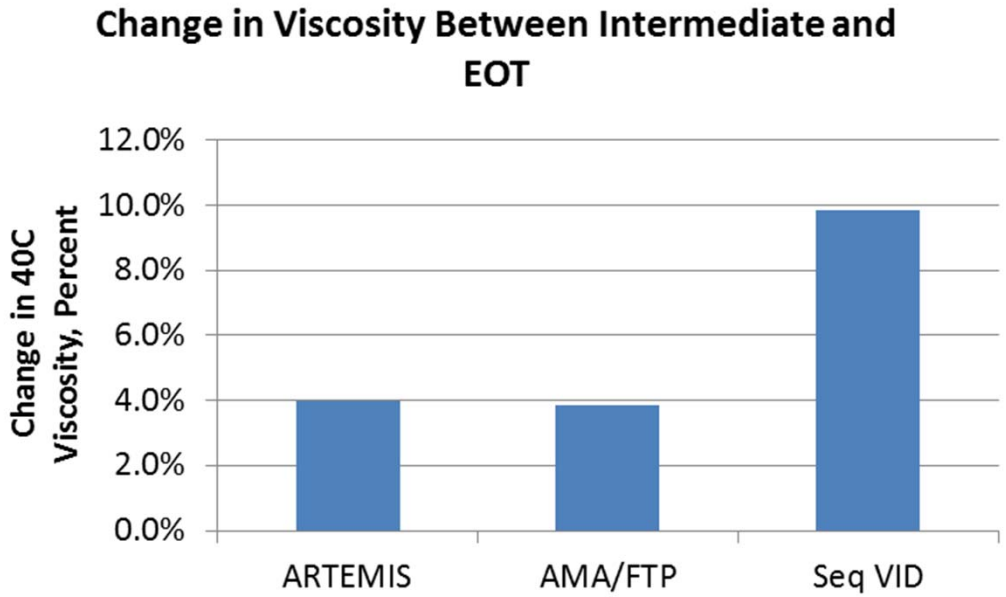
Excessive Oil Stress During Standard VID Aging

- **Oils experience higher level of viscosity increase in the VID**
- **Typical 5W-20's experience 4% PVIS in vehicles while VID can produce up to 10%. Similar trend observed in HTHS@100**
- **Oil consumption is negligible in vehicles while significant in VID (up to 1.4L)**



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Afton Recommendations

1. **Reduce the Sequence VID oil aging condition from 120°C to 100°C, keeping all other aging conditions the same**
   - Will produce less volatility-related oil loss
   - Will produce stress on the oil more closely related to real-world operation
   - Produces a fuel economy trend that is more closely related to real-world
2. **Change the Sequence VID high-temperature measurement conditions from 115°C to 100°C*. This will increase the separation between viscosity grades while maintaining discrimination of FM**

Stage #	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
Speed, rpm	2000	2000	1500	695	695	695
Power, kw	22	22	16.5	1.5	1.5	2.9
Oil Temp, C	100	65	100	100	35	100
Coolant In Temp, C	94	65	94	94	35	94
Stage Weight	0.300	0.032	0.310	0.174	0.011	0.172

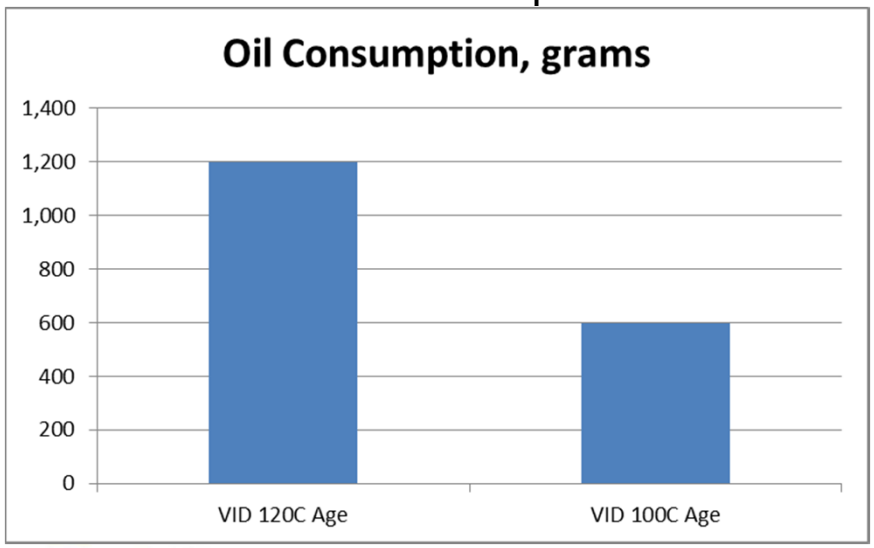
* A commensurate 15C reduction in coolant temperature is necessary for control purposes.

