Sequence IV Surveillance Panel | MINUTES

Revision Date *7/31/2017 11:32:00 AM*

Relevant Test:	Sequence IVA and IVB
Note Taker:	Chris Mileti
Meeting Date:	07-12-2017
Comments:	Update on experiments run at Intertek, Southwest and Lubrizol in preparation for upcoming prove-out testing.

1. AGENDA ITEMS:

a) Background:

i) The agenda for this meeting (***IV Agenda 7-12-17 v2***) was distributed by Bill Buscher on 07-11-2017 at 6:45 PM EST.

b) Agenda Items (IV Agenda 7-12-17 v2):

i) Previous action item review

ii) ***Haltermann KA24E Green Fuel Status:***
  (1) Update from Haltermann.
  (2) Preparation for delivery status update from labs.

iii) ***Sequence IVB Hardware Status:***
  (1) Update from OHT on chamfering Batch-C intake camshafts.
  (2) Update from OHT and/or Toyota on status of next batches of critical hardware.

iv) ***Lubrizol's Sequence IVB Activities:***
  (1) Review of oil level trials.

v) ***Southwest's Sequence IVB Activities:***
  (1) Update and review of oil separator trials.
  (2) Test procedure draft status.

vi) ***Intertek's Sequence IVB Activities:***
  (1) Update and review of prove-out tests.
  (2) Discuss revisions to the engine coolant temperature QI calculation.

vii) ***Next Steps:***
  (1) Vote on any new changes to incorporate into the Sequence IVB test method.
  (2) Discuss and agree on next steps for prove-out testing, lab activities and restarting the precision matrix.

viii) ***Sequence IVB Timeline:***
  (1) Discuss the timeline that will be reported to the AOAP on 07-13-2017.

ix) Motion and action item review

x) Next meeting

xi) Adjourn

2. REVIEW OF ACTION ITEMS:

a) Coolant Temperature Control:

i) During a previous meeting, the Surveillance Panel agreed to control the outlet temperature of the coolant instead of the inlet temperature.
ii) Intertek ran several tests to evaluate this new control strategy.
  (1) The original quality index calculations (which were established when the inlet temperature was controlled) obviously generated negative QI values (around -16) for the new control strategy.
  (2) New QI limits will be needed for the new control strategy.
  (3) Intertek also noted larger swings in coolant temperature variation with the new control strategy.
iii) Lubrizol did not incorporate these coolant temperature changes into its recent oil level trials.
iv) Exxon also changed their stand to the new coolant temperature control strategy.
  (1) They agree with Intertek that the new control strategy results in larger swings in coolant temperature.
v) Afton started their engine for the first time yesterday.
  (1) However, they are not yet ready to check QI values.
vi) ***Action Item:***
  (1) Intertek suggested taking a 1-hour sample of data from each lab (using the Lubrizol template) and providing it to the statisticians.
    (a) They can then determine revised QI limits for the coolant outlet temperature.

b) Review of IVB Data Dictionary:
i) TMC has not yet started working on the new IVB Data Dictionary.
  (1) They are waiting for marked-up versions of the current IVB Data Dictionary.
  (2) They anticipate being able to quickly update the document.
  (3) The TMC does want a final/approved version of the test procedure before any changes to the Data Dictionary are made.

c) Batch of KA24E Haltermann Fuel with 185ppm Sulfur:
i) Two of the labs have already returned their fuel to Haltermann.
ii) Haltermann adjusted the sulfur content of this batch and is ready to return it to the labs.
  (1) Haltermann strongly recommends that each lab de-inventory their storage tanks before they take possession of the adjusted fuel.

d) Keyence:
i) Lubrizol has negotiated a price reduction of 10% for the Generation-2 software.
  (1) Keyence will extend this price reduction to Intertek, Southwest and Afton.
  (2) Exxon already has the latest version of the software.
ii) Lubrizol and Intertek have already received the Generation-2 (G-2) software.
iii) Afton is close to issuing their purchase order to Keyence.
iv) Southwest plans to order the software but has not yet issued a purchase order.
v) ***Keyence Problems at Intertek:***
  (1) The control board (that controls the lights) failed on Intertek's macroscope.
  (2) Keyence loaned them a temporary macroscope while their damaged unit was sent back to Japan for repairs.
  (3) Intertek's original macroscope showed significant differences in E.O.T. measurements with and without the application of talc.
    (a) Interestingly, the loaned macroscope showed very little change in E.O.T. measurements when talc was used.
    (b) The loaned macroscope behaves similarly to the Lubrizol macroscope in this respect.

(4) Intertek's original macroscope has been repaired and returned to them.
    (a) The repaired macroscope now exhibits a much smaller difference between measurements taken with and without talc.

vi) A metrology workshop and Keyence round-robin will need to be conducted after all of the labs have upgraded to the G-2 software.

e) Lubrizol Oil Level Trials:

i) Lubrizol has completed a series of oil level trials.
ii) Lubrizol visually confirmed that the Sequence IVB test conditions (i.e. reduced initial oil charge, high frequency of oil samples and oil consumption due to bore polishing) are starving the oil pump.
iii) Lubrizol has evaluated two alternate oil pick-up tube designs that will mitigate this problem.

f) Section 4 of Engine Assembly Manual:

i) Intertek and Southwest still need to work on Section 4 of the Engine Assembly Manual.

g) OHT Updates:

i) OHT is developing a specific clutch alignment tool for the Toyota engine.
ii) Intertek feels that better alignment should result in reduced wear on the pilot bearings.
    (1) They did note that labs will still need to inspect their main bearings.

3. NEW DISCUSSION:

a) Haltermann Fuel Status:

i) The final mixing is in process to adjust the entire batch of KA24E fuel.
ii) The adjusted fuel will have a sulfur level of approximately 128-130ppm.
    (1) The new sulfur specification for the KA24E fuel is a target of 130ppm with a range of 120-140ppm.
iii) Haltermann will issue a final C of A within the next few days.
iv) The adjusted fuel will ship within the next week (assuming that all of the labs are ready to receive the shipment).
    (1) Intertek and Lubrizol confirmed that they are ready to receive their shipments.
v) Haltermann is prepared to donate 4,000-gallons of KA24E fuel to support the 2nd Precision Matrix.
    (1) This should be enough fuel for over 20-tests.
vi) Haltermann is inventorying the KA24E fuel at two locations:
    (1) Sterling, MI
    (2) Baytown, TX

b) Update from OHT:

i) ***Camshafts:***
    (1) There are (66) Batch-C intake camshafts.
        (a) Ten of these intake camshafts are being modified with lobe chamfers.
    (2) There are (70) Batch-D exhaust camshafts.

ii) ***Engines:***
    (1) There are (6) OHTIVB-16000-1 engines remaining.
    (2) OHT has consigned each independent lab one of these engines for DOE testing.
        (a) Both engines have already shipped and should arrive tomorrow.

iii) OHT is prepared to donate all of the critical hardware for the 2nd Precision Matrix.

c) Lubrizol Oil Level Presentation:

*i) **Silicone Pacification:***

(1) The purpose of this trial was to visually monitor the oil level in the sump in relation to the pick-up tube (and not to directly measure oil aeration).

(2) So the decision was made to forego running a silicone pacification/mitigation cycle in order to save time.

ii) Ford Motorcraft utility oil was used for the trials because it is readily available in the Lubrizol lab.

iii) Precautions were taken between trials to remove as much of the oil as possible from the engine.

(1) The oil pan was removed from the engine and cleaned.

(2) Pools of oil were removed from the valve deck.

(3) The external oil system was disassembled and purged with air.

*iv) **1st Trial – Determine the Amount of Oil Required to Fill External Oil System:***

(1) Lubrizol modified a stock oil pan with a large sight glass.

(a) The sight glass was added to the exhaust-side of the pan to allow for direct observation of the oil pick-up tube.

(b) A small port was installed on the intake-side of the oil pan to insert a backlight.

(2) A considerable amount of oil is required to fill the external oil system (lines, Oberg filter and heat exchanger).

(a) The dotted white line [in the image below] shows 3000mL in the engine when the external oil system is empty.

(b) The dotted yellow line [in the image below] shows 3000mL in the engine when the external oil system is full.

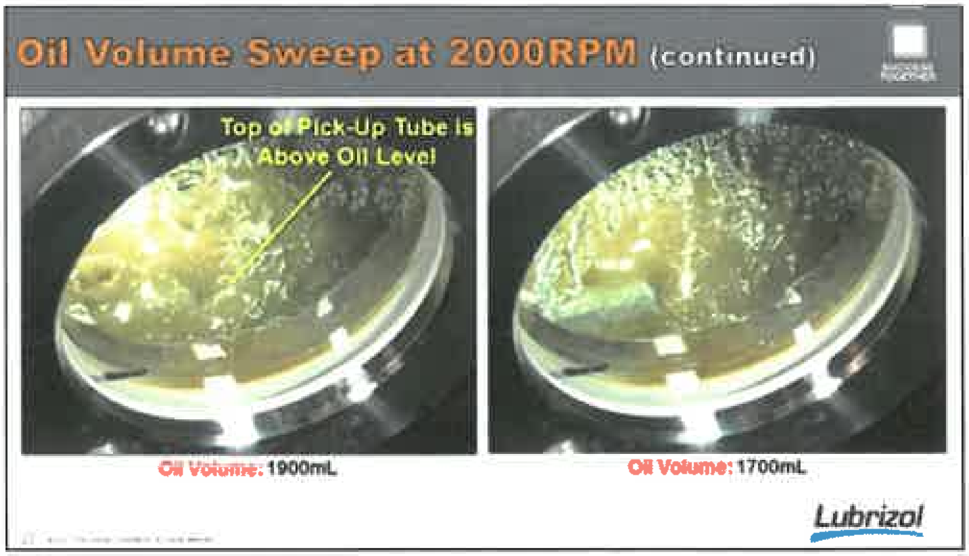
(c) The difference between the dotted yellow line and the dotted blue line [in the image below] shows the approximate amount oil required to supply the engine at 2000RPM.

v) ***2nd Trial – Determine if Pick-Up Tube Is Exposed to Air:***

(1) The silhouette of the pick-up tube becomes visible as the oil volume drops below 2000mL and the engine is at 2000RPM.

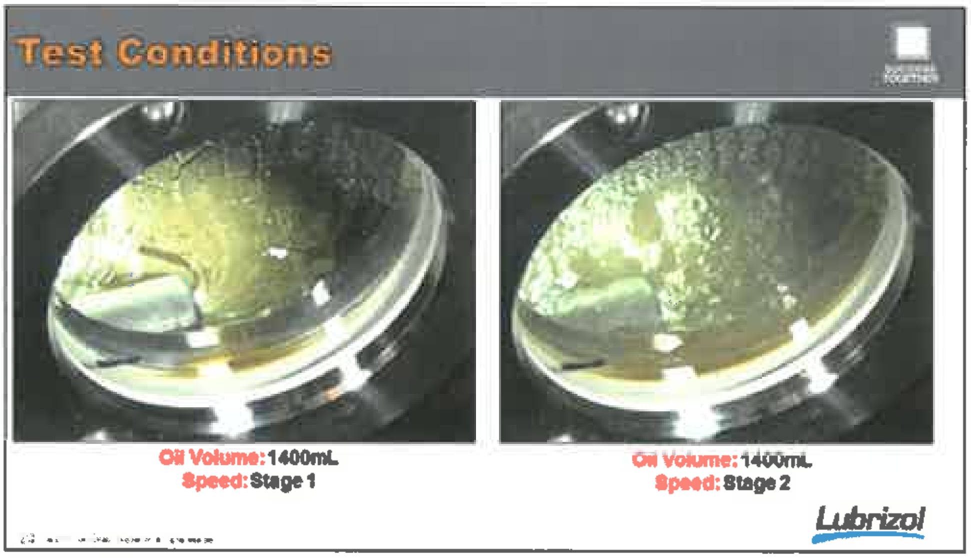
(2) The pick-up tube breaks the surface of the oil when the oil volume drops below 1900mL and the engine is at 2000RPM.

(a) The pick-up tube is presumably ingesting air at this point.



(3) The top half of the pick-up tube is above the surface of the oil when the oil volume drops below 1500mL and the engine is at 2000RPM.
  (a) The oil pump is presumably being starved at this point.

(4) There is very little oil draining from the top of the engine when the oil volume is at 1400mL and the stand is running at test conditions.
  (a) This is observational evidence that the oil pump is being severely starved.

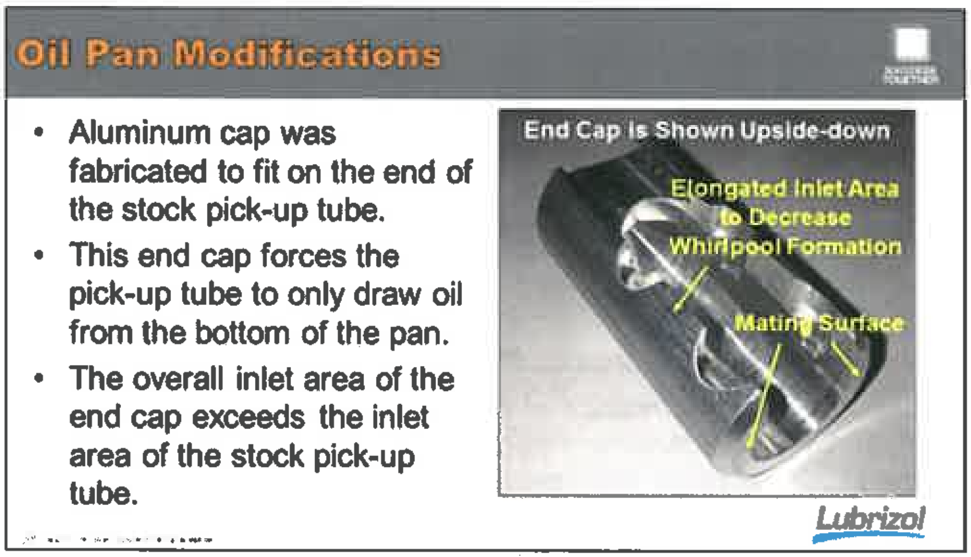


vi) ***3rd Trial – Evaluate the Performance of a Slotted Pick-Up Tube Design:***

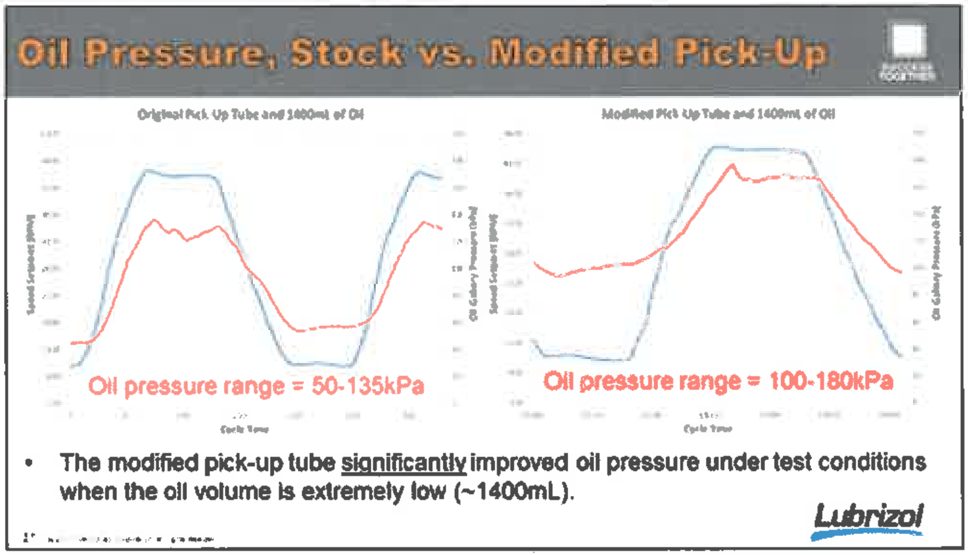
(1) Lubrizol modified the stock oil pick-up tube design by welding an aluminum cap to the end.

(2) The purpose of this end cap was to lower the inlet of the pick-up tube so that it is closer to the bottom of the oil pan.

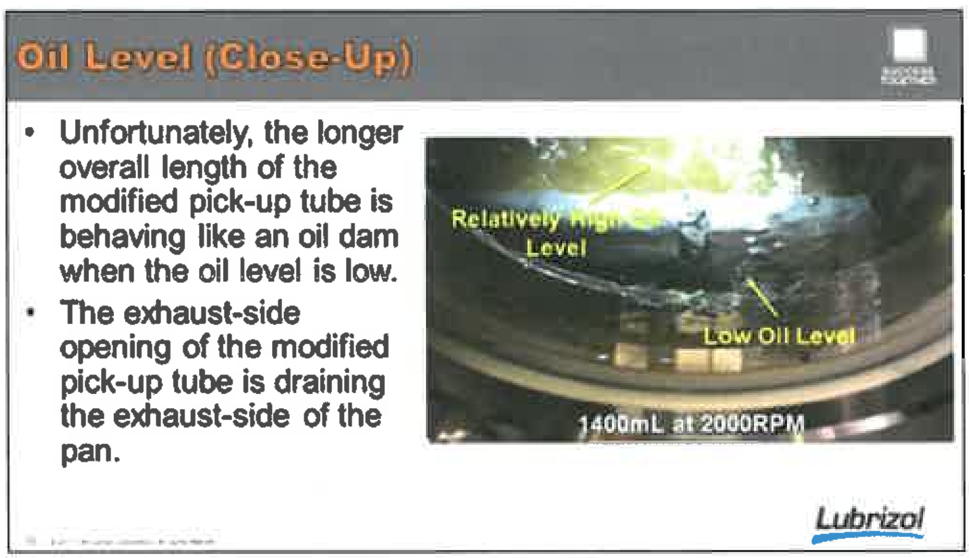
(a) This end cap also utilized a slotted opening to [hopefully] reduce the formation of whirlpools at the surface of the oil.



(3) The slotted pick-up tube design significantly improved the engine's ability to maintain oil pressure under extremely low oil volumes (~1400mL).

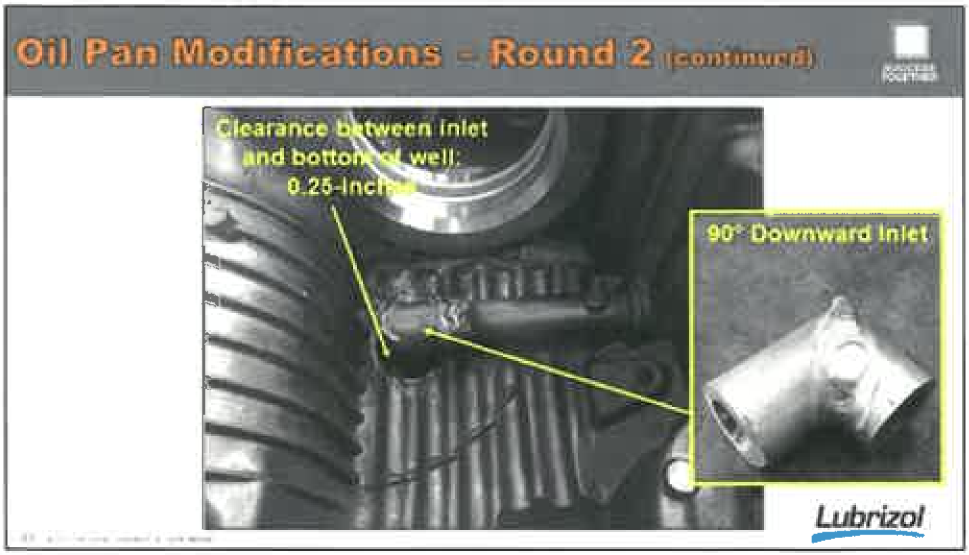


(4) Unfortunately, the longer overall length of the modified oil pick-up tube behaved like a dam across the bottom of the oil pan when the oil volume was extremely low.

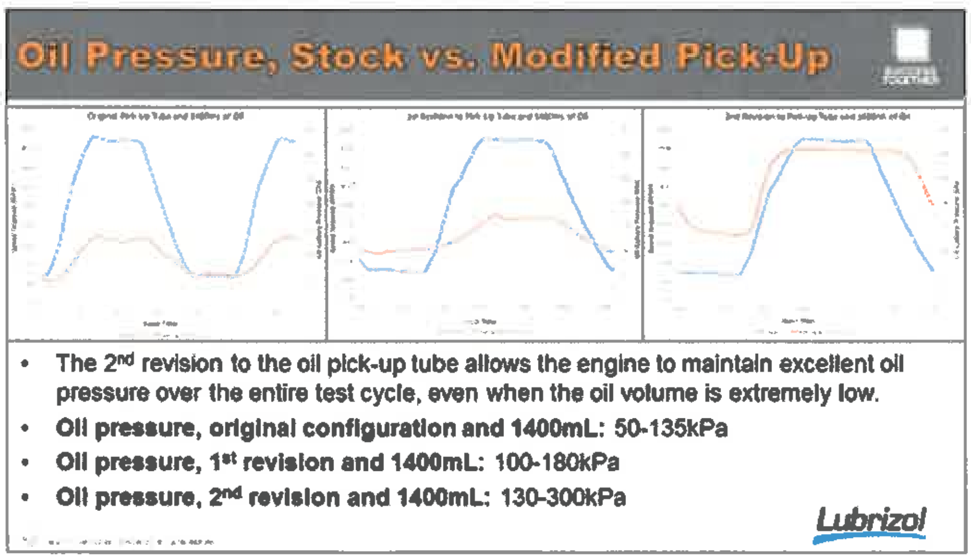


vii) ***4th Trial – Evaluate the Performance of an Oil Well Design:***

(1) Lubrizol removed the aluminum end cap that was evaluated during the 3rd trial.
(2) A downward-facing inlet was installed in its place.
(3) A small, circular well was added to the floor of the oil pan directly below the downward inlet.



(4) The oil well design proved to be superior to the slotted design under extremely low oil volumes (~1400mL).
   (a) The engine was able to maintain significantly better oil pressure under test conditions.
   (b) There is visibly more oil draining from the top of the engine and around the back of the sight glass.



viii) ***Intertek's Comments:***
(1) Each lab should be able to modify a single oil pan with the oil-well design that they can use for their prove-out testing.
   (a) This will give OHT time to produce modified oil pans for the 2nd Precision Matrix.
   (b) There was a consensus within the Surveillance Panel that this plan would be acceptable.
(2) Intertek recently <u>measured</u> the volume of the external oil system and found it to be around 530mL.
   (a) This is very close to Lubrizol's <u>calculated</u> external oil volume of 521.5mL.
   (b) Lubrizol noted that the small discrepancy between measured and calculated volume is probably due to the fact that Lubrizol did not include fittings in its calculations.

ix) ***Exxon's Comments:***
(1) In light of the Lubrizol findings, do we still want to increase the oil charge?