Experiment 1: TMC 1010 Oil Aging Data

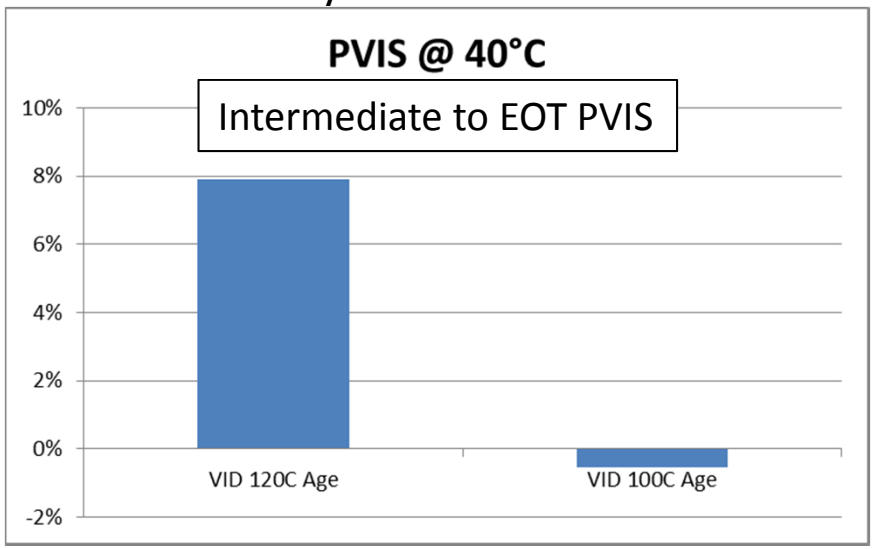
- **Back to back testing in same engine/stand**
- **Test A: 120°C Oil Aging Temp with 100°C Measurement Temps**
- **Test B: 100°C Oil Aging Temp with 100°C Measurement Temps**

- **Conclusion: Less severe aging causes less oil consumption and results in PVIS that is more similar to vehicle-aged oils.**