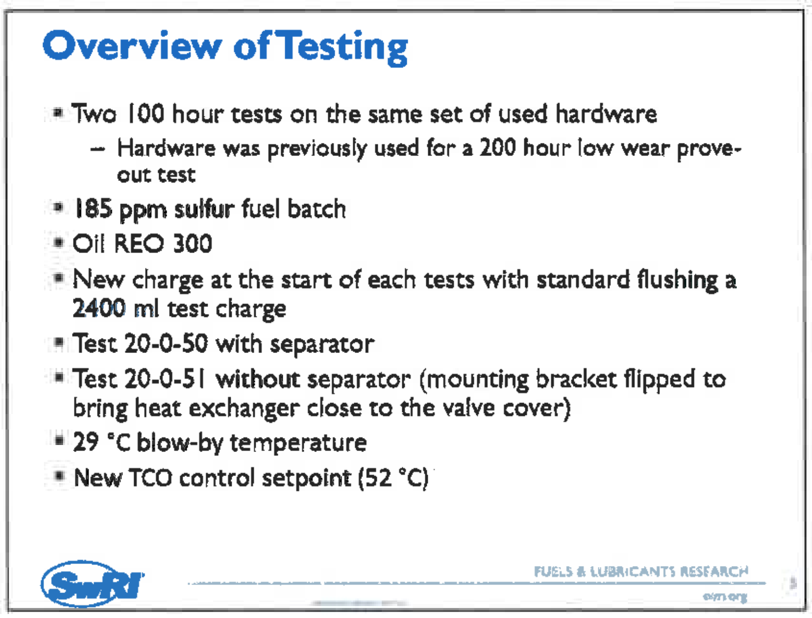
(2) The group debated Exxon's question and came to the consensus that it is better to err on the side of caution in terms of oil volumes.
(a) A larger initial oil volume will significantly reduce the risk of oil pump starvation.
(b) Also, it is much easier to make this change now than it would be after the Precision Matrix.
(c) Lubrizol continued to express concern about increasing the initial oil charge.
(i) Increasing the initial oil charge could shift the test too mild.

x) ***Aeration:***
(1) Toyota stated that there is no targeted level of aeration for this test.
(2) Instead, they want to reduce aeration as much as possible.
(3) The oil pan modifications, in addition to the increased initial oil charge, will both help to eliminate any possibility of aeration.

xi) ***Action Items:***
(1) Lubrizol to provide drawings of their oil pan modifications to the Surveillance Panel.
(2) Lubrizol to send the oil pan with the sight glass to Intertek.
(a) Intertek will repeat the Lubrizol trials.

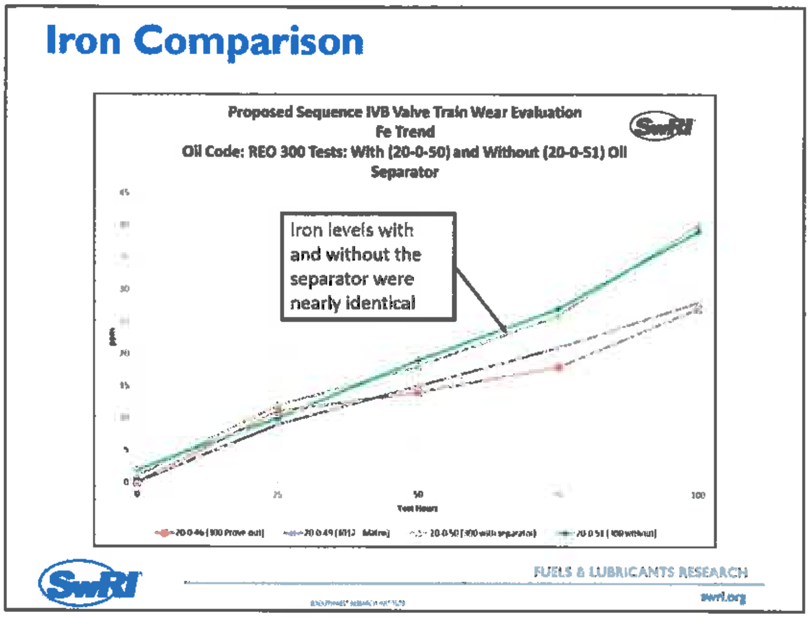
d) Southwest Oil Separator Presentation:

i) ***Slide #3:***



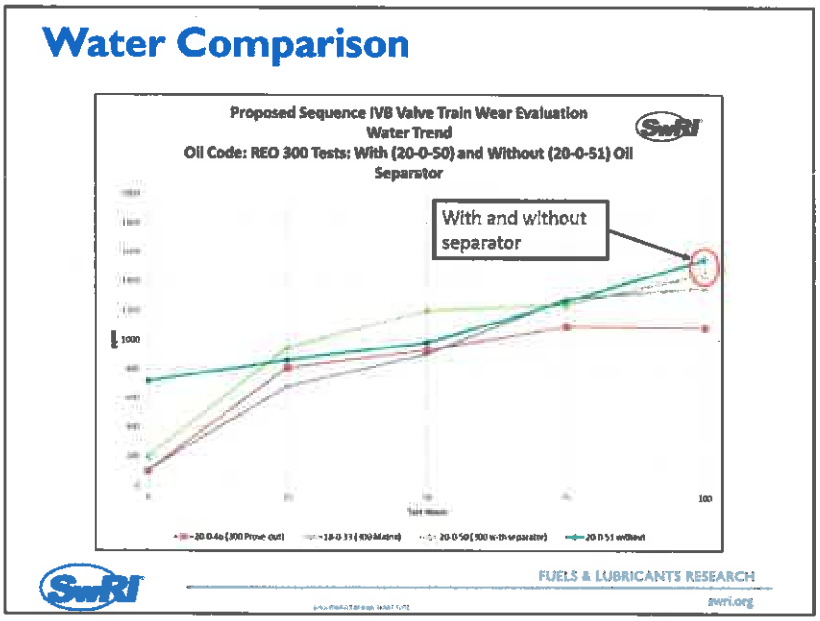
(1) All of these trials were done with the 185ppm fuel batch that was used for the initial Precision Matrix.

ii) ***Slide #5:***



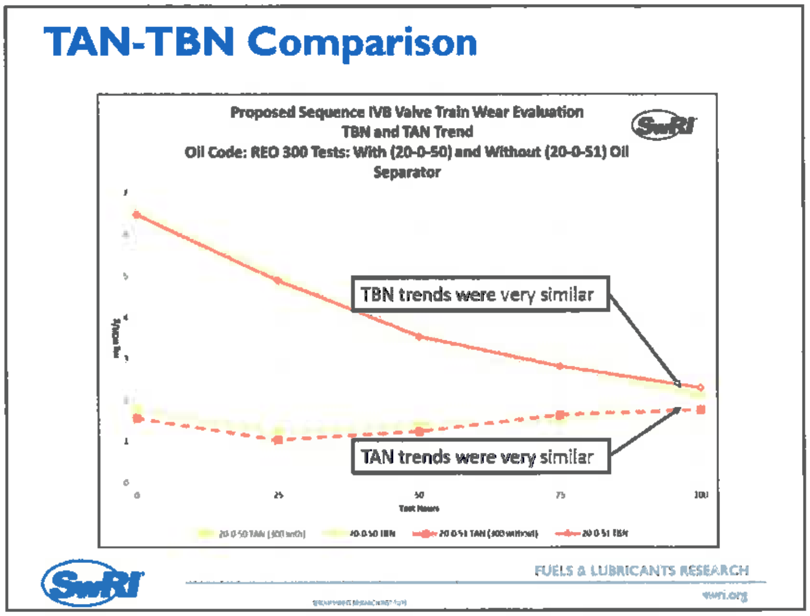
(1) Iron levels were identical between oil samples that were taken with and without the oil separator.

iii) ***Slide #6:***



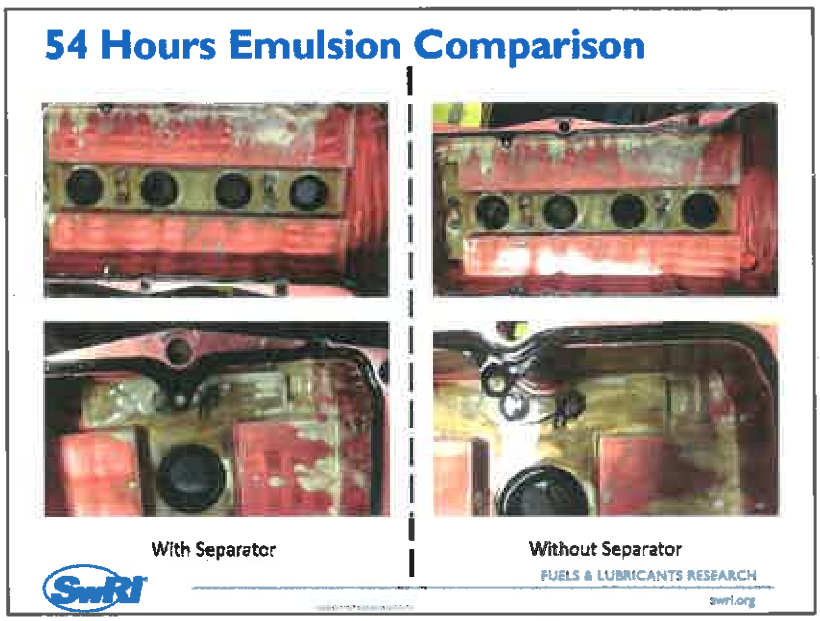
(1) Water content was very similar between oil samples that were taken with and without the oil separator.

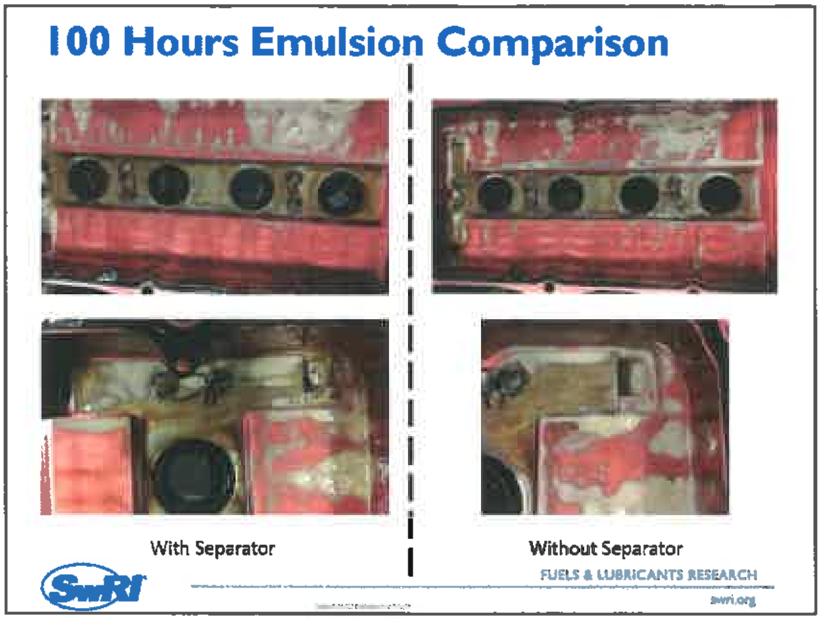
iv) ***Slide #7:***



(1) The TAN and TBN trends are both very similar between oil samples that were taken with and without the oil separator.

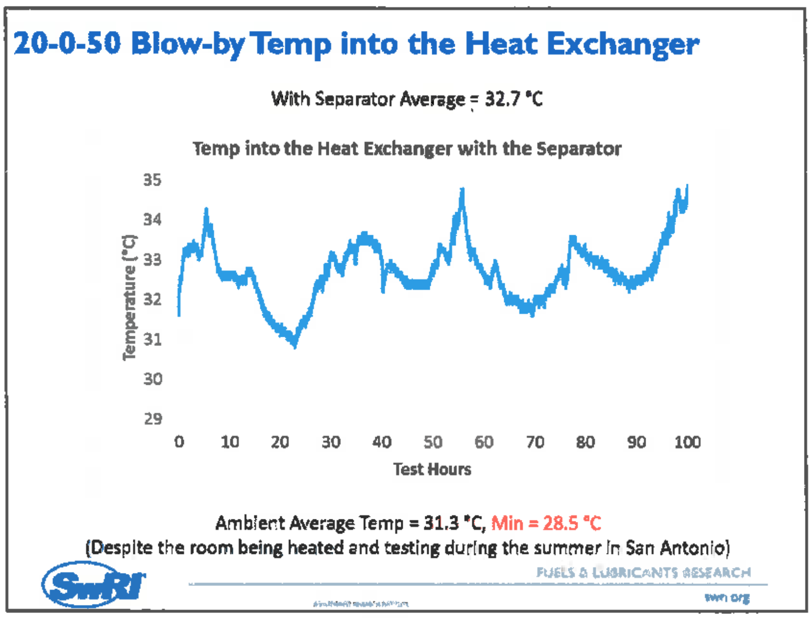
v) ***Slide #8 and Slide #9:***

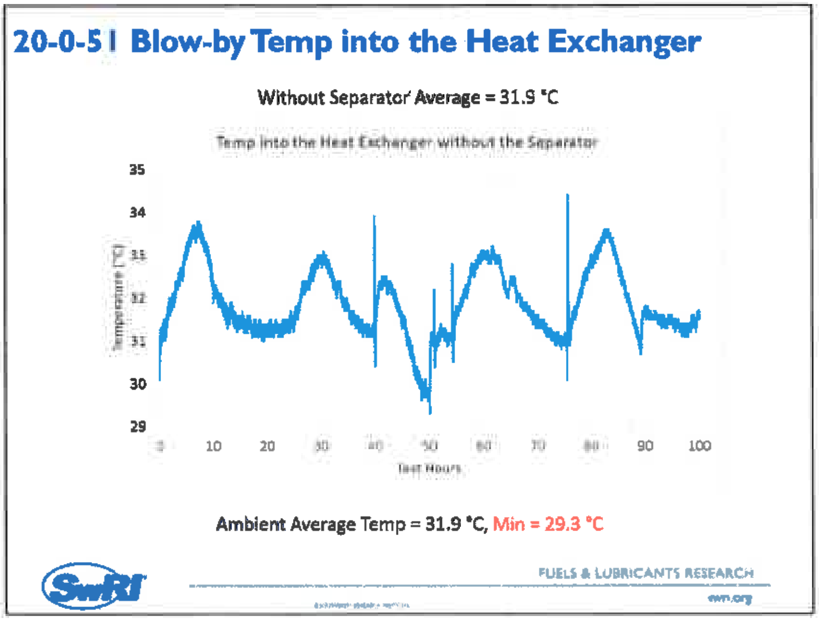




(1) Removing the oil separator did not have a significant impact on the amount of emulsion that formed under the rocker arm cover.

vi) ***Slide #10 and Slide #11:***





(1) Southwest measured significant swings in the blowby temperature between daytime and nighttime.

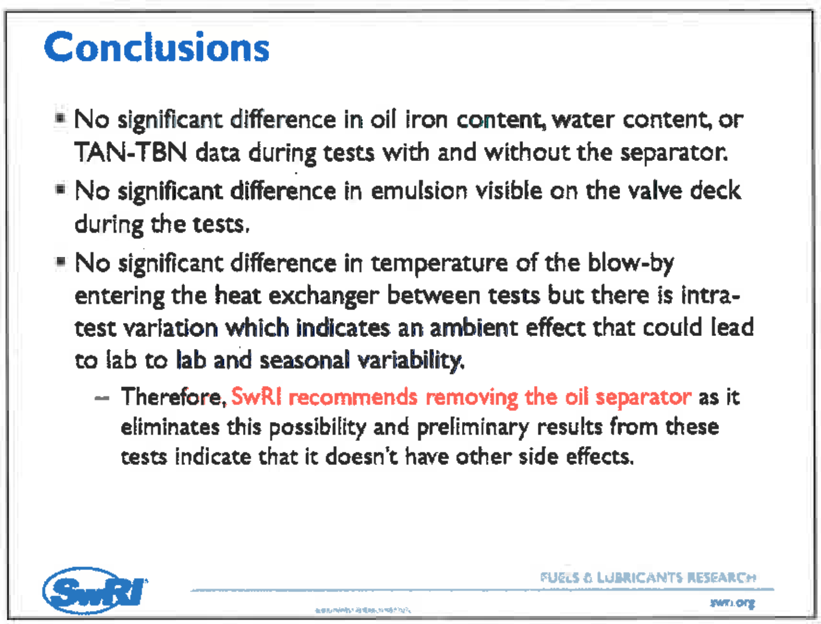
(2) These swings were present both with and without the oil separator installed.

(a) *Blowby temperature swing with oil separator:* 28.5°C to 31.3°C

(b) *Blowby temperature swing without oil separator:* 29.3°C to 31.9°C

(3) These swings were unexpected because their Sequence IVB stand is in an environmentally controlled room.

vii) ***Slide #12:***



(1) There were no significant changes in any of the monitored parameters when the oil separator was removed.

(2) Southwest recommends removing the oil separator in order to simplify the external blowby system.

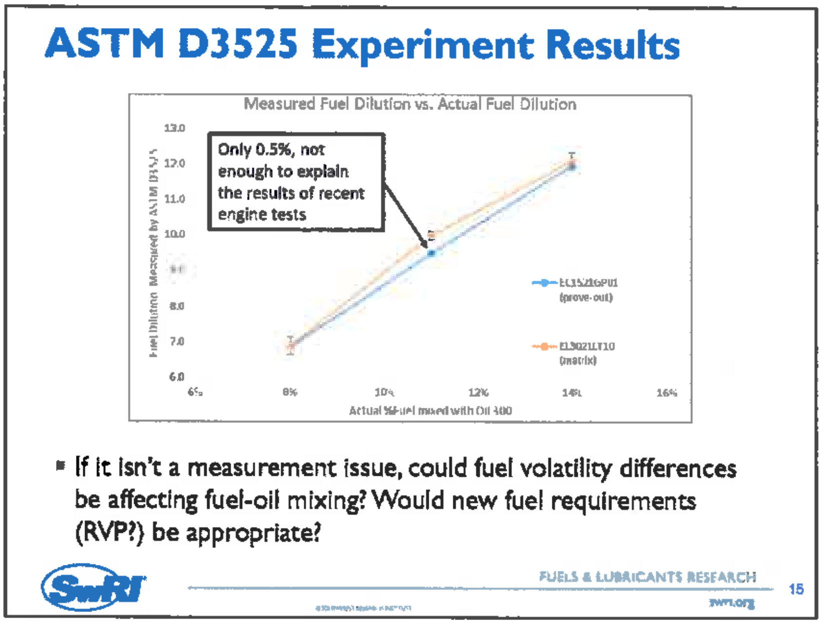
viii) ***Afton's Comments:***

(1) The oil separator is essentially a heat sink that makes the test stand more susceptible to changes in ambient conditions.

(2) They would like Southwest to provide details on how they revised the plumbing of the external blowby system when they removed the oil separator.

e) Southwest Fuel Dilution Study:

i) Slide #15:



(1) There is not a significant difference in fuel dilution measurements between the two fuel batches with the D3525 method.

(2) The difference between the two fuel batches at 11% is currently unexplained.

(a) However, this difference is not of a magnitude that would explain the differences seen between Intertek and Southwest during prove-out and Precision Matrix testing.

(b) So the differences may not be due to the measurement technique.

ii) Southwest questioned whether the fuel dilution differences being seen between labs actually have an impact on intake lifter wear.

f) Southwest Update on Draft Procedure:

i) Southwest sent a copy of the draft procedure to Intertek and Lubrizol.

ii) The TMC will post a copy of this draft procedure to their website so that the entire Surveillance Panel can review it.

g) Intertek Update on Recent Prove-Out Tests:

i) Intertek recently ran several prove-out tests at the request of Toyota.

ii) One of these three tests utilized the new high-event camshaft lobe failure oil (a.k.a. IVB-LFO-1).

(1) The remaining two tests used REO300 and REO1012.

iii) Intertek applied the following changes to these tests (Bill Buscher email, 07-07-2017 at 4:27PM EST):

(1) Change in initial oil charge measurement from volume to mass.

(2) Standardization of engine coolant flow direction.

(a) Coolant flows into the inlet pipe and out of the rear of the cylinder head.

(3) Change in the coolant temperature control point from the inlet to the outlet (rear of the cylinder head).

(4) Change in the coolant temperature set-point from 49°C (coolant inlet) to 52°C (coolant outlet).

(5) Change from 185ppm sulfur KA24E fuel to 124ppm sulfur KA24E fuel.

(6) Change from 2400mL (2100g) to 3000mL (2600g) initial oil charge volume.
(7) Change from 1oz (30mL) to 2oz (60mL) 25-hour interval oil sample volumes.
(a) This will eliminate the need for sample "pour backs".

iv) Intertek cannot share wear results from the high-event camshaft lobe failure oil per their customer's request.
(1) However, they can share that this oil did not experience a camshaft lobe failure.

v) All of these tests had negative coolant temperature QI's as a result of the new coolant temperature control strategy.

vi) Intertek has distributed summaries from these tests to the Surveillance Panel (Bill Buscher email, 07-07-2017 at 4:27PM EST).

h) Discussion about 2nd Precision Matrix:

i) The independent labs are not in a position to donate a significant number of additional tests.

ii) ***Exxon's Lab:***
(1) Exxon is ready to start prove-out testing.
(a) They are willing to conduct scoping trials similar to what Lubrizol did with the oil level study.
(2) Exxon is also interested in participating in the Precision Matrix (as the 4th lab) if they can prove equivalency to the other three labs.
(3) Toyota stated that Exxon probably cannot participate in the 2nd Precision Matrix at this time because they do not yet have a history of test results.
(a) However, both Toyota and Intertek agreed that Exxon could run in parallel to the 2nd Precision Matrix.
(b) Both Toyota and TMC agreed that the Exxon results could be used to set targets.

iii) ***Lubrizol's Lab:***
(1) Lubrizol has committed to running prove-out tests.
(2) Lubrizol still needs to have some internal discussions before it can commit to participating in the Precision Matrix.

iv) ***Afton's Lab:***
(1) Afton may be willing to provide supplemental data near the end of the Precision Matrix.
(2) They just fired their engine for the first time yesterday.

i) Discussion about Incremental (5-Hour) Oil Samples:

i) Afton would like the Surveillance Panel to consider removing the 5-hour oil samples.

ii) ***Intertek's Comments:***
(1) Intertek is open to this possibility, but would like the 5-hour oil samples to remain in place at least through the prove-out testing.
(2) The Surveillance Panel will need to vote to remove these samples prior to the Precision Matrix.
(3) They support Afton's proposal because the smaller 5-hour samples are difficult to accurately measure.

iii) ***Infineum's Comments:***
(1) They would like to see the prove-out and Precision Matrix tests run the same way in regards to the oil sample schedule.
(2) However, outside of that they are not opposed to removing the 5-hour oil samples.

iv) ***Exxon's Comments:***
(1) Exxon agrees with Infineum that the oil sample schedule needs to be the same between the prove-out and Precision Matrix tests.

v) There was a general consensus among the Surveillance Panel members to increase the volume of the 25-hour oil samples from 1oz to 2oz.