50% lower oil consumption at 100C



Considerably less PVIS at 100C



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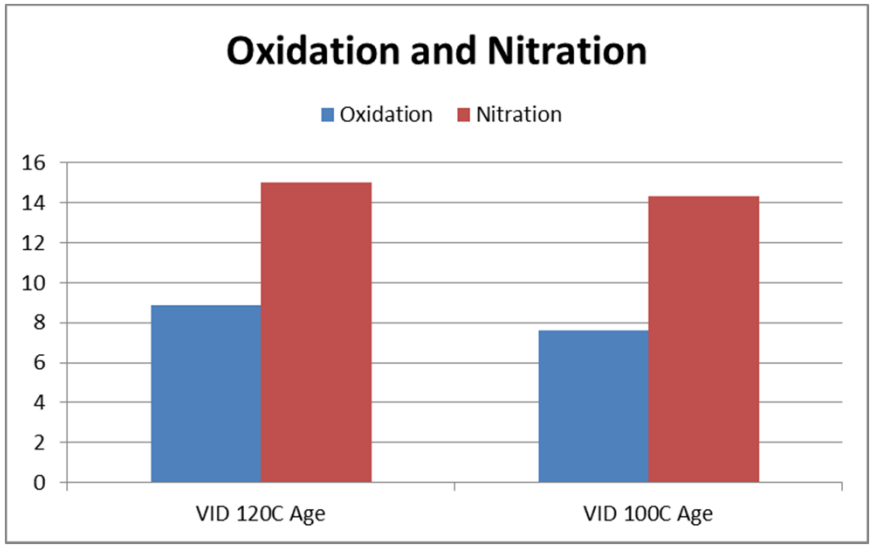
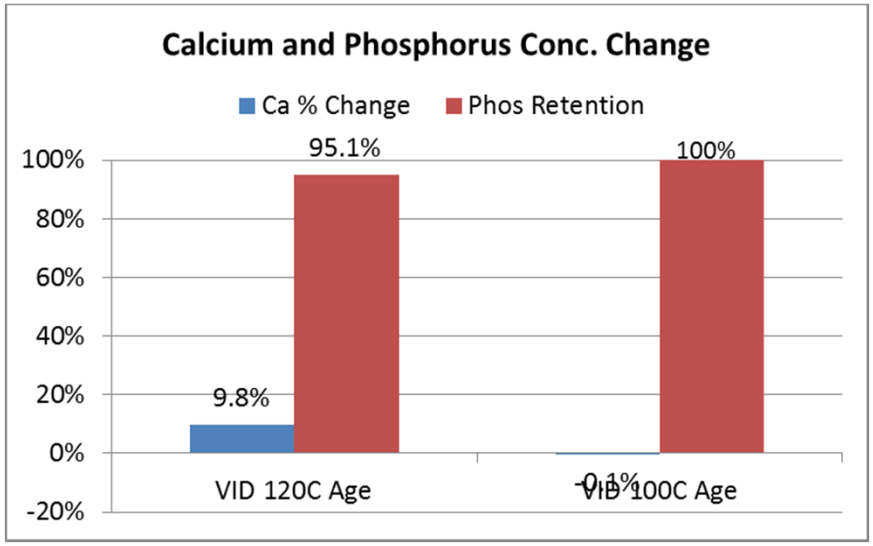
Oxidation, Nitration, and Volatility

- **Oxidation and Nitration of used oils are in a comparable range**
- **Ca concentration indicates more volatility at 120°C**
- **Lower Phos Retention at standard VID aging condition indicates increased amount of thermal stress on the oil**





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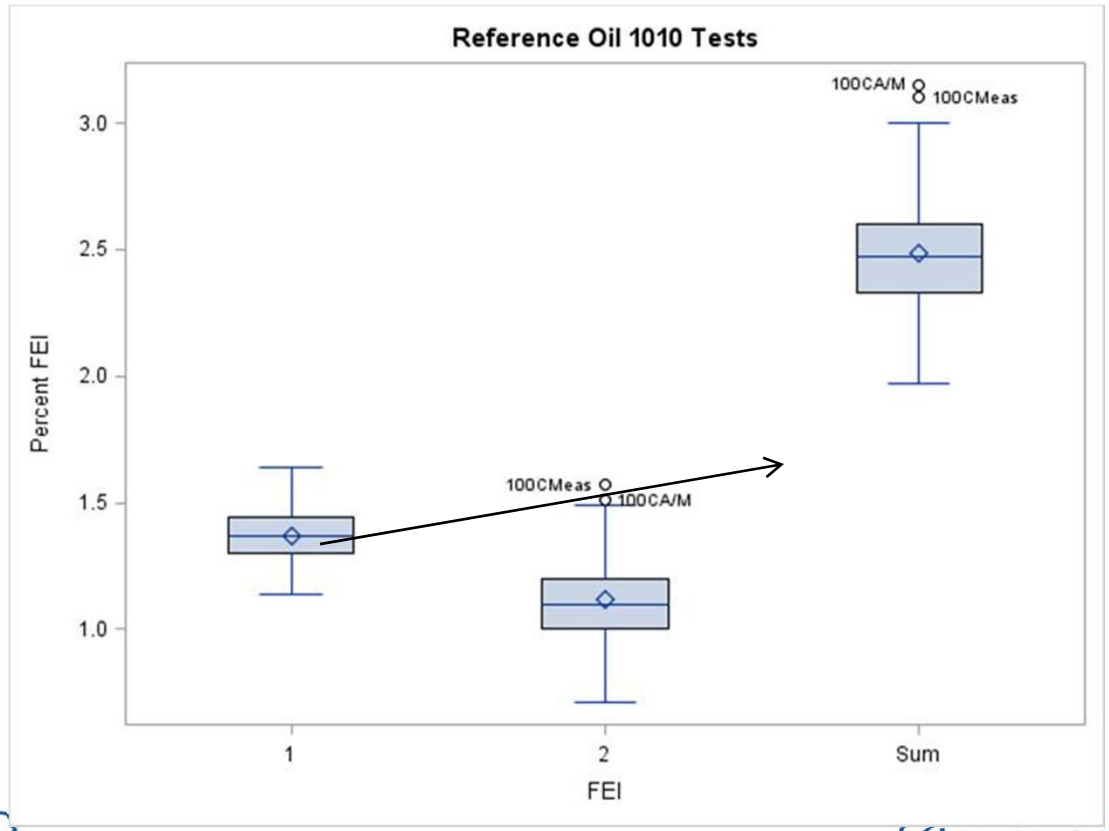
FEI Measurement Results

- **Revised measurement conditions result in improved retention and SUM, irrespective of aging temperature**
- **Improves FEI 2, bringing it into closer alignment with vehicles**

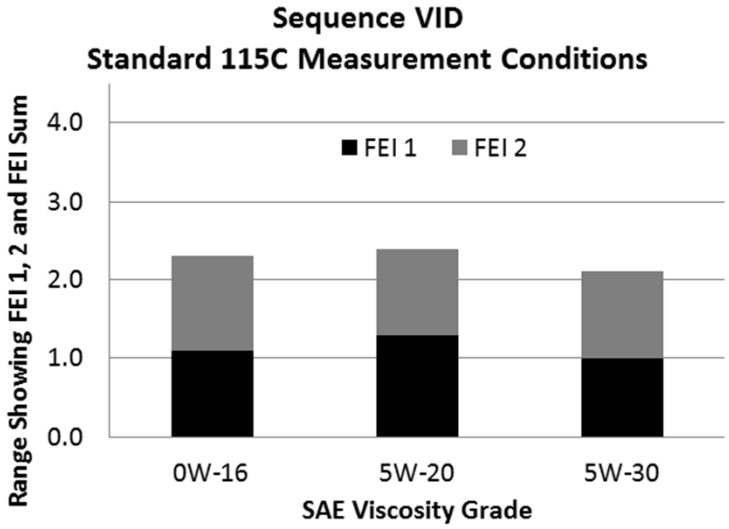


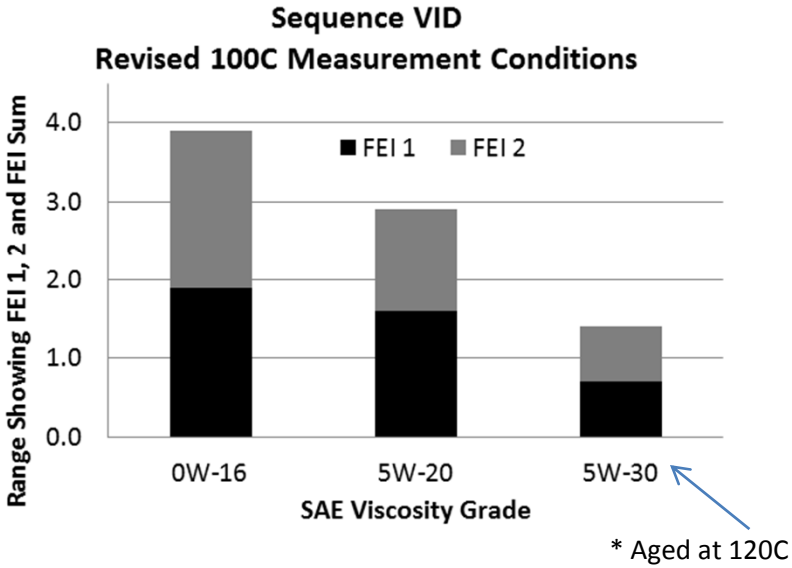
Experiment 2: Measurement Temperature Study