(1) This will eliminate the need for "pour backs" as the samples are moved from one subtest to the next subtest.

j) Discussion about Chamfered Intake Camshafts:

i) There was consensus within the Surveillance Panel to run chamfered intake camshafts for all prove-out tests.

k) Motion to Approve Changes to Test Procedure:

i) Intertek submitted a motion to the Surveillance Panel to approve a series of changes to the test procedure.

(1) Toyota seconded the motion.

ii) ***Motion:*** "*Agree to move forward with the following changes, based on data and results presented to-date:*

(1) Change in initial oil charge measurement from volume to mass.

(2) Standardization of engine coolant flow direction to into the coolant inlet pipe and out of the rear of the cylinder head, as is the production coolant flow direction for the Toyota 2NR-FE engine.

(3) Change in the coolant temperature control point from coolant in to coolant out (rear of the cylinder head).

(4) Change in the coolant temperature set-point from 49°C (Coolant In) to 52°C (Coolant Out).

(5) Change from 185 ppm Sulfur content KA24E Green fuel to 130±10 ppm Sulfur content KA24E Green fuel.

(6) Change from 2,400 ml (2,100 g) to 3,000 ml (2,600 g) initial oil charge volume.

(7) Change from 1 ounce (30 ml) to 2 ounce (60 ml) 25-hour interval oil sample volumes. This will eliminate the "analyze and return sample for other analyses requirement" that we currently have, to conduct kinematic viscosity analysis.

(8) Eliminate the 3 ml 5-hour interval oil samples at 105, 110, 115, 120, 130, 135, 140 ,145, 155, 160, 165, 170, 180, 185, 190 and 195 hours.

(9) Change to OHT chamfered intake camshafts.

(10) Change to OHT modified oil pan with the additional Lubrizol recommended/design modifications.

(11) Eliminate oil separator from and revise plumbing, as per Southwest, for the external blowby system."

iii) ***Results of Vote:***

(1) *The following organizations voted affirmatively:* Intertek, OHT, Valvoline, Afton, Toyota, TEI, Southwest, Lubrizol, Haltermann, Infineum, Ford (Toyota voted by proxy), Exxon, Oronite and BP.

(2) *The following organizations waived:* TMC

(3) The final vote count of 14-0-1 was a pass.

l) Forward Action Plan for Prove-Out Testing:

i) Lubrizol requested that no prove-out testing is conducted until the Surveillance Panel can review and approve a final draft test procedure.

ii) ***Southwest to conduct (3) tests using their Precision Matrix stands:***

(1) *Run 1, Stand 20:* IVB-LFO-1

(2) *Run 2, Stand 18:* REO300

(3) *Run 1, Stand 18:* REO1012

iii) ***Intertek to conduct (3) repeat tests using their Precision Matrix stands:***

(1) *Run 1, Stand 165:* IVB-LFO-1

(2) *Run 1, Stand 102:* REO300

(3) *Run 2, Stand 102:* REO1012

iv) ***Lubrizol to conduct (2) tests:***
(1) Run 1: REO1012
(2) Run 2: REO300

v) ***Exxon to conduct (2) tests:***
(1) Run 1: REO300
(2) Run 2: REO1012

Action Items	Person responsible	Completion Date
Collect engine coolant temperature data using new strategy, and provide the data to statisticians.	All Labs	
Statisticians to recommend new QI targets and limits for revised coolant temperature control strategy.	Statisticians	
Lubrizol to distribute drawings of oil pan modifications (i.e. oil well).	Lubrizol	
Lubrizol to investigate influence of oil sample valve on oil sample foaming.	Lubrizol	
Lubrizol to send modified oil pan (with sight glass) to Intertek.	Lubrizol	
Intertek to repeat and confirm Lubrizol oil level trials.	Intertek	
Statisticians to recommend oils and run order for labs that are offering supplemental data for the 2nd Precision Matrix.	Statisticians	
Update and approve Sequence IVB draft procedure.	All Labs	

Follow-up Notes/Updates:	Initials	Date Added

MEMBERSHIP
SEQUENCE IV SURVEILLANCE PANEL

JULY 12, 2017

~~June 8, 2017~~

NAME	COMPANY-ADDRESS-PHONE-FAX-EMAIL	SIGNATURE
Bowden, Jason	OH Technologies, Inc. 9300 Progress Parkway P.O. Box 5039 Mentor, OH 44061-5039 Phone No.: 440-354-7007 Fax No.: 440-354-7080 Email: jhbowden@ohtech.com	✓
Buscher III, William	Intertek Automotive Research 5404 Bandera Road San Antonio, TX 78238 Phone No.: 210-647-9489 or 210-240-8990 cell Fax No.: 210-684-6074 Email: william.buscher@intertek.com	✓
Buscher, Jr., William	Buscher Consulting Services P.O. Box 112 Hopewell Jct., NY 12533 Phone No.: 914-897-8069 Fax No.: 914-897-8069 Email: buschwa@aol.com	
Savant, Amol	Valvoline 22nd & Front Streets Ashland, KY 41114 Phone No. Fax No.: Email:	✓
Pecinovsky, Katerina	Afton Chemical Corporation 500 Spring Street P.O. Box 2158 Richmond, VA 23217-2158 Phone No.: 804-788- Fax No.: 804-788- Email:	✓
Grundza, Rich	ASTM Test Monitoring Center 6555 Penn Avenue Pittsburgh, PA 15206 Phone No.: 412-365-1031 Fax No.: 412-365-1047 Email: reg@astmtmc.cmu.edu	✓
Hsu, Jeffery	Shell Global Solutions 3333 Highway 6 South Houston, TX 77082 Phone No.: 281-544-8619 Fax No.: 281-544-8150 Email: j.hsu@shell.com	
Kowalski, Teri	Toyota Motor North America, Inc. 1555 Woodridge Ann Arbor, MI 48105 Phone No.: 734- 995-4032 or 734-355-8082 cell Fax No.: 734- 995-9049 Email: teri.kowalski@tema.toyota.com	✓

July 12, 2017

~~June 8, 2017~~

MEMBERSHIP
SEQUENCE IV SURVEILLANCE PANEL

NAME	COMPANY-ADDRESS-PHONE-FAX-EMAIL	SIGNATURE
Lanctot, Dan	Test Engineering, Inc. 12718 Cimarron Path San Antonio, TX 78249 Phone No.: Fax No.: Email: DLanctot@tei-net.com	✓
Rais, Khaled	Southwest Research Institute 6220 Culebra Road P.O. Drawer 28510 San Antonio, TX 78228-0510 Phone No.: 210-522-3842 Fax No.: 210-684-7523 Email: khaled.rais@swri.org	✓
Tarry, Preston	BP 1500 Valley Road Wayne, NJ 07470 Phone No.: Fax No.: Email:	✓
Hopp, Meryn	GM Powertrain Mail Code 483-730-322 823 Joslyn Rd. Pontiac, MI 48340-2920 Phone No.: Fax No.: Email:	
Mileti, Chris	Lubrizol Corporation 29400 Lakeland Blvd. Wickliffe, OH 44092 Phone No.: 440-347-2521 Fax No.: 440-347-4096 Email: christopher.mileti@Lubrizol.com	✓
Overaker, Mark	Haltermann Solutions 15635 Jacintoport Blvd. Houston, TX 77345 Phone No.: 832-376-2202 Fax No.: Email: mhoveraker@jhaltermann.com	✓
Rieth, Ryan	Infineum USA L.P. 1900 E. Linden Avenue Linden, NJ 07036-0536 Phone No.: 908-474-7377 Fax No.: 908-474-3637 Email: Ryan.Rieth@Infineum.com	✓
Romano, Ron	Ford Motor Company 1800 Fairlane Drive Allen Park, MI 48101 Phone No.: 313-845-4068 Fax No.: 313-323-8042 Email: rromano@ford.com	✓

MEMBERSHIP
SEQUENCE IV SURVEILLANCE PANEL

July 12, 2017

~~November 16, 2016~~

NAME	COMPANY-ADDRESS-PHONE-FAX-EMAIL	SIGNATURE
Sagawa, Takumaru	Nissan Motor Co., Ltd. 560-2, Okatsukoku, Atsugi city Kanagawa 243-0192 Phone No.: 046-270-1515 Fax No.: 046-270-1585 Email: t-sagawa@mail.nissan.co.jp	
Salvensen, Cliff	ExxonMobil Research & Engineering Co. 600 Billingsport Road P.O. Box 480 Paulsboro, NJ 08066-0480 Phone No.: 856-224-2954 Fax No.: Email: clifford.r.salvesen@exxonmobil.com	✓
Sinha, Kaustav Robert voting for OR	Chevron Oronite Company LLC 4800 Fournace Place Bellaire, TX 77401 Phone No.: 713-432-6642 Fax No.: 713-432-3330 Email: LFNQ@chevron.com	
Tang, Haiying	Chrysler Group LLC 800 Chrysler Drive Auburn Hills, MI Phone No.: Fax No.: Email: haiying.tang@fcagroup.com	
[illegible]	Phone No.: Fax No.: Email:	
	Phone No.: Fax No.: Email:	
	Phone No.: Fax No.: Email:	
	Phone No.: Fax No.: Email:	

JULY 12, 2017

NON-MEMBER MAILING LIST
SEQUENCE IV SURVEILLANCE PANEL

~~June 8, 2017~~

NAME	COMPANY-ADDRESS-PHONE-FAX-EMAIL	SIGNATURE
Adams, Mark	Tribology Testing Labs Phone No.: 989-980-4418 Fax No.: Email: mark@tribologytesting.com	
Altman, Ed	Afton Chemical Corporation 500 Spring Street P.O. Box 2158 Richmond, VA 23217-2158 Phone No.: 804-788-5279 Fax No.: 804-788-6358 Email: ed.altman@aftonchemical.com	✓
Boese, Doyle	Infineum USA L.P. 1900 E. Linden Avenue Linden, NJ 07036-0536 Phone No.: 908-474-3176 Fax No.: 908-474-3637 Email: doyle.boese@infineum.com	
Bowden, Adam	OH Technologies, Inc. 9300 Progress Parkway P.O. Box 5039 Mentor, OH 44061-5039 Phone No.: 440-354-7007 Fax No.: 440-354-7080 Email: adbowden@ohtech.com	
Bowden, Dwight	OH Technologies, Inc. 9300 Progress Parkway P.O. Box 5039 Mentor, OH 44061-5039 Phone No.: 440-354-7007 Fax No.: 440-354-7080 Email: dhbowden@ohtech.com	
Bowden, Matt	OH Technologies, Inc. 9300 Progress Parkway P.O. Box 5039 Mentor, OH 44061-5039 Phone No.: 440-354-7007 Fax No.: 440-354-7080 Email: mbowden@ohtech.com	
Brys, Jerome	Lubrizol Corporation 29400 Lakeland Blvd. Wickliffe, OH 44092 Phone No.: 440-347-2631 / 440-943-1200 Fax No.: 440-943-9013 Email: jabs@lubrizol.com	✓
Campbell, Bob	Afton Chemical Corporation 500 Spring Street P.O. Box 2158 Richmond, VA 23217-2158 Phone No.: 804-788- Fax No.: 804-788-6358 Email: bob.campbell@aftonchemical.com	✓

NON-MEMBER MAILING LIST
SEQUENCE IV SURVEILLANCE PANEL

July 12, 2017

~~June 8, 2017~~

NAME	COMPANY-ADDRESS-PHONE-FAX-EMAIL	SIGNATURE
Castanien, Chris	Neste Phone No.: Fax No.: Email: Chris.Castanien@nesteoil.com	
Clark, Sid	Southwest Research Institute 50481 Peggy Lane Chesterfield, MI 48047 Phone No.: 586-873-1255 Email: sidney.clark@swri.org	
Clark, Jeff	ASTM Test Monitoring Center 6555 Penn Avenue Pittsburgh, PA 15206 Phone No.: 412-365-1032 Fax No.: 412-365-1047 Email: jac@astmtmc.cmu.edu	
Dvorak, Todd	Afton Chemical Corporation 500 Spring Street P.O. Box 2158 Richmond, VA 23217-2158 Phone No.: 804-788- Fax No.: 804-788-6358 Email: todd.dvorak@aftonchemical.com	
Farnsworth, Gordon	Infineum USA L.P. 1900 E. Linden Avenue Linden, NJ 07036-0536 Phone No.: 570-934-2776 Fax No.: 908-474-3637 Email: gordon.farnsworth@infineum.com	✓
Kelly, Jack	Lubrizol Corporation 29400 Lakeland Blvd. Wickliffe, OH 44092 Phone No.: 216-943-1200 Fax No.: Email: jack@lubrizol.com	
Knight, Clayton	Test Engineering, Inc. 12718 Cimarron Path San Antonio, TX 78249 Phone No.: 210-862-5987 cell Fax No.: 210-690-1959 Email: cknight@tei-net.com	
Kostan, Travis	Southwest Research Institute 6220 Culebra Road P.O. Drawer 28510 San Antonio, TX 78228-0510 Phone No.: 210-522-2407 Fax No.: 210-684-7523 Email: travis.kostan@swri.org	

NON-MEMBER MAILING LIST
SEQUENCE IV SURVEILLANCE PANEL

JULY 12, 2017

~~June 8, 2017~~

NAME	COMPANY-ADDRESS-PHONE-FAX-EMAIL	SIGNATURE
Lang, Patrick	Southwest Research Institute 6220 Culebra Road P.O. Drawer 28510 San Antonio, TX 78228-0510 Phone No.: 210-522-2820 or 210-240-9461 cell Fax No.: 210-684-7523 Email: patrick.lang@swri.org	✓
Linden, Jim	Linden Consulting LLC 673 Campus Road Rochester Hills, MI 48309 Phone No.: 248-321-5343 Fax No.: Email: lindenjim@jlindenconsulting.com	
Lochte, Michael	Southwest Research Institute 6220 Culebra Road P.O. Drawer 28510 San Antonio, TX 78228-0510 Phone No.: 210-522-5430 Fax No.: 210-684-7523 Email: michael.lochte@swri.org	✓
Lopez, Al	Intertek Automotive Research 5404 Bandera Road San Antonio, TX 78238-1993 Phone No.: 210-647-9465 or 210-862-7935 cell Fax No.: 210-523-4607 Email: al.lopez@intertek.com	✓
Matasic, James	Lubrizol Corporation 29400 Lakeland Blvd. Wickliffe, OH 44092 Phone No.: 440-347-2487 Fax No.: Email: James.Matasic@Lubrizol.com	
Martinez, Jo	Chevron Oronite Company LLC 100 Chevron Way, 71-7548 P.O. Box 1627 Richmond, CA 94802-0627 Phone No.: 510-242-5563 Fax No.: 510-242-1930 Email: jomartinez@chevron.com	
McMillan, Mike	Infineum 5019 Deer Creek Cir N Washington, MI 48094 Phone No.: 586-677-9198 Fax No.: Email: mmcmillan123@comcast.net	
O'Malley, Kevin	Lubrizol Corporation 29400 Lakeland Blvd. Wickliffe, OH 44092 Phone No.: 440-347-4141 Fax No.: Email: Kevin.OMalley@lubrizol.com	

NON-MEMBER MAILING LIST
SEQUENCE IV SURVEILLANCE PANEL

JULY 12, 2017

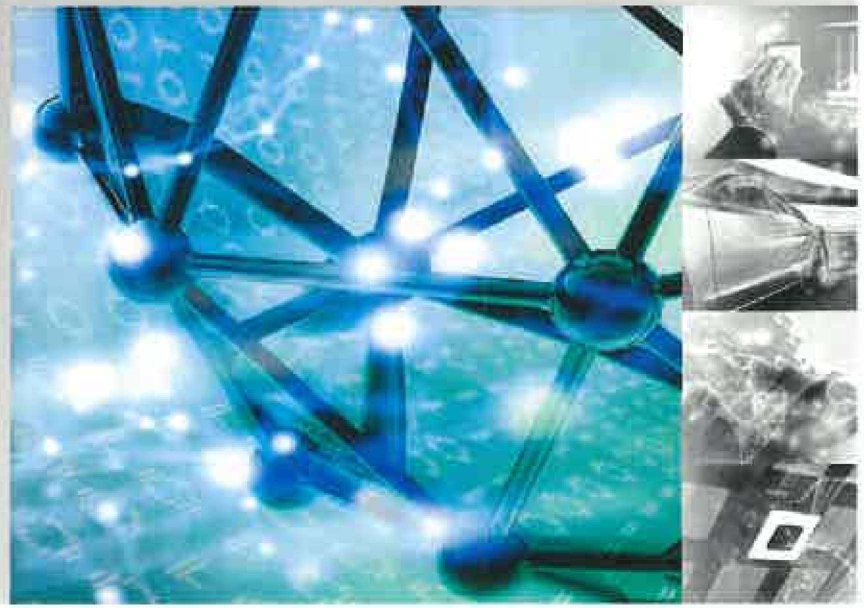
~~June 8, 2017~~

NAME	COMPANY-ADDRESS-PHONE-FAX-EMAIL	SIGNATURE
Pastor, Jofran	Infineum Phone No.: Fax No.: Email: jofran.pastor@infineum.com	
Porter, Christian	Afton Chemical Corporation 500 Spring Street P.O. Box 2158 Richmond, VA 23217-2158 Phone No.: 804-788-5837 Fax No.: 804-788-6358 Email: christian.porter@aftonchemical.com	
Rais, Khaled	Southwest Research Institute 6220 Culebra Road P.O. Drawer 28510 San Antonio, TX 78228-0510 Phone No.: Fax No.: 210-684-7523 Email: khalad.rais@swri.org	
Ritchie, Andrew	Infineum USA L.P. 1900 E. Linden Avenue Linden, NJ 07036-0536 Phone No.: 908-474-2097 Fax No.: 908-474-3637 Email: andrew.ritchie@infineum.com	✓
Savant, Amol	Ashland Inc. 22nd & Front Streets Ashland, KY 41114 Phone No.: Fax No.: Email: ACSavant@ashland.com	
Smolenski, Don	Evonik Phone No.: Fax No.: Email:	
Stockwell, Robert	Chevron Oronite Company LLC Phone No.: Fax No.: Email: Robert.Stockwell@chevron.com	✓
Sutherland, Mark	Test Engineering, Inc. 12718 Cimarron Path San Antonio, TX 78249 Phone No.: 210-867-8357 Fax No.: 210-690-1959 Email: msutherland@tei-net.com	

NON-MEMBER MAILING LIST
SEQUENCE IV SURVEILLANCE PANEL

JULY 12, 2017
~~June 8, 2017~~

NAME	COMPANY-ADDRESS-PHONE-FAX-EMAIL	SIGNATURE
Taylor, Chris	Phone No.: 210-710-4627 Fax No.: Email: chris.taylor@vpracing-fuels.com	
Warholic, Mike	Phone No.: 908-287-9596 Fax No.: Email: Hapjthom@aol.com	
~~Warholic, Mike~~ CHARLIE LEVERETT	IN Phone No.: 609-744-6782 Fax No.: Email: Michael.Warholic@Infineum.com	✓
~~[illegible]~~ PRASAD TUMATI	HALT Phone No.: Fax No.: Email:	✓
SATOSHI HIRANO	TOY Phone No.: Fax No.: Email:	✓
ADAM MEIER	EX Phone No.: Fax No.: Email:	✓
CARLTON COKER	IAR Phone No.: Fax No.: Email:	✓
CHET COLLINS	SWRI Phone No.: Fax No.: Email:	✓
JORDAN SMITH	EX	✓