- **Six tests using same DI, formulated into three grades**
  - Three standard tests (120/115)
  - Three revised tests* (100/100)

Test Oil	KV100, cSt	KV40, cSt	VI	HTHS@150C cP	CCS, cP
SAE 5W-30	10.9	63	168	3.2	4771 @ -30
SAE 5W-20	8.4	45	165	2.6	3200 @ -30
SAE 0W-16	7.3	37	167	2.3	4700 @ -35

- **Revised conditions improve discrimination and headroom**





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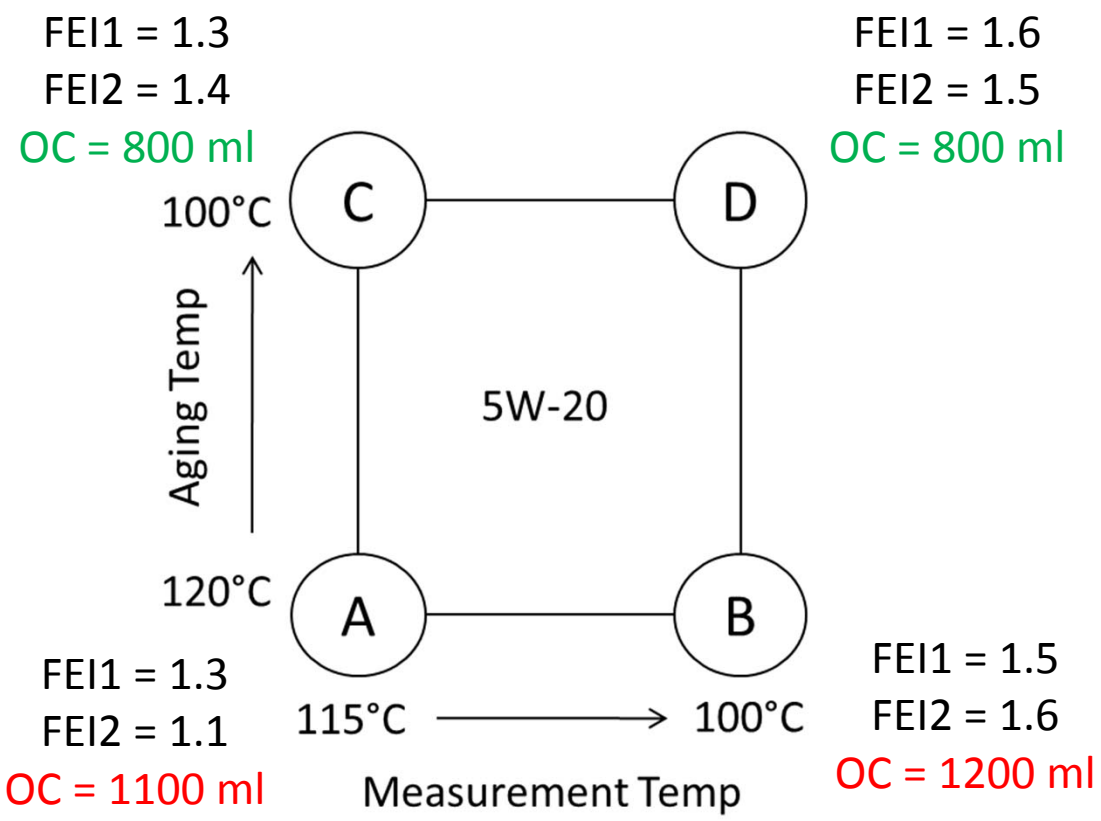
Experiment 3: DOE on Oil Consumption and FEI