Sequence IVB Test

Oil Level Trials

Lubrizol

Calibration Procedure

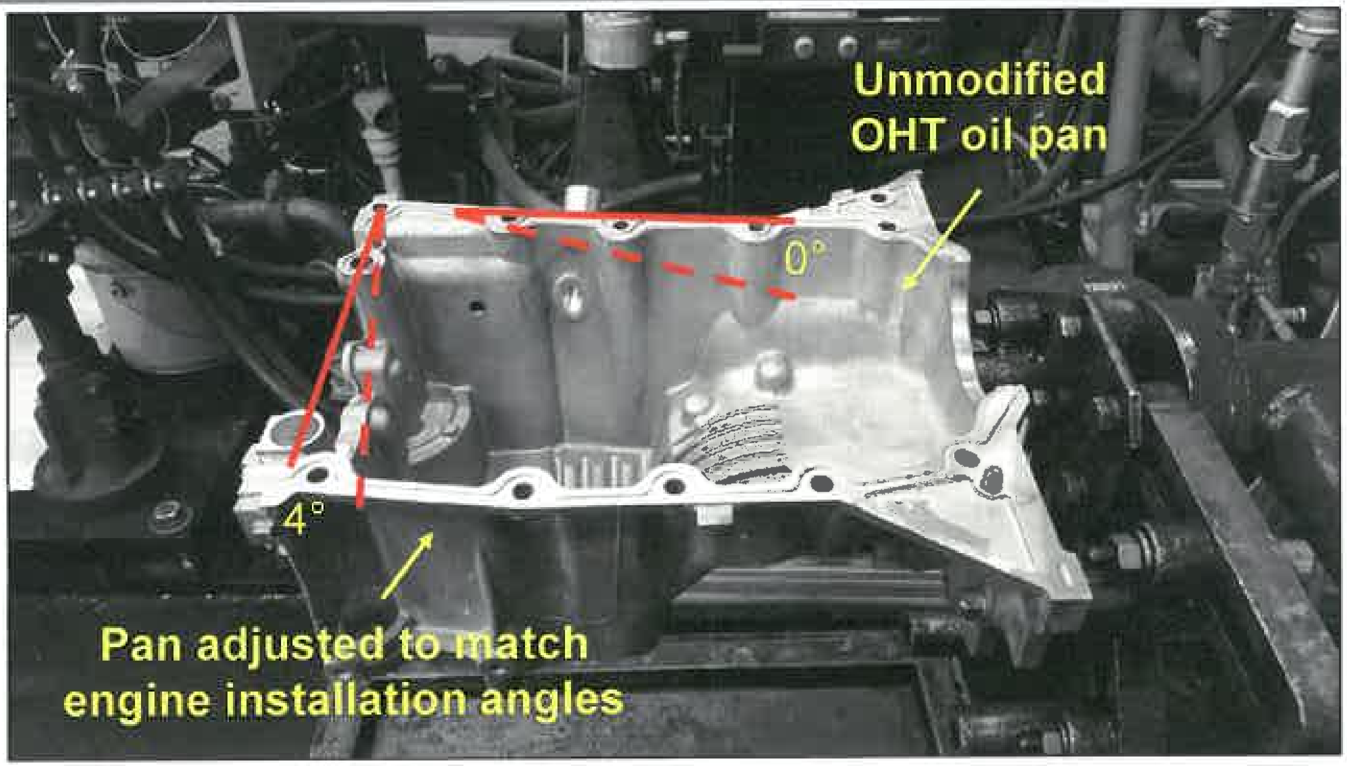
SUCCESS TOGETHER

- OHT oil pan mounted to engine rollover cart
- Oil pan adjusted to match installation angle of engine
- EF-411 was used for trial
- Oil was added to the pan in 100mL increments
- Dipstick reading was taken at each oil level
- Operator identified the oil level necessary to cover the opening of the oil pick-up tube

Lubrizol

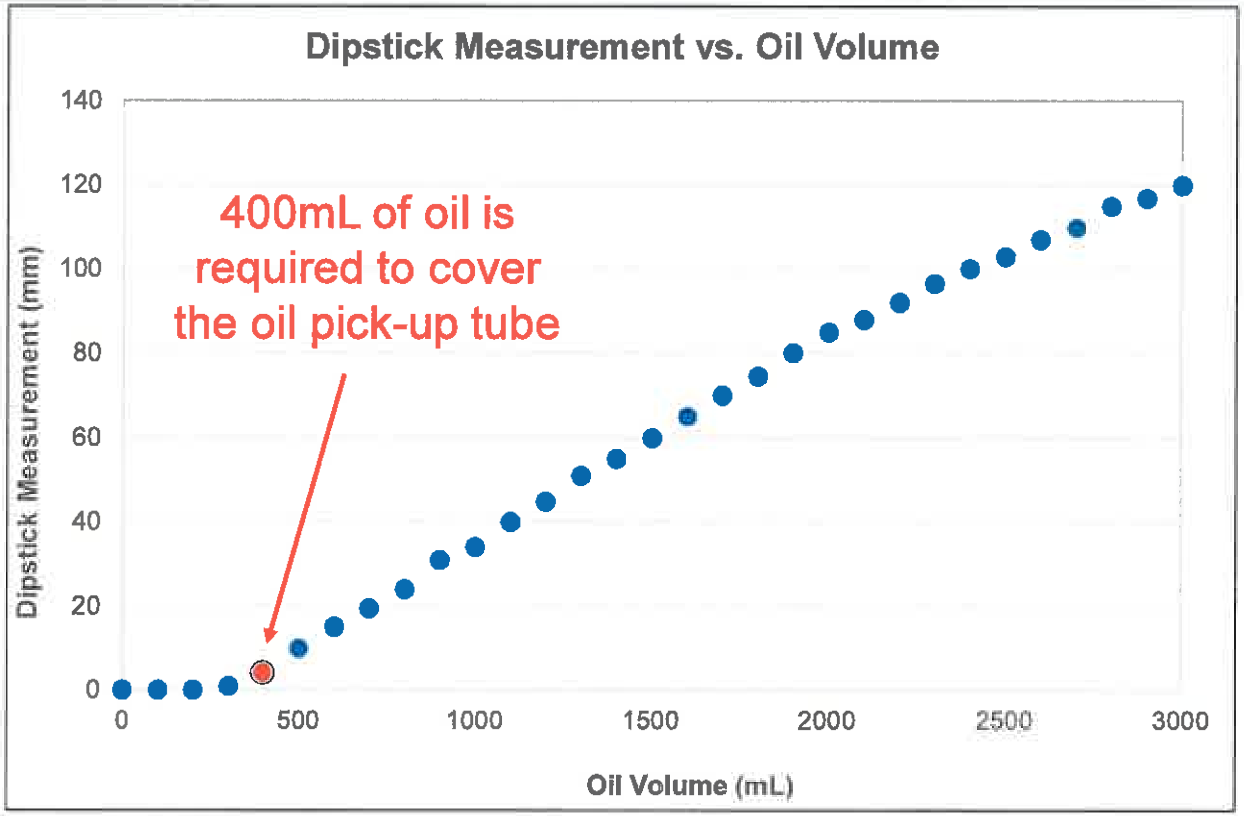
Oil Pan Set-Up

SUCCESS TOGETHER



Lubrizol

Dipstick Calibration Curve



Lubrizol

Lubrizol

Overview of 06-13-2017 Trial

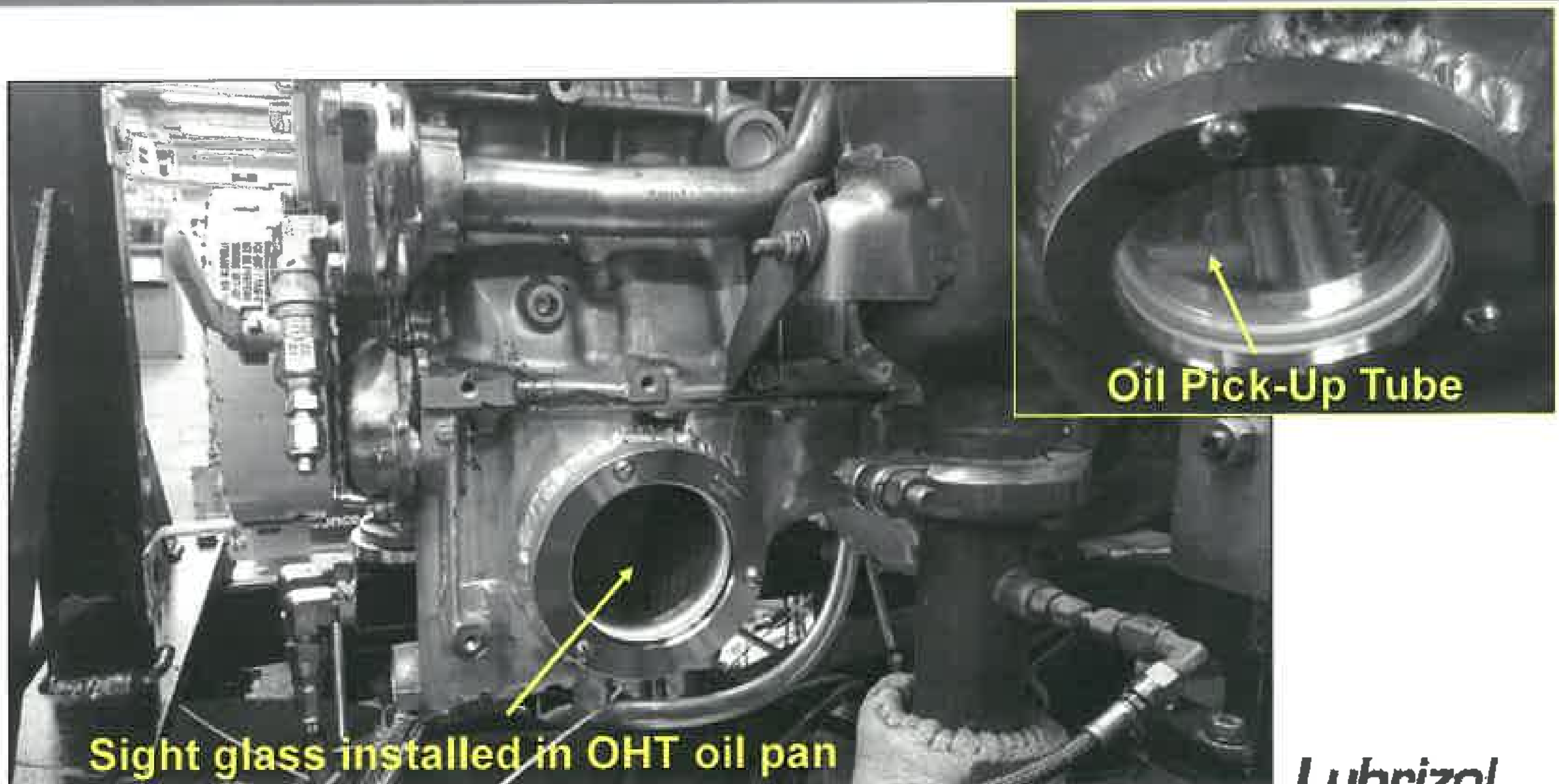
SUCCESS TOGETHER

- **Engine Modifications:**
  - Sight glass welded into exhaust side of OHT oil pan
  - Plexiglas installed over timing chain access window
- **Oil:** 3000mL (Ford Motorcraft)
- **Goal:** Determine how to optimize conditions for filming
- **Procedure:** Engine accelerated from 1000RPM to 2000RPM and back to 1000RPM

Lubrizol

Engine Modification #1 - Oil Pan Sight Glass

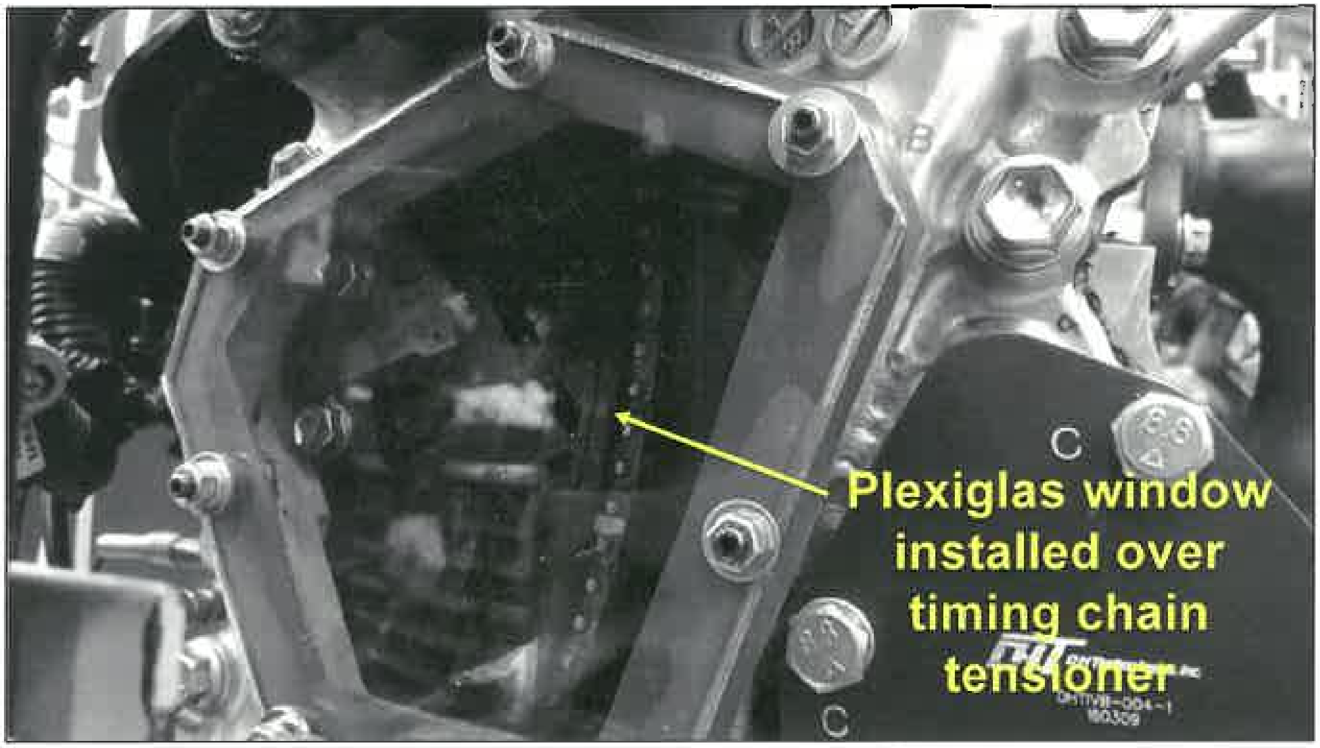
SUCCESS TOGETHER



Lubrizol

Engine Modification #2 – Front Cover Window

SUCCESS TOGETHER



Lubrizol

Initial Oil Level Observations

SUCCESS TOGETHER

Total Oil Volume: 3000mL
Engine Speed: 0RPM
External Oil System: Empty

Total Oil Volume: 3000mL
Engine Speed: 1200RPM
External Oil System: Full

Total Oil Volume: 3000mL
Engine Speed: 0RPM
External Oil System: Full

Lubrizol

Oil Level Comparison (3000mL Charge)

SUCCESS TOGETHER

Lubrizol

Conclusions from 06-13-2017 Trial

SUCCESS TOGETHER

- A considerable amount of the initial oil charge is used to fill the external oil system and oil passages in the engine.
- The amount of oil splashing on the sight glass is minimal (at least through 2000RPM).
- Visibility of the oil in the sump (and the oil pick-up tube) can be improved with backlighting.
  - The oil pan has been removed and is currently being modified to accommodate an internal light.

Lubrizol

Lubrizol

Overview of 06-13-2017 Trial

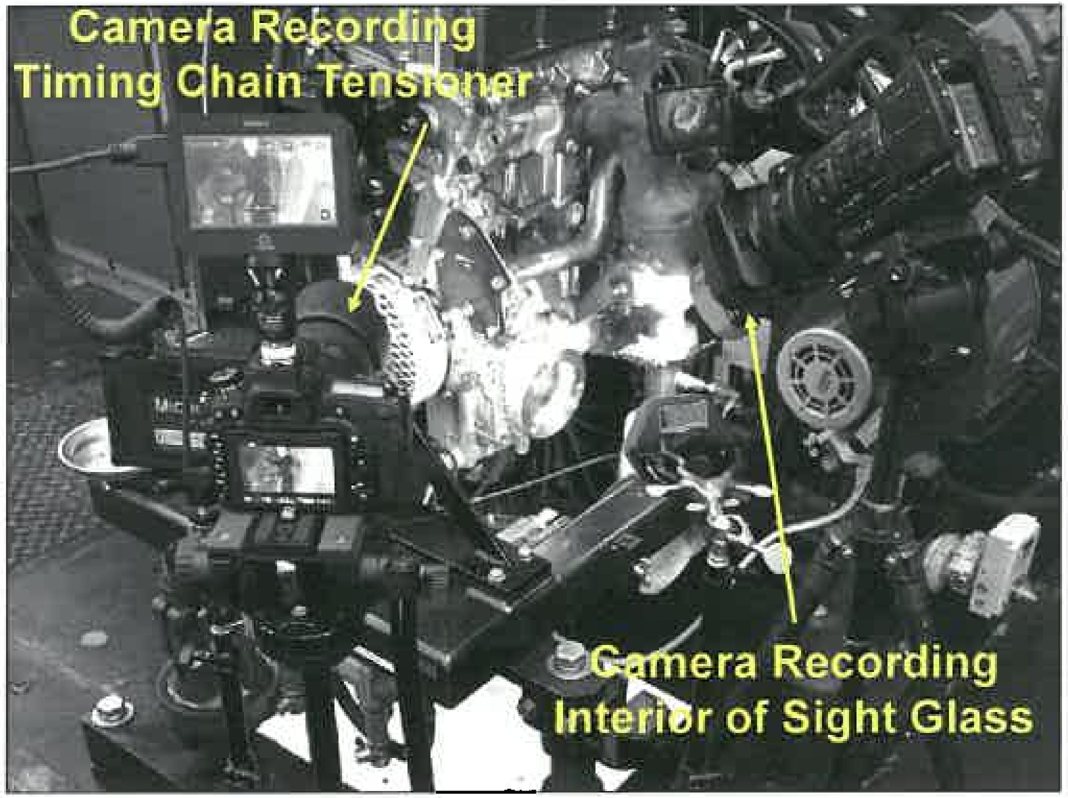
SUCCESS TOGETHER

- **Oil Pan Modification:**
  - Backlighting added to interior of oil pan
  - Light is pointed downward at the pick-up tube to prevent glare on the sight glass window.
- **Oil:** 2400mL (Ford Motorcraft)
- **Procedure:**
  - Monitor oil level as pump and external lines are primed
  - Monitor oil level as speed increased from 800→4300RPM
  - Monitor oil level as volume decreased from 2400→1400mL

Lubrizol

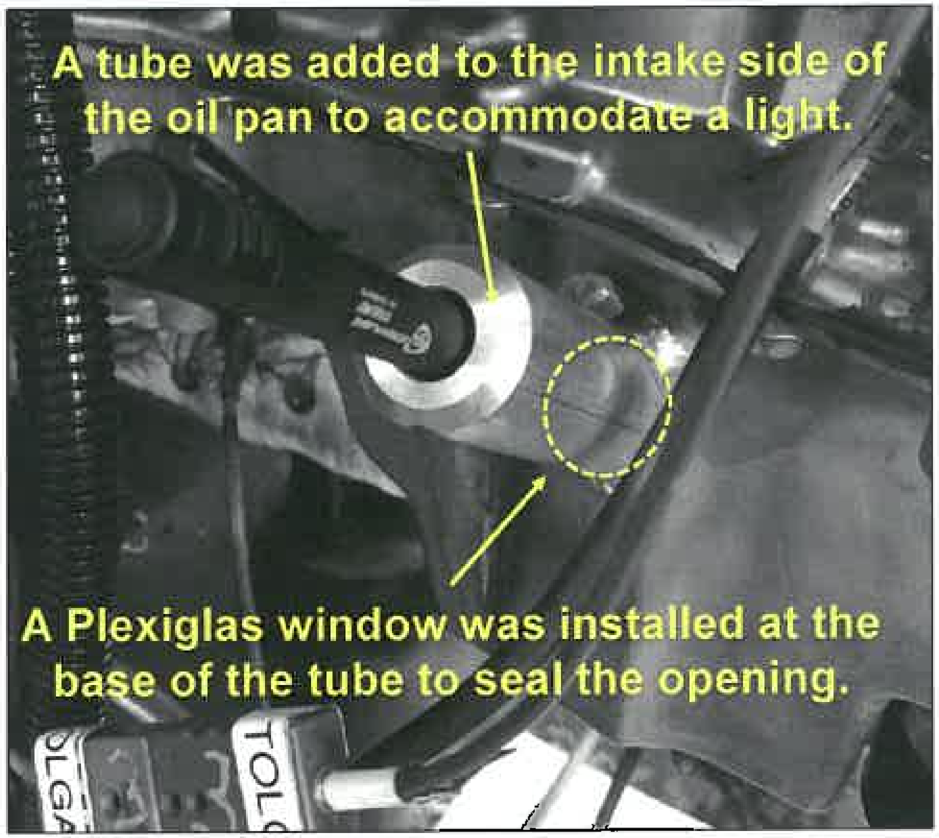
Test Set-Up

SUCCESS TOGETHER



Lubrizol

Backlighting



Lubrizol

Initial Oil Level Observations

SUCCESS TOGETHER

Oil Volume: 2400mL, **Speed:** 0RPM
External Oil System: Empty

Oil Volume: 2400mL, **Speed:** 0RPM
External Oil System: Full

Lubrizol

Steady-State Speed Sweep

SUCCESS TOGETHER

Oil Volume: 2400mL
Speed: 1000RPM

Oil Volume: 2400mL
Speed: 4300RPM

Lubrizol

Oil Volume Sweep at 2000RPM

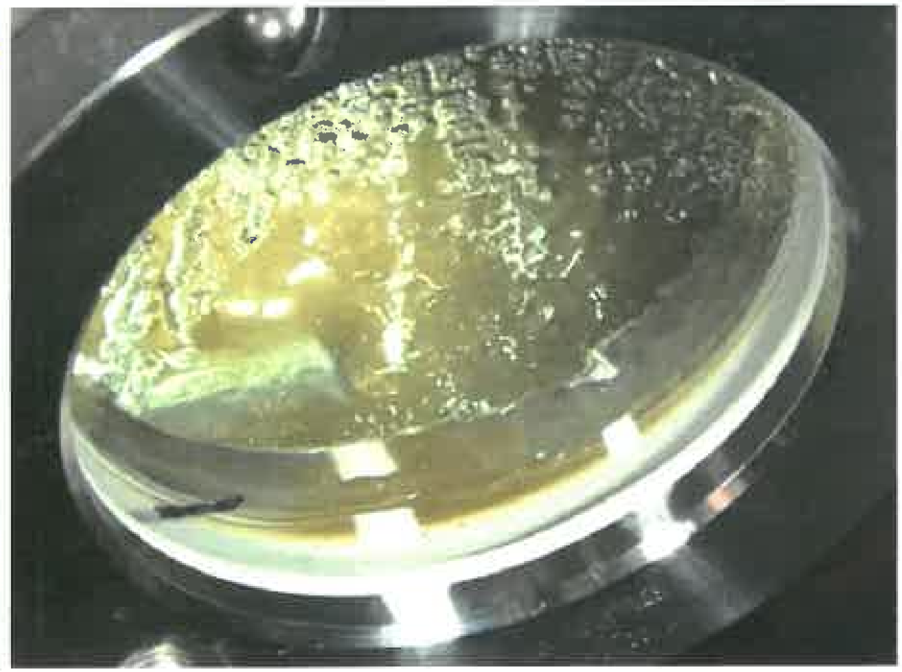
Oil Volume: 2400mL

Oil Volume: 2000mL

Oil Volume Sweep at 2000RPM (continued)