SAE 5W-20 - 1010

Conclusions:

- Lower aging temperature reduced oil consumption by ~30%
- Lower measurement temperature improved FEI response



Conclusions

- **Lowering Sequence VID aging to 100°C and revising high-temperature measurement conditions to 100°C imparts several desirable effects:**
  - Test temperatures more closely correlate with normal vehicle operating temperatures and thus yields more realistic estimation of oil's impact on FE retention
  - Lower measurement temperature improves discrimination
  - Lower aging temperature improves oil consumption, leading to more realistic aging and evaluation of formulations
  - Both changes brings the test into closer alignment with vehicles operating in the real world

Recommendations

- **The Sequence VI Surveillance Panel consider these proposals and determine the best way to assess them in the “VIE” engine.**
- **Afton’s Part: We will continue to share our comparisons with the panel, using the VIE engine**
- **Vehicle Data: Afton will share data from a 2012 Chevrolet Malibu with the 3.6L V6 engine as they become available.**

Thank you!

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Supplemental Information since ACC Meeting on 9/11/12

Information developed since first mailing

The “Alt 2 Cycle”

- **Afton agreed to investigate a modified approach whereby Stages 4 and 6 remain at 115C and Stages 1 and 3 are changed to 100C.:**
  - Age oils at 100C
  - This would allow for a more enhanced estimation of FM effects at boundary-like conditions
  - A need for a re-weighting of stages would be a likely outcome with this approach

Stage #	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
Speed, rpm	2000	2000	1500	695	695	695
Power, kw	22	22	16.5	1.5	1.5	2.9
Oil Temp, C	100	65	100	115	35	115
Coolant In Temp, C	94	65	94	109	35	109
Stage Weight	0.300	0.032	0.310	0.174	0.011	0.172

* A commensurate 15C reduction in coolant temperature is necessary for control purposes.

FM vs non-FM Results Under “Alt 2” Conditions

- **Back to back runs in the same engine**
- **SAE 5W-20**
  - Same base stock, DI and VM
    - With and without FM