SUCCESS TOGETHER

Oil Volume: 1900mL

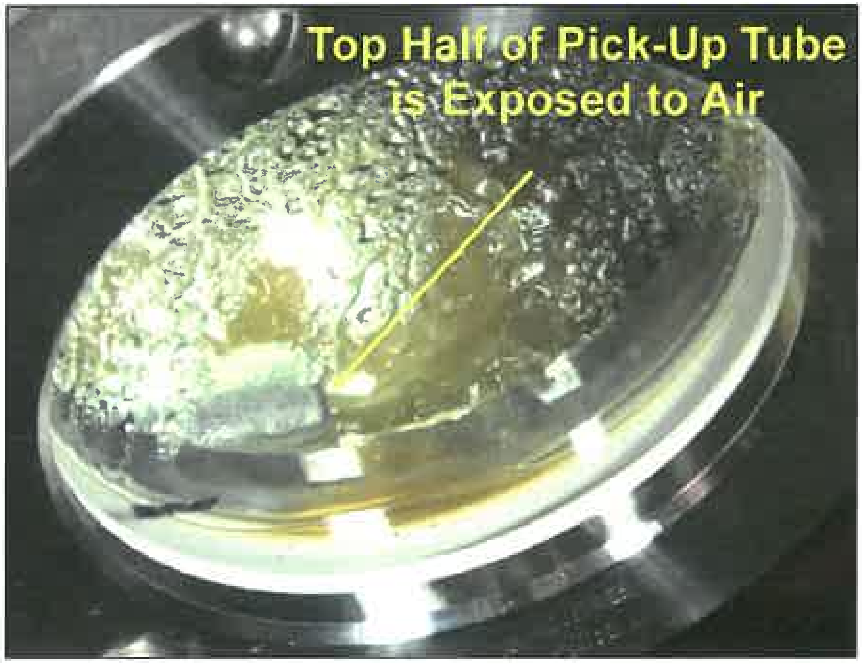


Oil Volume: 1700mL

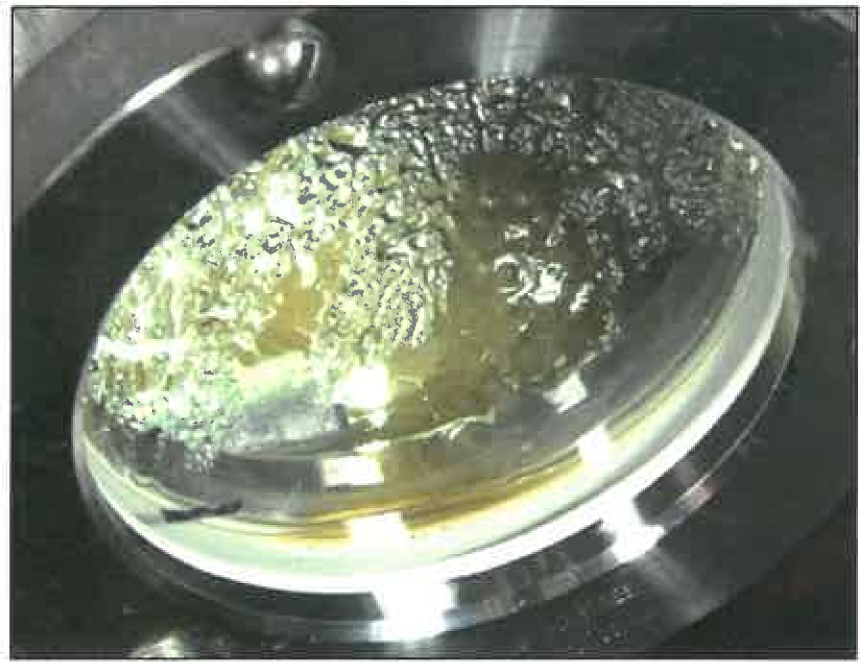
Lubrizol

Oil Volume Sweep at 2000RPM (continued)

SUCCESS TOGETHER



Oil Volume: 1500mL

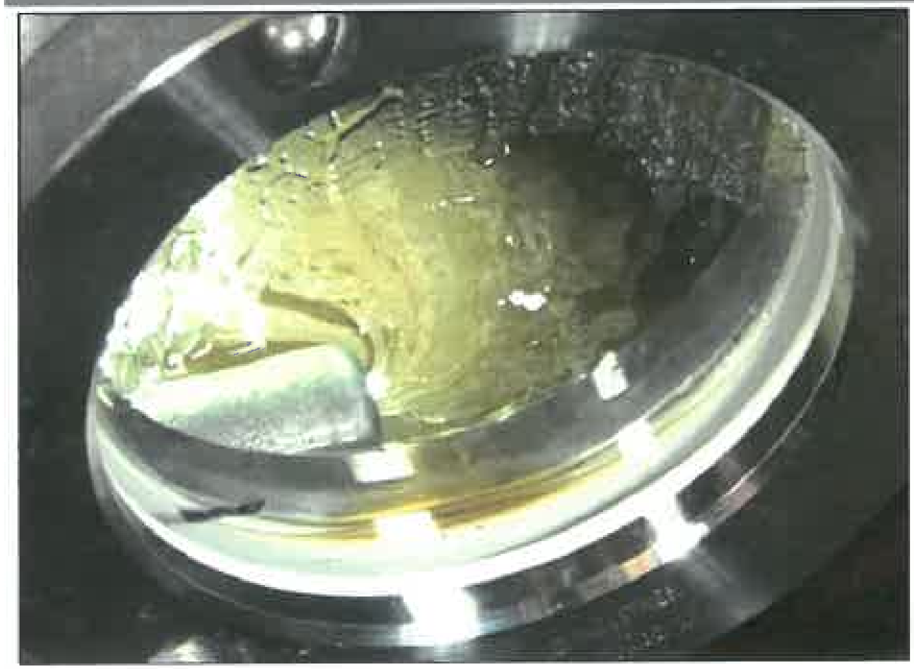


Oil Volume: 1400mL

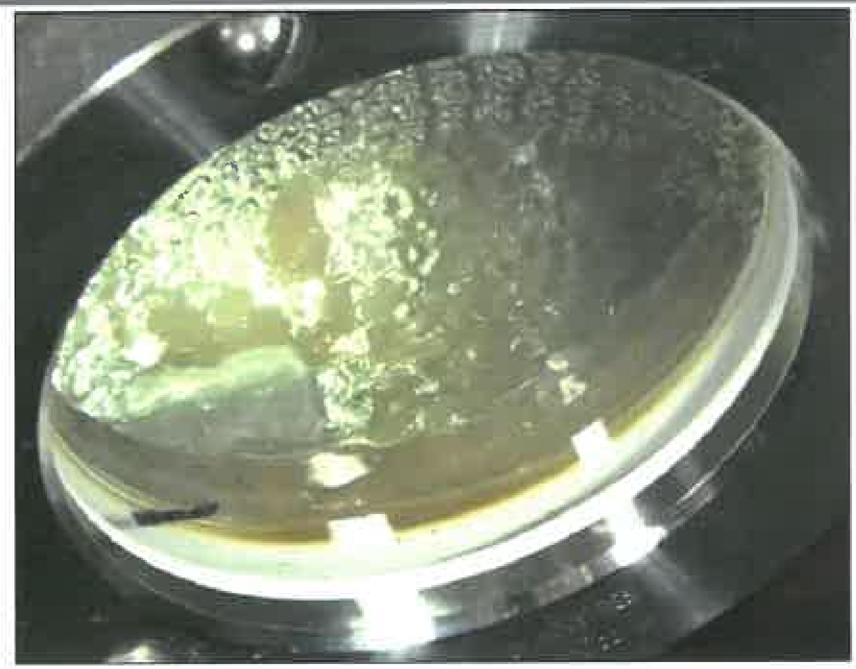
Lubrizol

Test Conditions

SUCCESS TOGETHER



Oil Volume: 1400mL
Speed: Stage 1



Oil Volume: 1400mL
Speed: Stage 2

Lubrizol

Conclusions from 06-15-2017 Trial

SUCCESS TOGETHER

- A considerable amount of the initial oil charge is used to fill the external oil system and oil passages in the engine.
- There was not a significant change in the visible oil level as the engine was accelerated from 1000 to 4300RPM.
- The oil pick-up tube broke the surface of the oil (at 2000RPM) at 500mL below the test charge.
- The oil pick-up tube became exposed to air (at 2000RPM) at 700mL below the test charge.
- Half of the oil pick-up tube was exposed to air (at 2000RPM) at 900mL below the test charge.

Lubrizol

Forward Action Plan

SUCCESS TOGETHER

- Editing is underway to synchronize the video of the timing chain tensioner with the video of the oil pan sight glass.
- Modifications to the oil pan pick-up tube are being evaluated.

Lubrizol

Calculated Volume of External Oil System

06-22-2017

Overview of 06-22-2017 Calculations

SUCCESS TOGETHER

- **Background:**
  - Lubrizol calculated the volume of oil required to fill the external oil system of the test stand.

Lubrizol

Measurements

SUCCESS TOGETHER

- **Measurements:**
  - *Hose lengths:*
    - Engine to Filter: 12-inches
    - Filter to Heat Exchanger: 10-inches
    - Heat Exchanger to Engine: 15-inches
    - **Total Hose Length:** 37-inches
  - *Hose inner diameter:*
    - ID = 0.3125-inches
  - *Measured volumes:*
    - Filter Housing: 250mL
    - Heat Exchanger (Shell): 225mL

Lubrizol

Measurements

SUCCESS TOGETHER

- **Calculations:**
  - *Volume of External Hoses:*

$$Volume\ of\ Hoses = Length \times (\pi r^2)$$
$$Volume\ of\ Hoses = 37 \times \pi \times 0.15625^2$$
$$Volume\ of\ Hoses = 2.838in^3 = 46.5cm^3 = 46.5\text{mL}$$

  - Total Volume (not including fittings):

$$Total\ Volume = 250 + 225 + 46.5 = 521.5mL$$

Lubrizol


Oil Pan Sight Glass Trials
06-26-2017

Overview of 06-26-2017 Trial

SUCCESS TOGETHER

- **Oil Pan Modification:**
  - The oil pick-up tube was modified so that the inlets are closer to the bottom of the oil pan.
- **Oil:** 2400mL (Ford Motorcraft)
- **Procedure:**
  - Monitor oil level and pressure with the new pick-up tube design as volume decreased from 2400→1400mL

Lubrizol

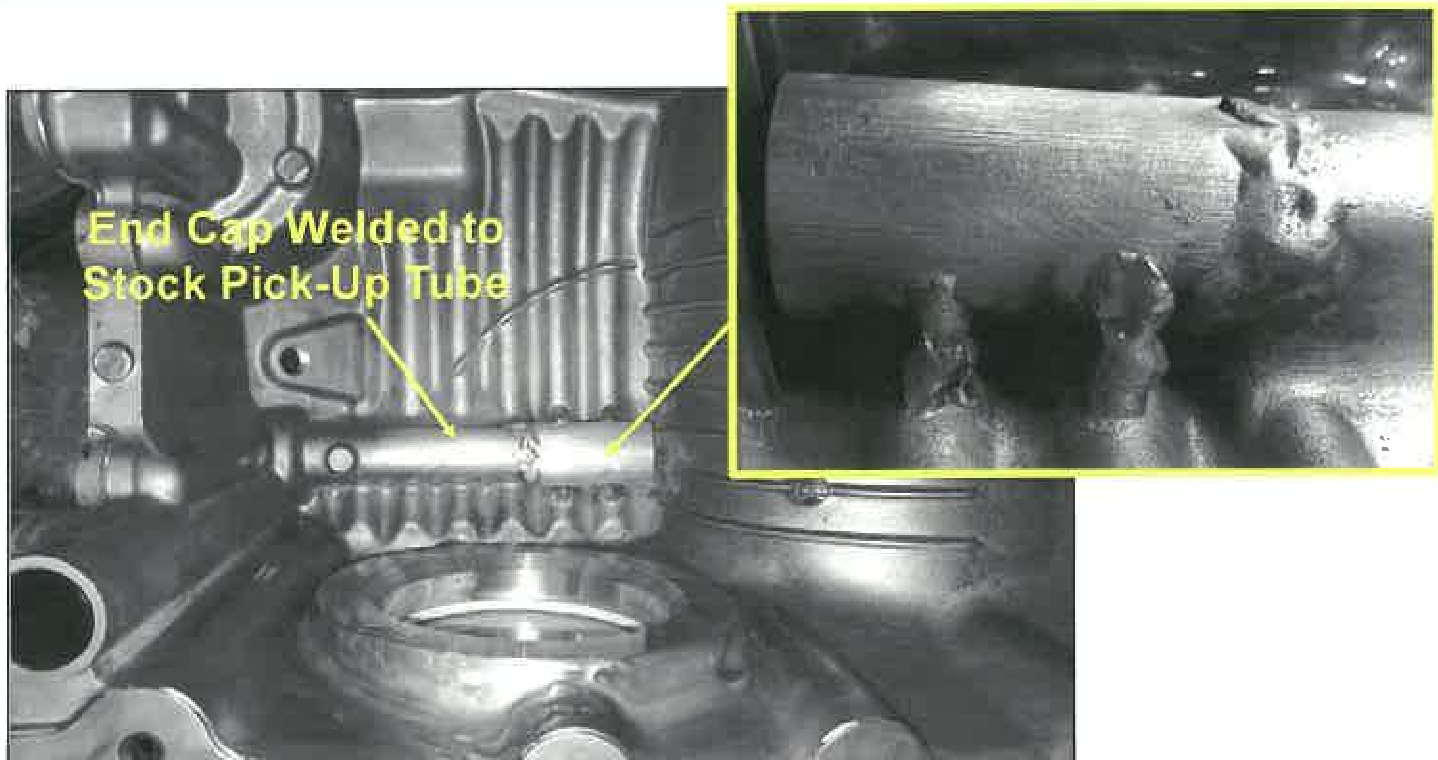
Oil Pan Modifications

- Aluminum cap was fabricated to fit on the end of the stock pick-up tube.
- This end cap forces the pick-up tube to only draw oil from the bottom of the pan.
- The overall inlet area of the end cap exceeds the inlet area of the stock pick-up tube.

Lubrizol

Oil Pan Modifications

SUCCESS TOGETHER



Lubrizol

Oil Volume Sweep at 2000RPM

SUCCESS TOGETHER

Oil Volume: 2400mL
Modified Pick-Up Tube

Oil Volume: 2000mL
Modified Pick-Up Tube

Lubrizol

Oil Volume Sweep at 2000RPM

SUCCESS TOGETHER

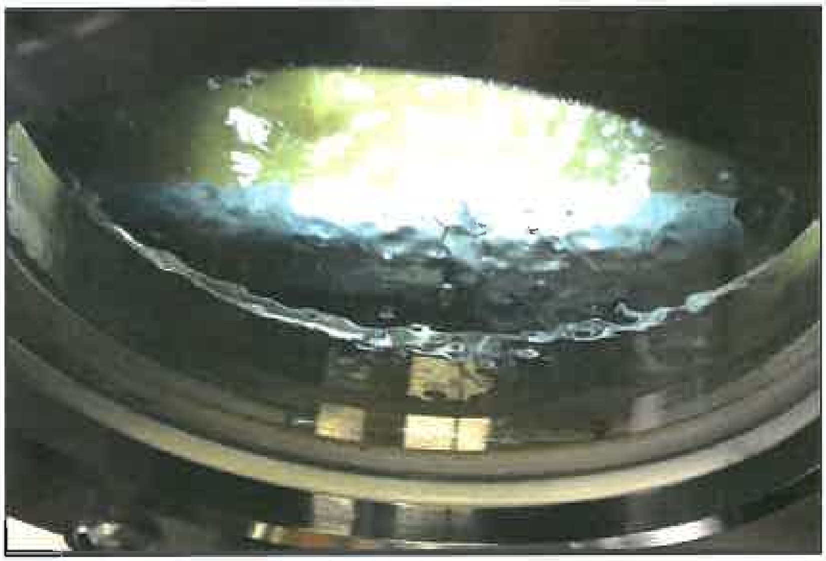
Oil Volume: 1900mL
Modified Pick-Up Tube

Oil Volume: 1700mL
Modified Pick-Up Tube

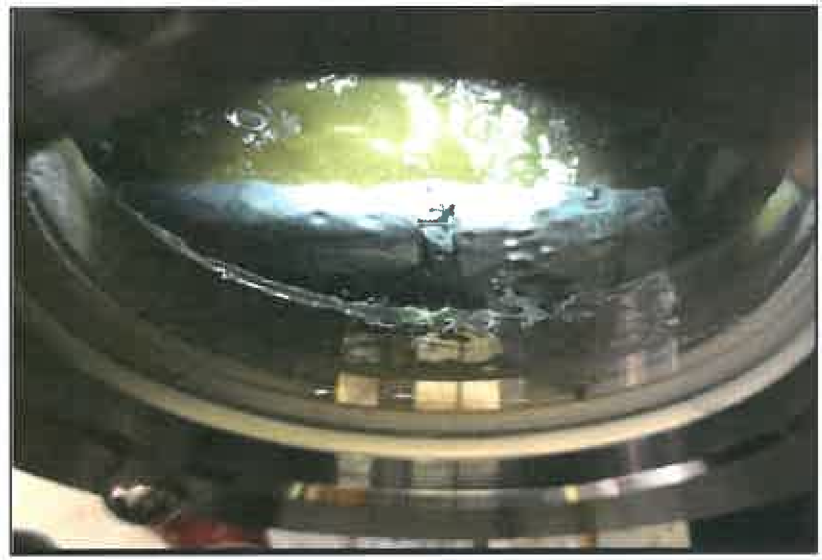
Lubrizol

Oil Volume Sweep at 2000RPM

SUCCESS TOGETHER



Oil Volume: **1500mL**
Modified Pick-Up Tube

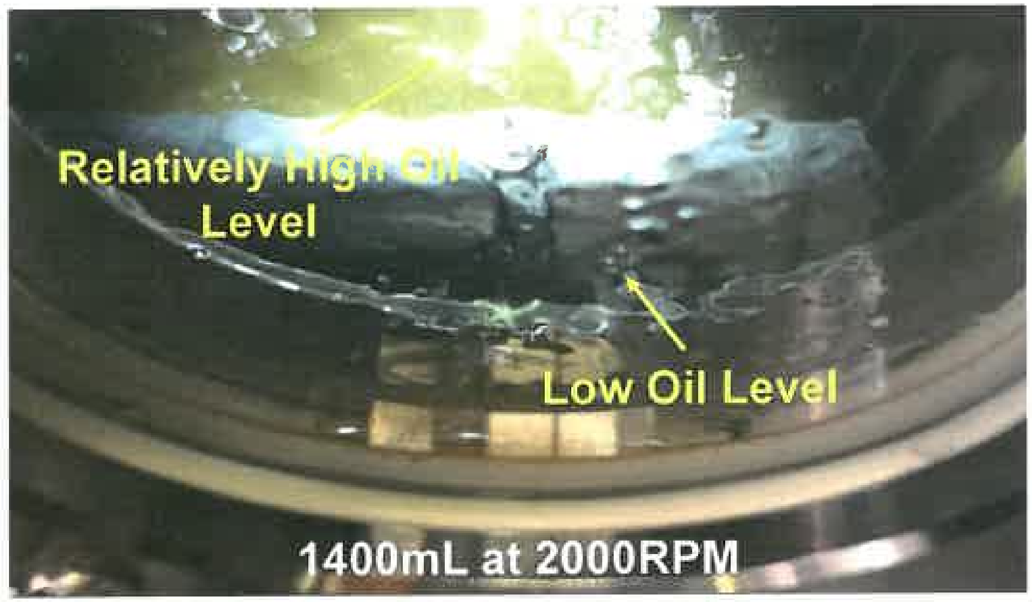


Oil Volume: **1400mL**
Modified Pick-Up Tube

Lubrizol

Oil Level (Close-Up)

- Unfortunately, the longer overall length of the modified pick-up tube is behaving like an oil dam when the oil level is low.
- The exhaust-side opening of the modified pick-up tube is draining the exhaust-side of the pan.



Bubbles in 100mL Oil Samples

SUCCESS TOGETHER

2300mL Sample → 1400mL Sample

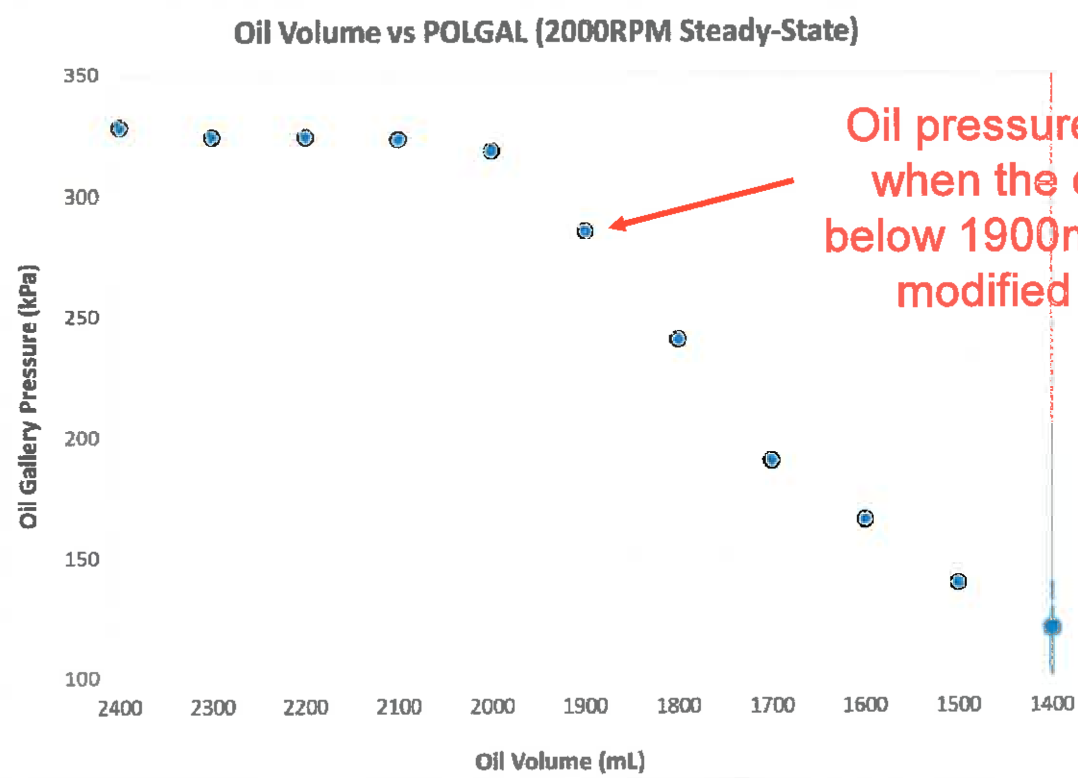
Increasing Amount of Foam in Oil Samples

- The modified pick-up tube reduced the amount of foam in the oil samples… but did not eliminate it.
- It is possible that the design of the oil sample valve is contributing to the foaming.

Lubrizol

Oil Pressure vs. Oil Volume

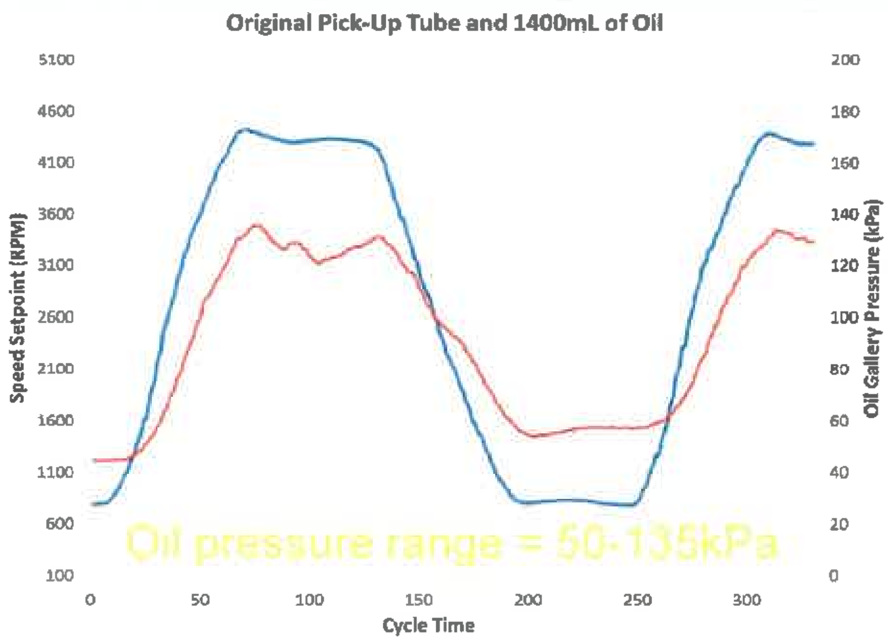
SUCCESS TOGETHER

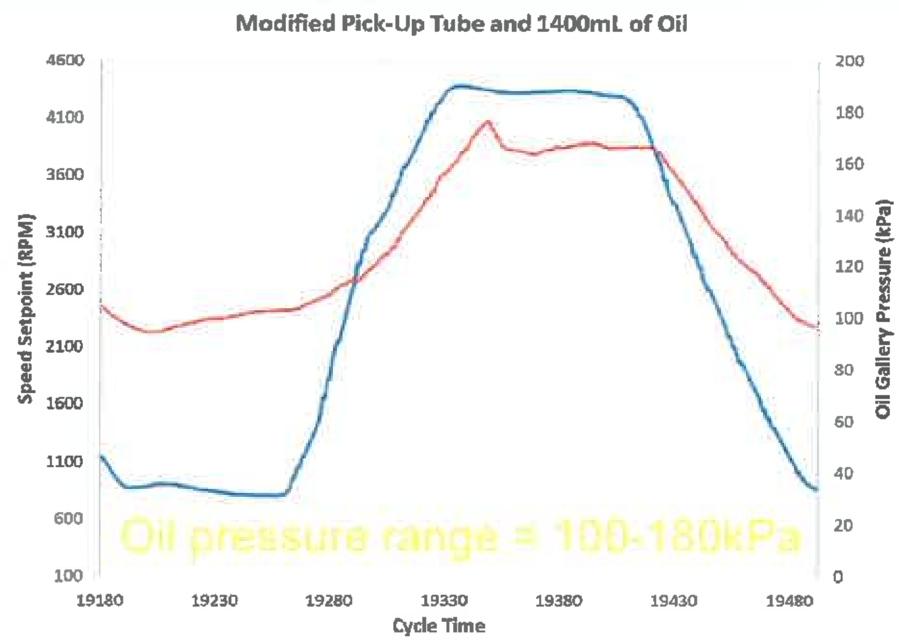


Oil pressure begins to drop when the oil volume falls below 1900mL (even with the modified pick-up tube)

Lubrizol

Oil Pressure, Stock vs. Modified Pick-Up





- The modified pick-up tube <u>significantly</u> improved oil pressure under test conditions when the oil volume is extremely low (~1400mL).

Lubrizol

Conclusions from 06-26-2017 Trial

SUCCESS TOGETHER

- The modified oil pick-up tube significantly improved oil pressure at low oil volumes.
- The modified oil pick-up tube appears to have decreased the amount of oil in the pan when the engine is running.
  - The pump is ingesting less air, so there is significantly more oil flowing through the top of the engine.
- Unfortunately, the modified oil pick-up tube can act as a dam when the oil level in the pan is extremely low.
  - When this occurs, the exhaust side of the pick-up tube may still be ingesting air.

Lubrizol

Forward Action Plan

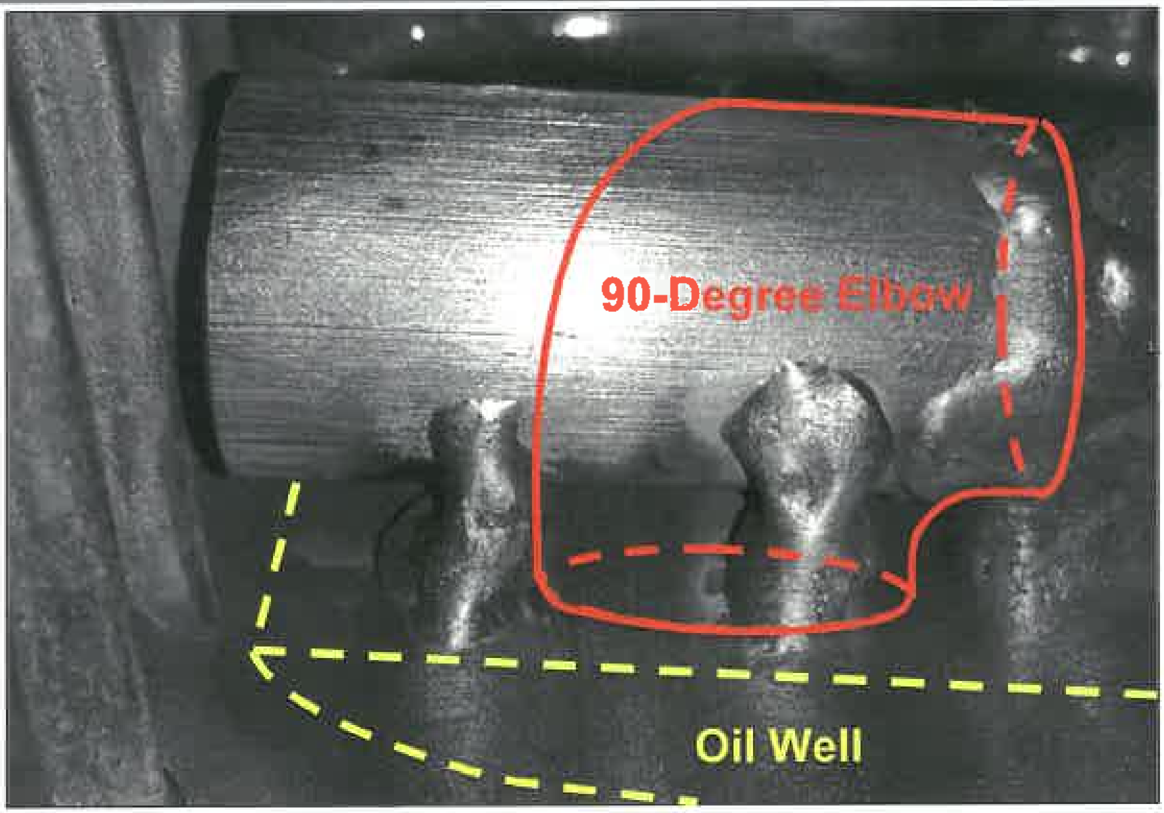
SUCCESS TOGETHER

- Lubrizol is going to remove the extension from the pick-up tube.
- The bottom of the oil pan will be modified with a small oil well underneath the pick-up tube.
- The original pick-up tube will be modified with a 90-degree downward extension that will pull oil from the well.

Lubrizol

Oil Pick-Up Tube Modifications – Round 2

SUCCESS TOGETHER



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Overview of 06-26-2017 Trial

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- **Oil Pan Modification:**
  - A 2nd modification to the oil pick-up tube was evaluated.
  - The inlet to the pick-up tube was redirected to point downward.
  - A small circular well was added below the pick-up tube.
- **Oil:** 2400mL (Ford Motorcraft)
- **Procedure:**
  - Monitor oil level and pressure with the 2nd pick-up tube design as volume decreased from 2400→1400mL

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Oil Pan Modifications – Round 2

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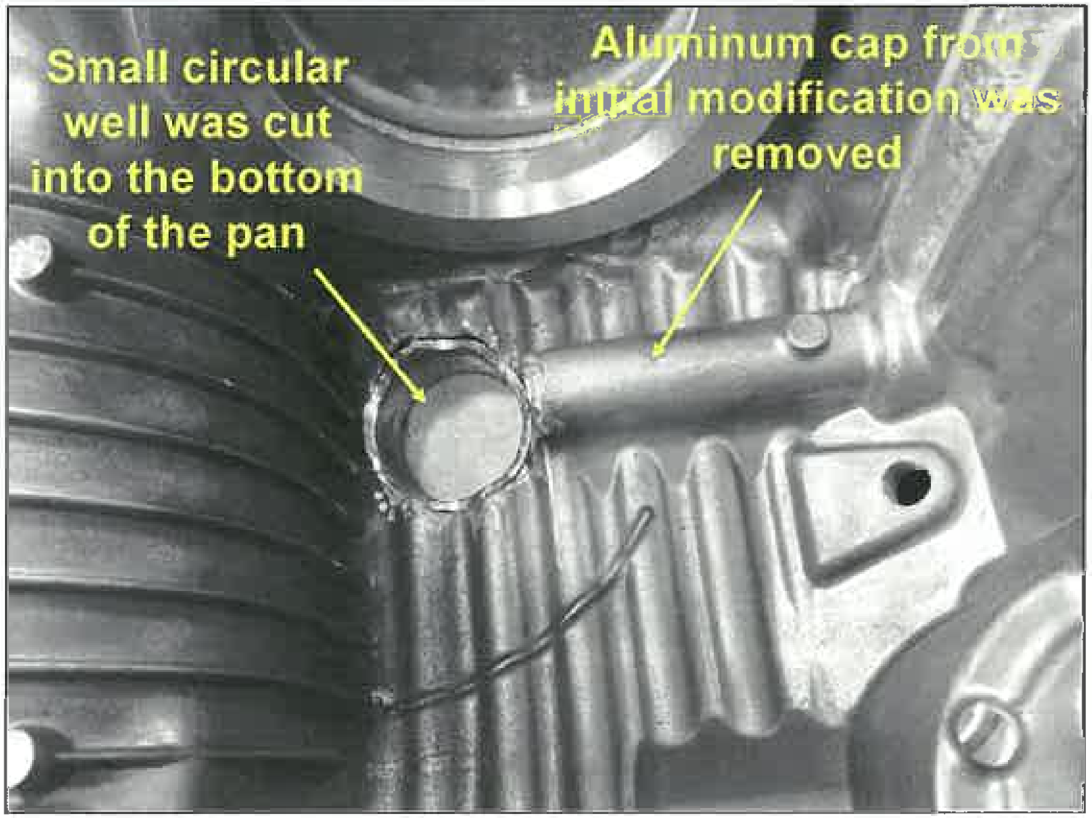

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Oil Pan Modifications – Round 2

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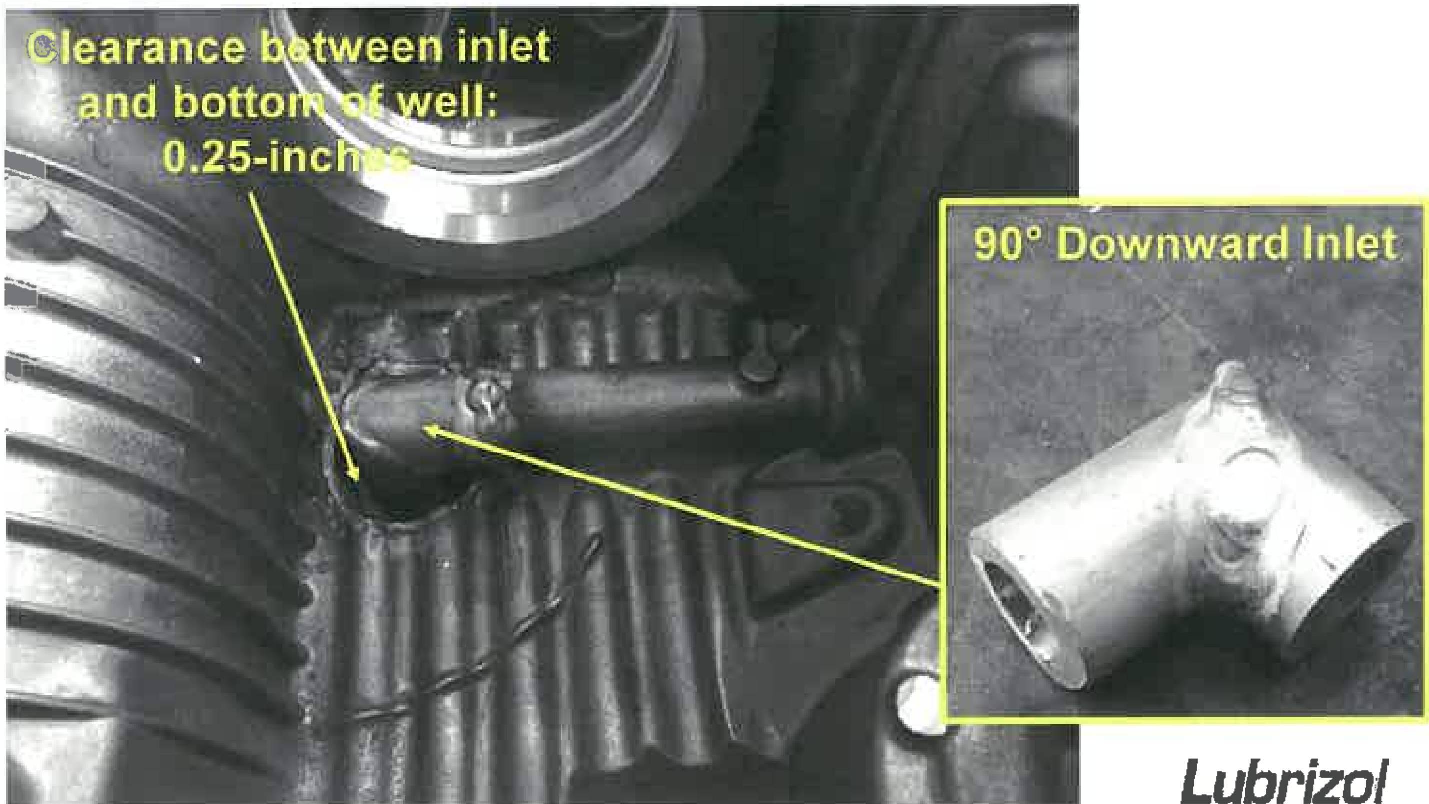

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Oil Volume Sweep at 2000RPM

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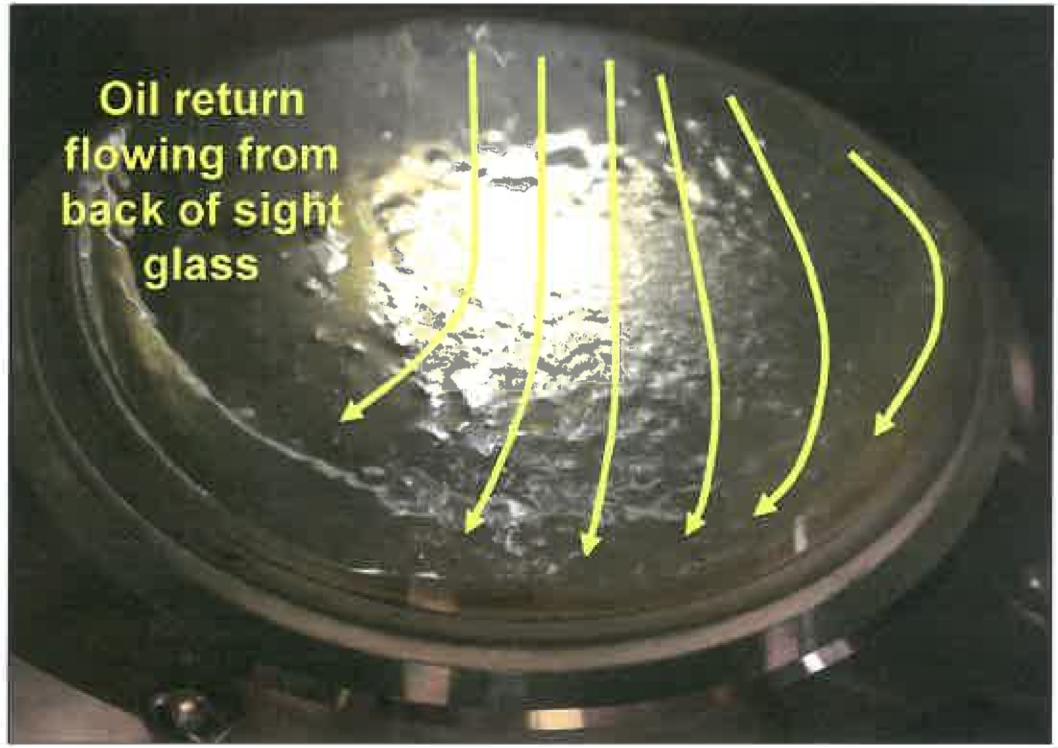
- This pick-up tube redesign is definitely pumping more oil to the top of the engine.
- The downside is that significantly more oil is draining past the sight glass – which is obstructing visibility.
- This trial was completed at 2000RPM to generate data for comparison to the previous trials.
- The trial will need to be repeated at a lower RPM to adequately image the pick-up tube.



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Oil Pressure vs. Oil Volume

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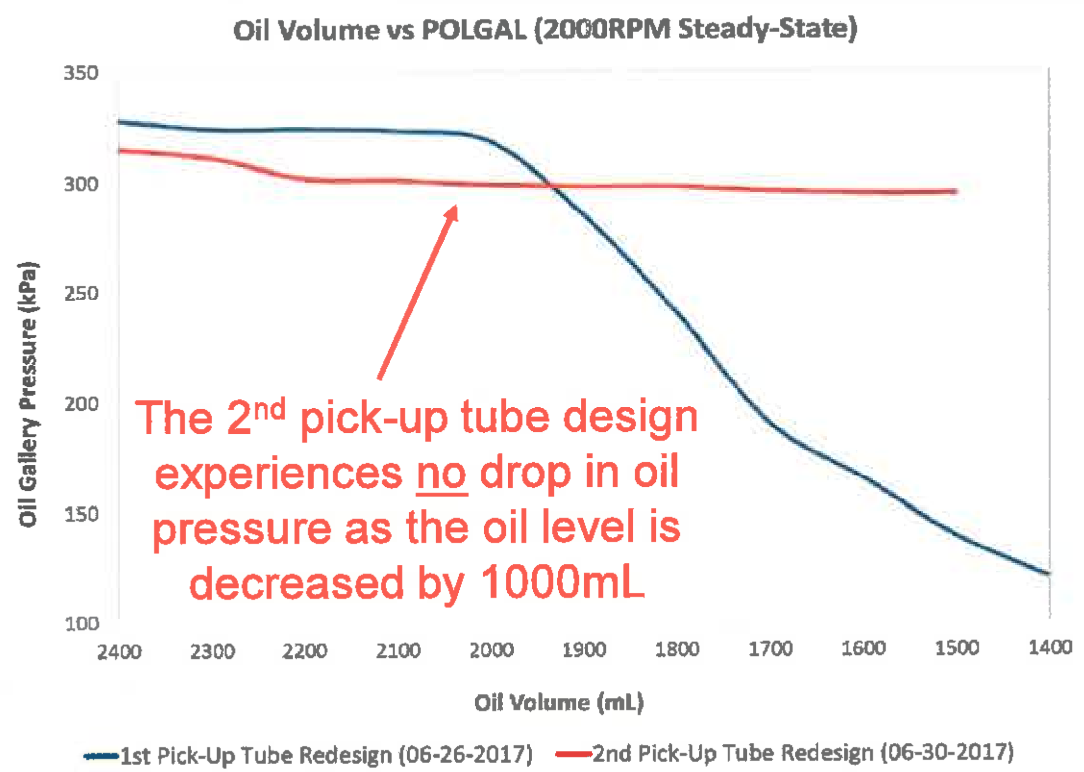

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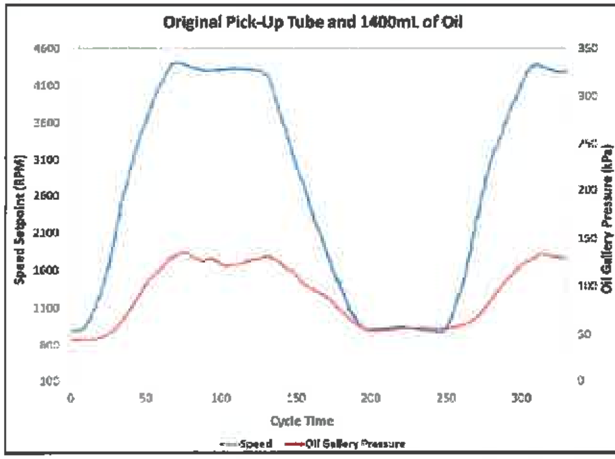
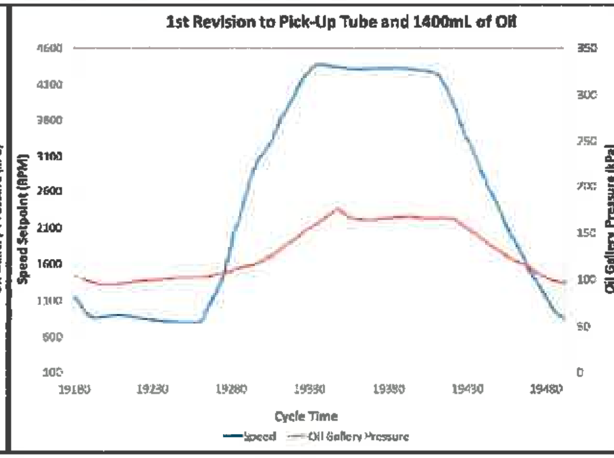
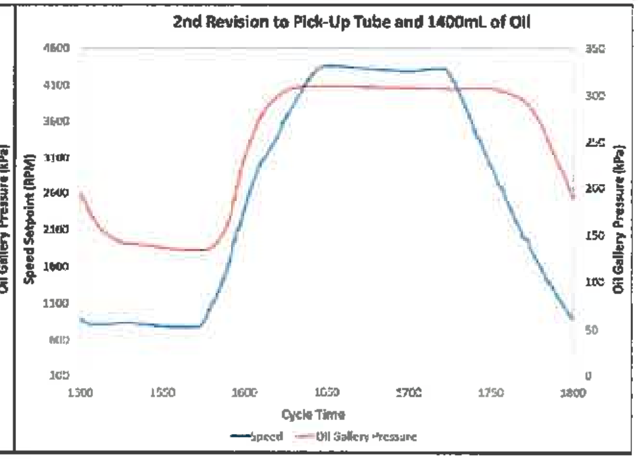
Oil Pressure, Stock vs. Modified Pick-Up







- The 2nd revision to the oil pick-up tube allows the engine to maintain excellent oil pressure over the entire test cycle, even when the oil volume is extremely low.
- **Oil pressure, original configuration and 1400mL:** 50-135kPa
- **Oil pressure, 1st revision and 1400mL:** 100-180kPa
- **Oil pressure, 2nd revision and 1400mL:** 130-300kPa

Conclusions from 06-30-2017 Trial

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- The 2nd modification to the oil pick-up tube (circular well and 90° elbow) allows the engine to maintain oil pressure at extremely low oil volumes.