Sequence “VIE” FEI 1 Results

Oil	Raw	Hr Adj
FM	1.65	1.57
No-FM	1.14	1.02

Stage Results Improvement vs BLB2

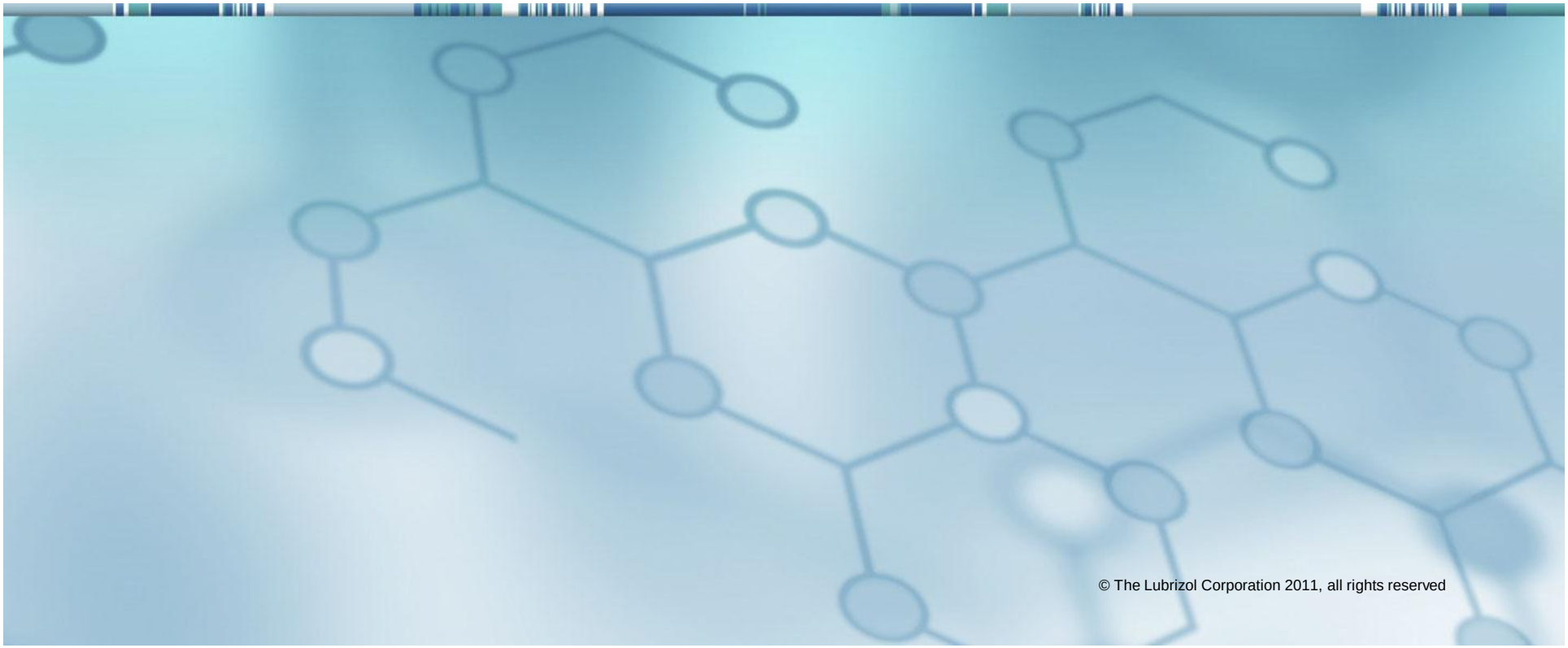
Oil Temp, °C	100	65	100	115	35	115
Stage	1	2	3	4	5	6
Improvement FM vs BLB2, %	2.06	2.72	1.36	0.47	5.41	-0.27
Improvement No FM vs BLB2, %	1.63	2.41	1.25	-1.76	6.1	-2.48
Delta	0.43	0.31	0.11	2.23	-0.69	2.21

Conclusions

- **Opportunities exist to bring the Sequence VI test into better alignment with the real-world**
- **The bias toward high temperatures affects both aging and FE measurement – decreasing test discrimination**
- **Lowering aging improves oil consumption and brings aging conditions into closer alignment with real world**
- **Lowering measurement conditions allows for better discrimination while still showing FM response**

Smaller Flow Range Fuel Flow Meters

September 26, 2012



Current Fuel Flow Meter

- Micro Motion CMFS010M:
  - Measurement Range: 0 – 108 kg/hr
- Approximate fuel flow rate by stage for baseline oil:
  1. 6 kg/hr
  2. 7 kg/hr
  3. 5 kg/hr
  4. 1 kg/hr
  5. 1 kg/hr
  6. 1 kg/hr
- Inaccuracy of Coriolis meters grows exponentially at the low end of the measurement range
- Testing operates in the lower 1-7% range of current meter

Lower Range Coriolis Meter Available

- When Micro Motion meter was selected, 108kg/hr was lowest measurement range available
- Cubemass 83A
  - Measurement Range: 0-20 kg/hr
  - Improved accuracy at idle stage flow rates
- According to LZ supplier Emerson Process Managment; Micro Motion is also expected to release a similar flow range device early next year

Comparison by the Numbers

- Inaccuracy less than half at flow rate for stages 4-6
- Pressure drop is much more significant at all test stages

	Micro Motion	Cubemass
Max Flow (kg/hr)	108	20
Pressure Loss at 1.0kg/hr flow (kPa)	0.07	0.83
Pressure Loss at 7.0kg/hr flow (kPa)	0.89	24.17
Mass Flow Accuracy at 1.0kg/hr flow (+/-%)	**0.25**	**0.1**
Mass Flow Accuracy at 7.0kg/hr flow (+/-%)	0.1	0.1