- There is no longer any indication that the oil pump is ingesting air.

- There appears to be an improved volume of oil flow to the top of the engine.

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Forward Action Plan

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- The 06-30-2017 trial was intended to validate the concept of using an oil well in conjunction with a 90° elbow on the pick-up tube.
- Another trial will need to be conducted at a lower engine speed so that the oil pick-up tube can be videotaped more clearly.
- Lubrizol plans to evaluate a different oil sample valve on the Golden Stand.
  - The current valve appears to be contributing to foam in the oil sample (which makes it impossible to adequately measure the sample volume).

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Forward Action Plan

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- One or two other laboratories will need to repeat the latest Lubrizol trial to confirm the results.

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Revision Log

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Revision	Initials	Date	Description
0	CHTM	06-12-2017	Oil pan dipstick calibration.
1	CHTM	06-13-2017	Scoping trials to determine how to optimize conditions for filming.
2	CHTM	06-15-2017	Full video trial conducted to evaluate speed sweep and oil volume changes.
3	CHTM	06-27-2017	Added calculations for volume of external oil system. Reviewed scoping trials with modified oil pick-up tube.
4	CHTM	07-02-2017	Reviewed scoping trial with 2nd modified oil pick-up tube.
5	CHTM	07-03-3027	Added additional results from 2nd modified oil pick-up tube trial.

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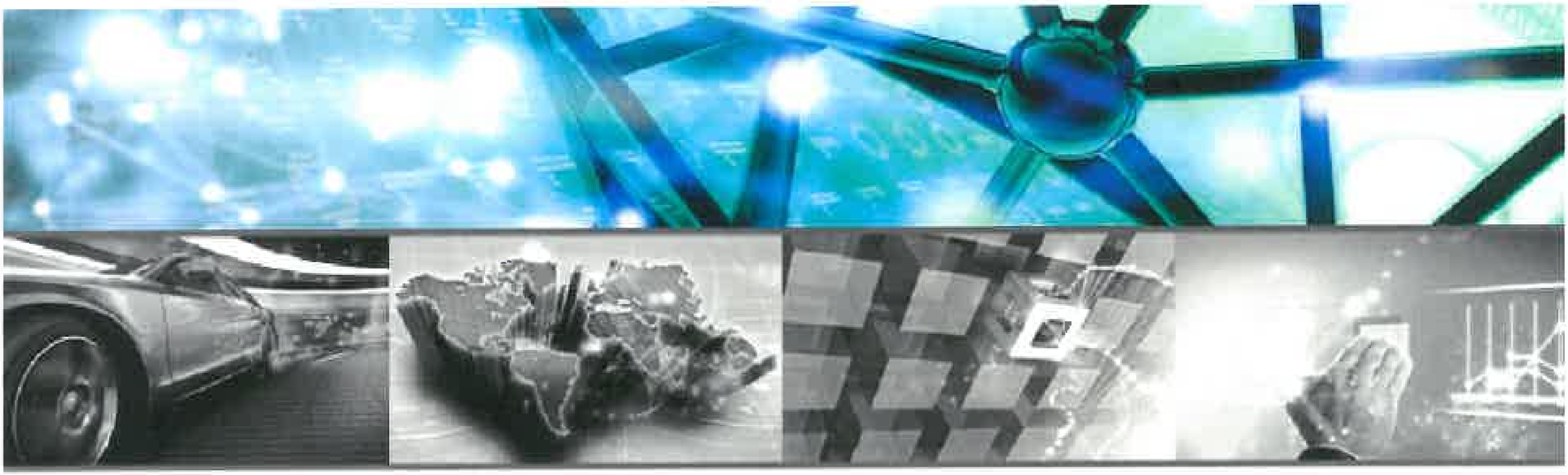

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Working together, achieving great things

When your company and ours combine energies, great things can happen. You bring ideas, challenges and opportunities. We'll bring powerful additive and market expertise, unmatched testing capabilities, integrated global supply and an independent approach to help you differentiate and succeed.

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IVB SwRI
July 12, 2017 Update

SOUTHWEST RESEARCH INSTITUTE®

Khaled Rais

Sequence IVB Oil Separator Tests

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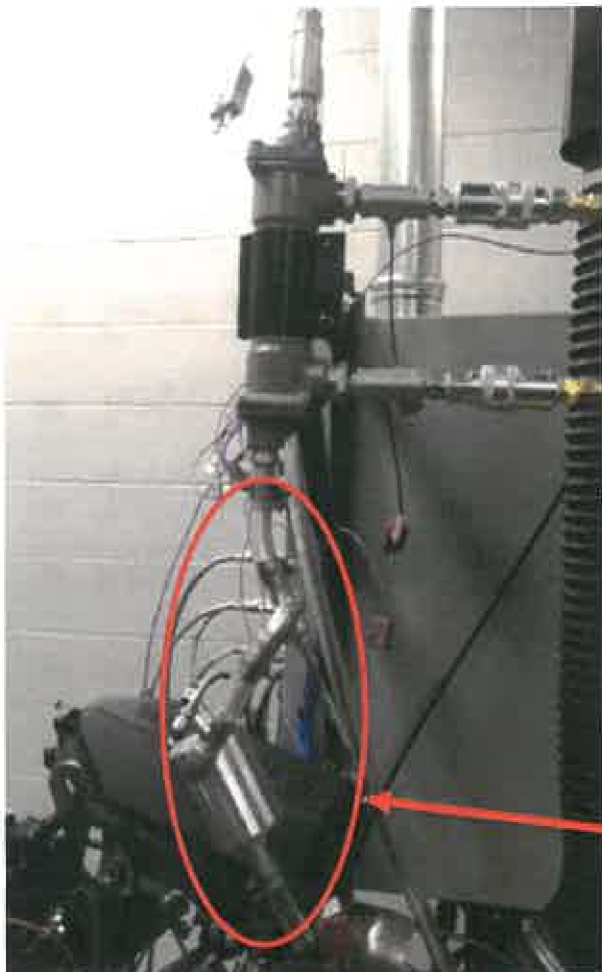
Khaled Rais

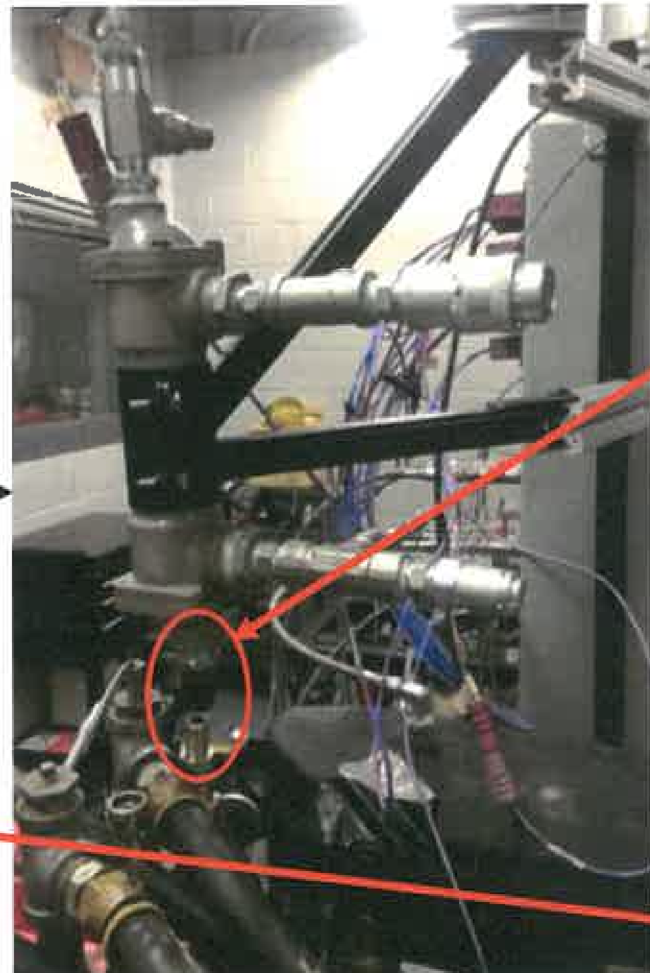
Overview of Testing

- Two 100 hour tests on the same set of used hardware
  - Hardware was previously used for a 200 hour low wear prove-out test
- 185 ppm sulfur fuel batch
- Oil REO 300
- New charge at the start of each tests with standard flushing a 2400 ml test charge
- Test 20-0-50 with separator
- Test 20-0-51 without separator (mounting bracket flipped to bring heat exchanger close to the valve cover)
- 29 °C blow-by temperature
- New TCO control setpoint (52 °C)

Blow-by System Comparison



Test 20-0-50

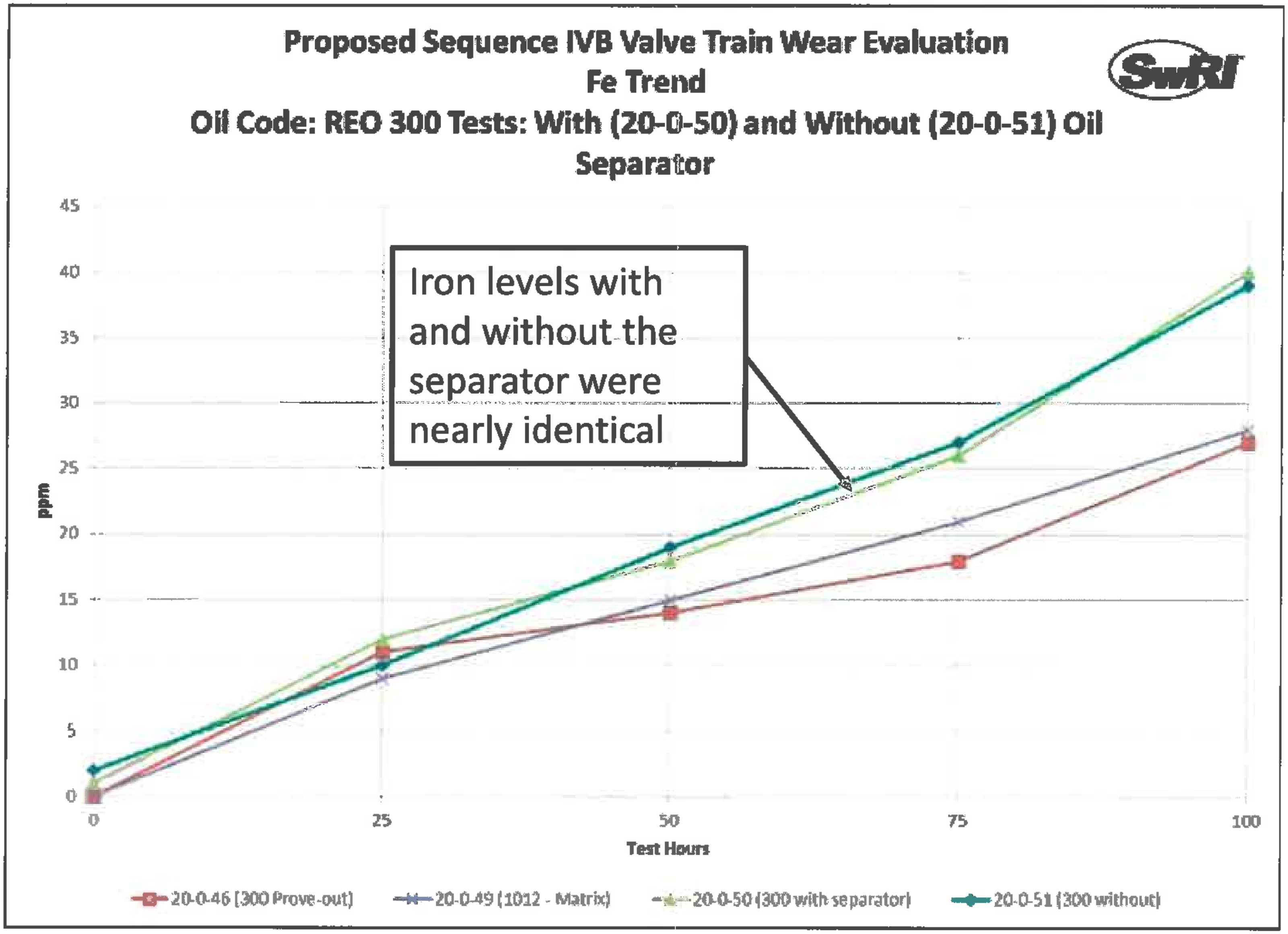


Test 20-0-51

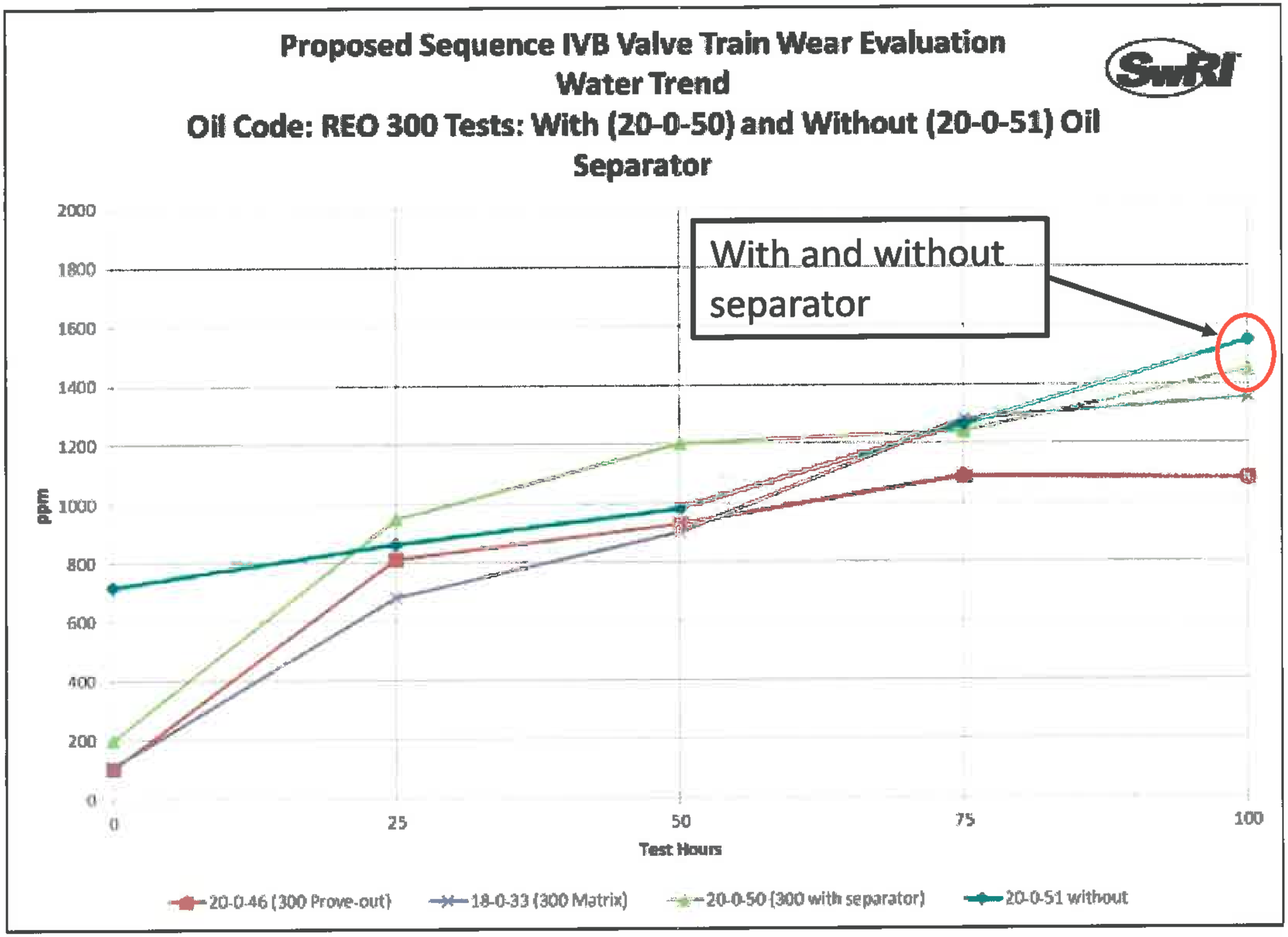
Flipped and extended the heat exchanger support bracket to bring the exit of the valve cover as close to the entrance of the heat exchanger as possible.