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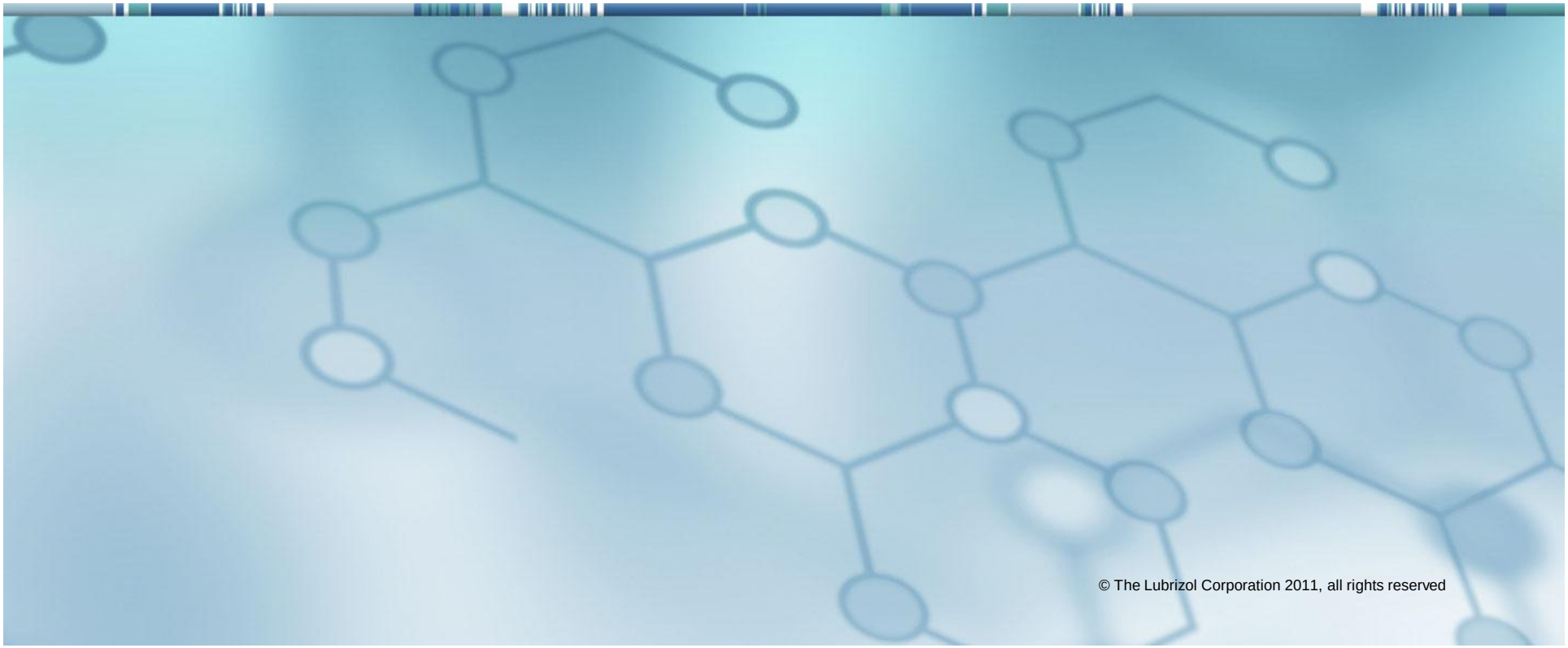
Moving Forward

- Further investigation potential improvement of testing using flow meter with lower measurement range
- Is it the inaccuracy a variability or a more consistent offset at the lower flow rates?
- Tentative plan is to acquire new flow meter and run bench test with both meters in series (capital expenditure has not been approved)
- Present proposal of capability specifications in the procedure rather than equipment specification as currently required

Knock Sensor Impact on Spark Timing for Sequence VI Testing

September 26, 2012



Background

- On a recent sequence VID test, a retarded spark timing was observed during the first three stages of the baseline oil from 27 degrees to 16 degrees
- The sensors were replaced and the test was restarted; however, an intermittent problem continued and it was discovered that the knock sensor wire insulation had been compromised due to long term heat exposure