This region for potential condensation is eliminated

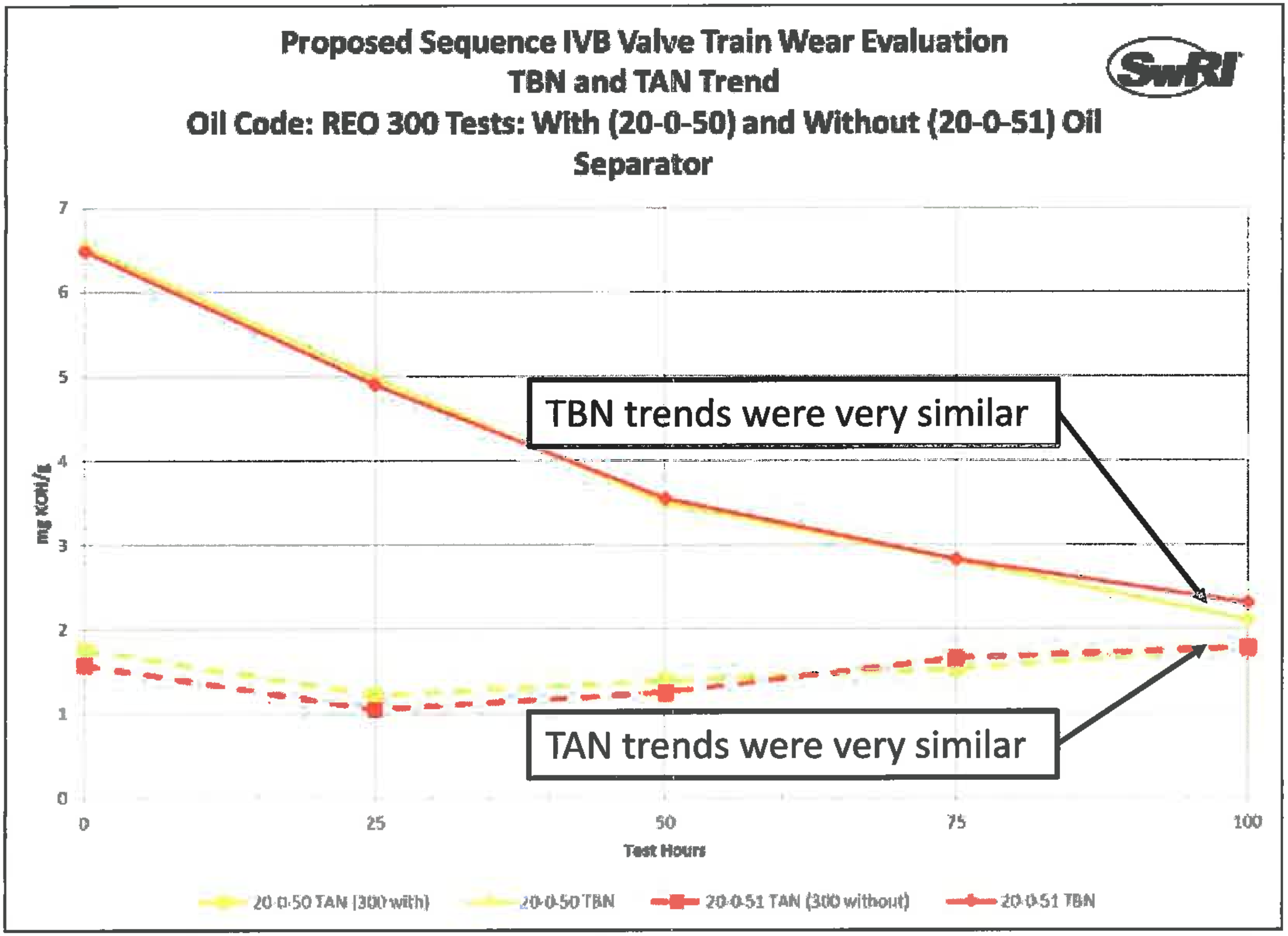
Iron Comparison



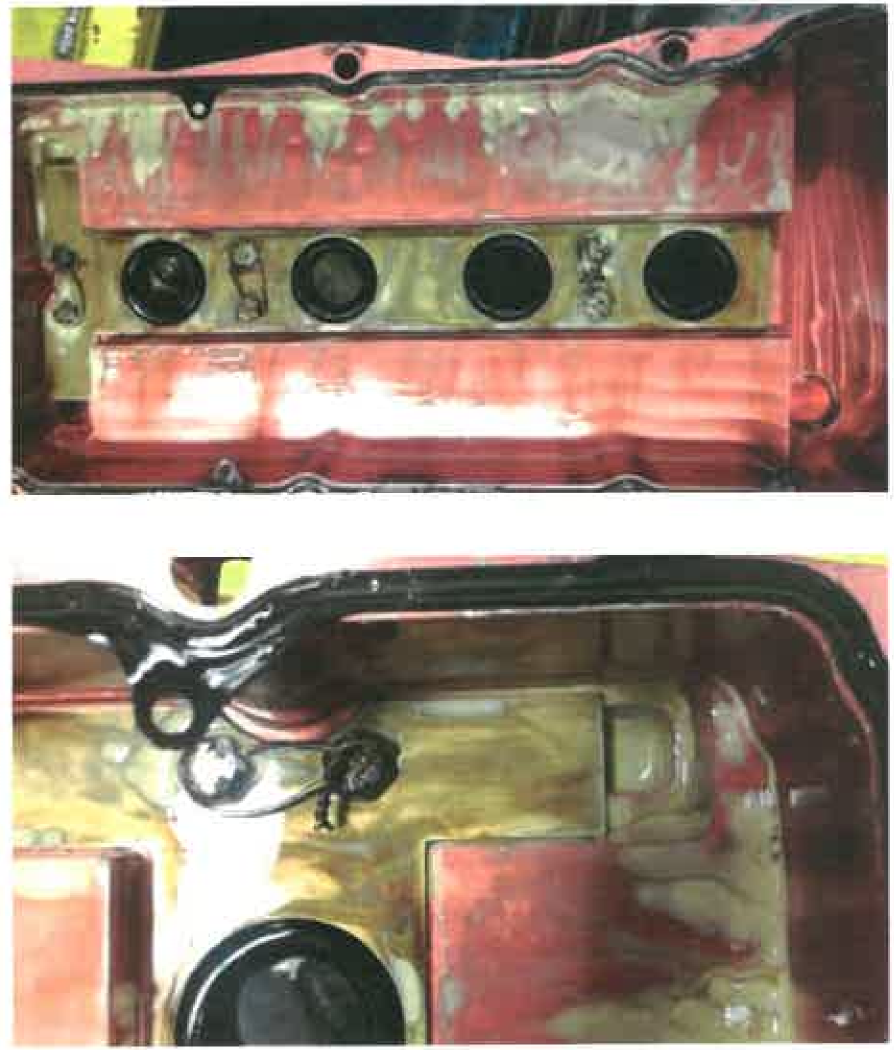
Water Comparison



TAN-TBN Comparison



54 Hours Emulsion Comparison



With Separator

Without Separator

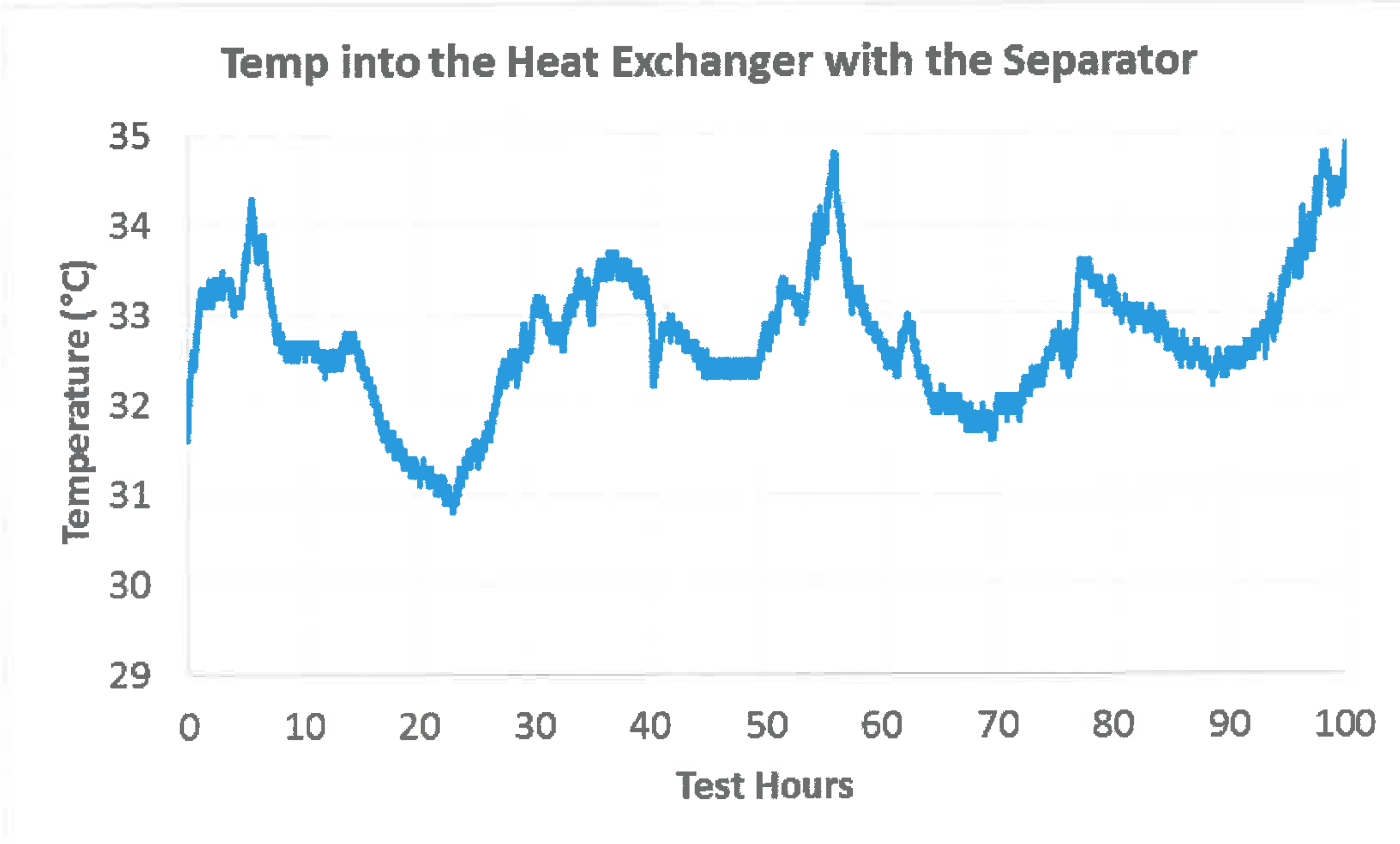
100 Hours Emulsion Comparison

With Separator

Without Separator

20-0-50 Blow-by Temp into the Heat Exchanger

With Separator Average = 32.7 °C

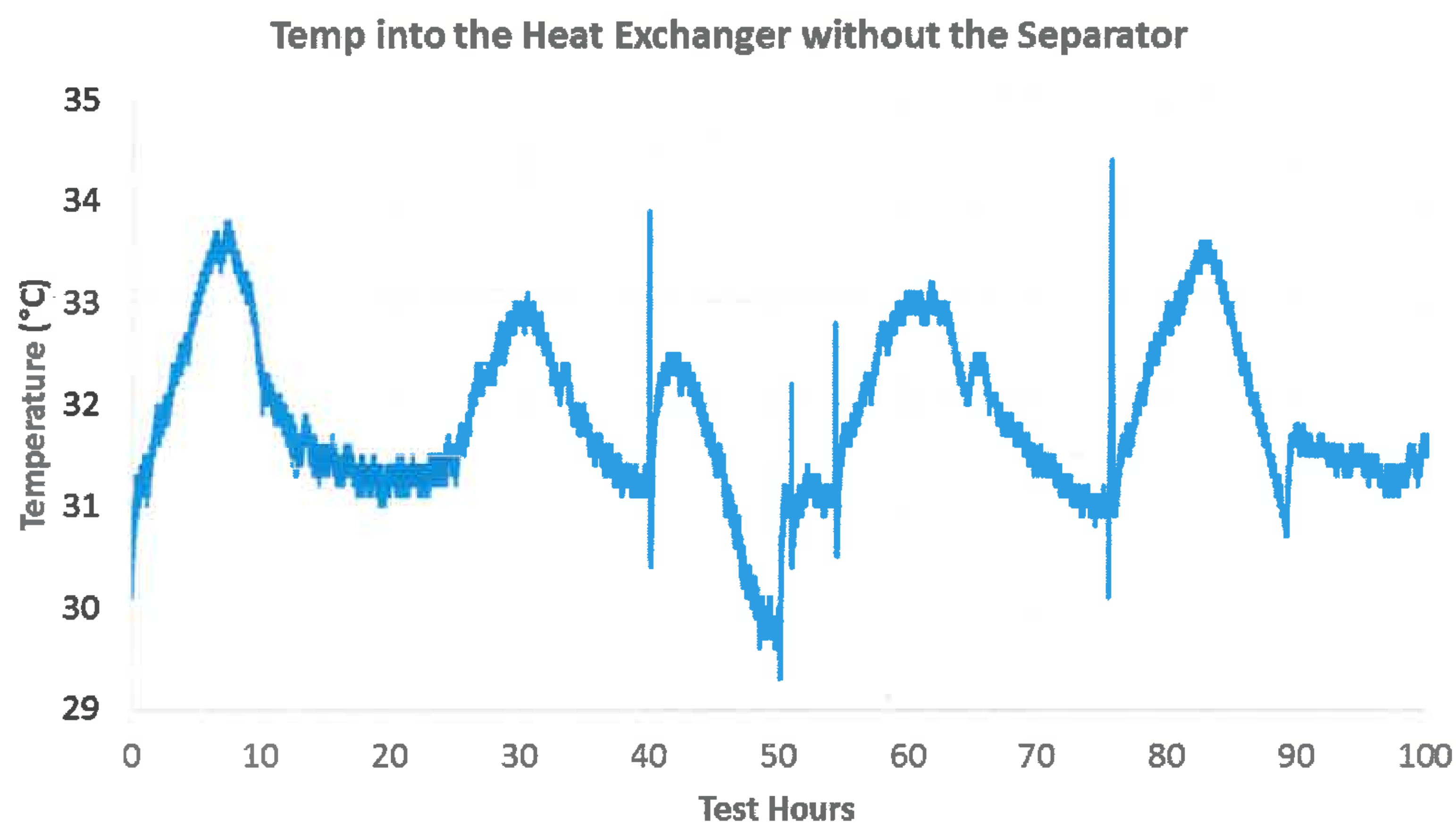


Ambient Average Temp = 31.3 °C, Min = 28.5 °C

(Despite the room being heated and testing during the summer in San Antonio)

20-0-51 Blow-by Temp into the Heat Exchanger

Without Separator Average = 31.9 °C



Ambient Average Temp = 31.9 °C, Min = 29.3 °C

Conclusions

- No significant difference in oil iron content, water content, or TAN-TBN data during tests with and without the separator.
- No significant difference in emulsion visible on the valve deck during the tests.
- No significant difference in temperature of the blow-by entering the heat exchanger between tests but there is intra-test variation which indicates an ambient effect that could lead to lab to lab and seasonal variability.
  - Therefore, SwRI recommends removing the oil separator as it eliminates this possibility and preliminary results from these tests indicate that it doesn't have other side effects.

KA24E Batch Effect on Fuel Dilution

SOUTHWEST RESEARCH INSTITUTE®

Khaled Rais

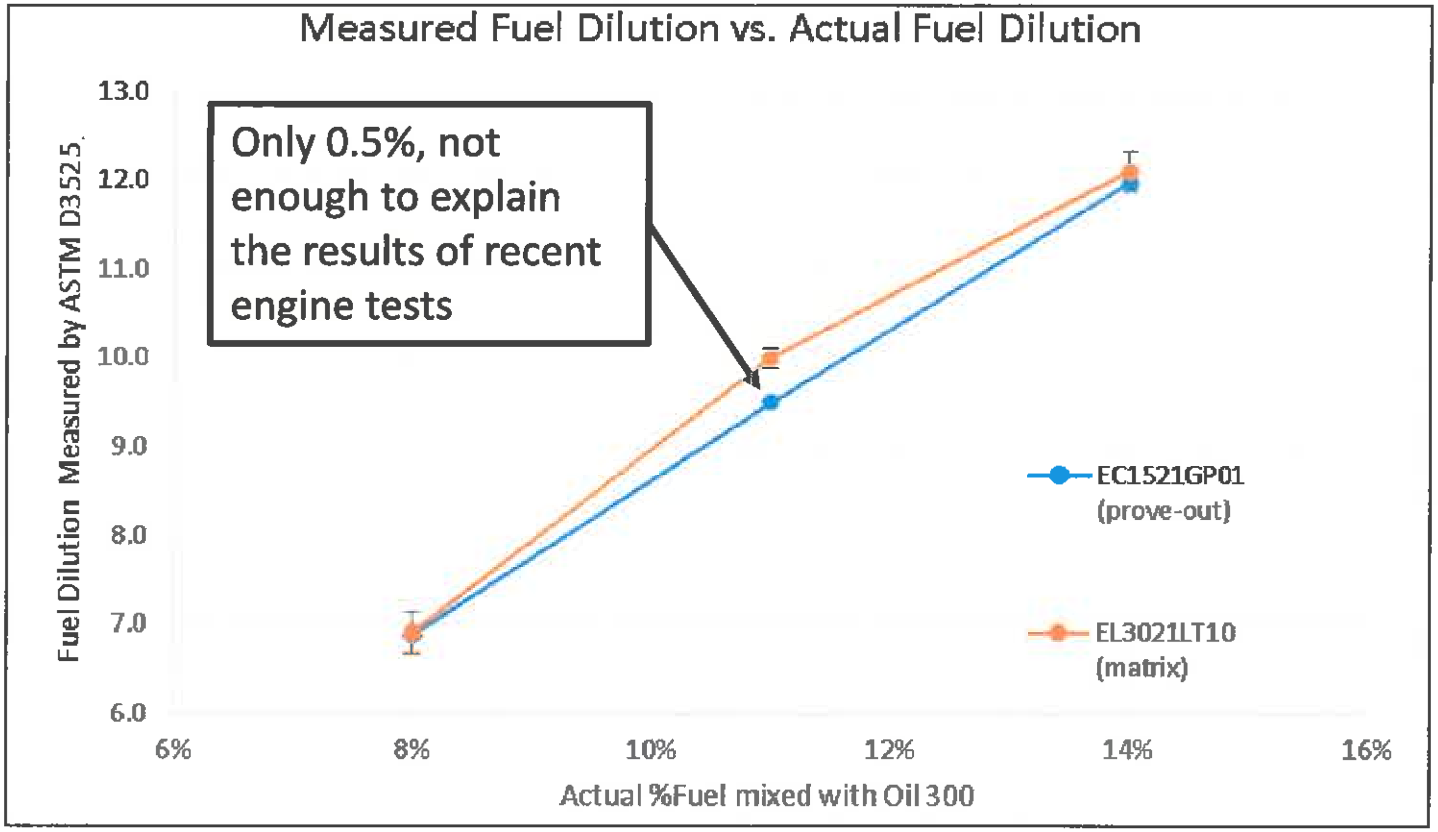
Fuel Dilution Difference Study

- Fuel dilution differences have been witnessed at SwRI and IAR.

EOT Fuel Dilution %	EC1521GP01	EL3021LT10
Oil 300	8.1	9.4
Oil 1012	7.5	8.6

- One possibility is that the ASTM D3525 method does not detect the hydrocarbons that change between fuel batches equally effectively.
- To test this theory, 8%, 11%, and 14% mixtures of fuel in oil 300 were made with two KA24E batches, EC1521GP01 (SwRI prove-out) and EL3021LT10 (matrix).
- ASTM D3525 was performed 3 times on each EC1521GP01 mixture and once on each EL3021LT10 mixture.

ASTM D3525 Experiment Results



- If it isn't a measurement issue, could fuel volatility differences be affecting fuel-oil mixing? Would new fuel requirements (RVP?) be appropriate?

From: Bill Buscher Intertek

To: Alfonso Lopez Intertek; "Lang, Patrick M."; "Clark, Sidney L."; "SATOSHI HIRANO"; "Teri Kowalski (TEMA TTC)"; "lindenjim@jlindenconsulting.com"; "t-sagawa@mail.nissan.co.jp"; "stephen.fields@nissan-usa.com"; "Romano, Ron (R.)"; "Tang Haiying (FCA) (haiying.tang@fcagroup.com)"; "Jeff Betz"; "Mark Sutherland"; "Dan Lanctot"; "dhbowden@ohtech.com"; "Jason Bowden (jhbowden@OHTech.com)"; "Matthew Bowden"; "fmf@astmtmc.cmu.edu"; "jac@astmtmc.cmu.edu"; "Rich Grundza"; "Rieth, Ryan"; "Ritchie, Andrew"; "Farnsworth, Gordon"; "Kaustav <Kaustav. Sinha@chevron. com> Sinha"; "Ed.Altman@aftonchemical.com"; "Bob.Campbell@aftonchemical.com"; "Brys, Jerome"; "tlcaudill@valvoline.com"; "Scott.Lindholm@shell.com"; "Jeff Hsu"; "Hapithom@aol.com"; "BuschWA@aol.com"; "Mike McMillan"; "Chris Castanien (Chris.Castanien@nesteoil.com)"; "Amol Savant"; "Kevin.OMalley@lubrizol.com"; "ray.seiz@infineum.com"; Martin Chadwick Intertek; "Dvorak, Todd"; "Martinez, Jo G. (jogm)"; "Doyle Boese"; "Affinito, Ricardo E"; "Lochte, Michael D."; "Stockwell, Robert T"; "Mileti, Christopher"; "Meryn.hopp@gm.com"; "Timothy Cushing"; John Glaser Intertek; "Mourhatch, Ramoun"; "Kostan, Travis G."; "Rais, Khaled"; "Karin.Haumann@shell.com"; "Mark Adams"; "Salvesen, Clifford R"; "James Matasic"; "Hosseini, Seyedeh Mahboobeh"; "Tarry, Preston"; "Pecinovsky, Katerina"; "Charlie"; "Scott.Lindholm@shell.com"; "Thom Smith (TRSmith@Valvoline.com)"; "Calcut, Brent"; Carlton Coker Intertek; "Collins, Chet A."; "arthur.t.andrews@exxonmobil.com"; "Overaker, Mark"; "ptumati@jhaltermann.com"; Meier, Adam Robert

Subject: Intertek IVB Prove-out Testing Update

Date: Friday, July 07, 2017 3:26:00 PM

Attachments: IVB100-8-62 IVB-LFO-1 Test Report v2.pdf
IVB100-8-62 Fe Content.pdf
IVB165-0-24 ASTM REO 300 Test Report.pdf
IVB165-0-24 Oil Analysis.xlsx
IVB102-0-58 ASTM REO 1012 Test Report.pdf
IVB102-0-58 Oil Analysis.xlsx
image002.png

Sequence IV Surveillance Panel,

Sequence IVB prove-out/scoping tests on IVB-LFO-1 (lobe failure candidate oil), ASTM REO 300 and ASTM REO 1012 (REO3) have been completed at Intertek and all post-test measurements have been completed.

The following changes were applied to these tests:

- Change in initial oil charge measurement from volume to mass.
- Standardization of engine coolant flow direction to into the coolant inlet pipe and out of the rear of the cylinder head, as is the production coolant flow direction for the Toyota 2NR-FE engine.
- Change in the coolant temperature control point from coolant in to coolant out (rear of the cylinder head).
- Change in the coolant temperature set-point from 49°C (Coolant In) to 52°C (Coolant Out).
- Change from 185 ppm Sulfur content KA24E Green fuel to 124 ppm Sulfur content KA24E Green fuel.
- Change from 2,400 ml (2,100 g) to 3,000 ml (2,600 g) initial oil charge volume.
- Change from 1 ounce (30 ml) to 2 ounce (60 ml) 25-hour interval oil sample volumes. This will eliminate the analyze and return sample for other analyses requirement that we currently have to conduct kinematic viscosity analysis.

Sequence IVB prove-out test IVB100-8-62, conducted on candidate oil **IVB-LFO-1**, reached end of test on Friday, 6/23/17, at 4:54pm. Completed Fe content analysis is attached. **NO LOBE FAILURES OCCURRED!!!** I've also included data from tests IVB100-6-60 (lobe failure between 150 and 155 hours) and IVB100-7-61 (lobe failure between 160 and 165 hours) for comparison. A test report is also attached.

Key results for prove-out test IVB100-8-62 are as follows:

- Camshaft Lobe Failure = **NO**
- Fe Content = **340 ppm at 200 hours**
- H2O Content = **2375 ppm at 200 hours**
- TAN/TBN Crossover = **Between 75 and 100 hours**
- Oil Consumption = **221.0 grams**

My observations on the effects of the changes listed above on candidate oil **IVB-LFO-1**, are included below:

- Eliminated intake camshaft lobe failures.
- Decreased intake lifter wear.
- Decreased exhaust lifter wear.
- Decreased oil consumption.
- Helped maintain oil pressure throughout the entire test.
- Decreased Fe content.
- Based on decrease of Fe content, might have decreased liner and ring wear.
- Increased fuel dilution. I don't have an explanation for this change.
- No change to kinematic viscosity trend.
- No change to H_2O content trend.

Sequence IVB prove-out test IVB165-0-24, conducted on **ASTM reference oil 300**, reached end of test on Saturday, 6/24/17, at 12:56pm. Completed oil analysis is attached. **NO LOBE FAILURES OCCURRED!!!** I've also included data from prior prove-out and precision matrix tests, conducted on **ASTM reference oil 300**, for comparison. A test report is also attached.

Key results for prove-out test IVB165-0-24 are as follows:

- Intake lifter average volume loss w/o Talc = **1.63 mm^3**
- Intake lifter average volume loss w/ Talc = **1.65 mm^3**
- Camshaft Lobe Failure = **NO**
- Intake Camshaft Average Heel to Toe Wear = **1.6 µm**
- Fe Content = **180 ppm at 200 hours**
- H2O Content = **2186 ppm at 200 hours**
- TAN/TBN Crossover = **Between 100 and 125 hours**
- Oil Consumption = **117.1 grams**

My observations on the effects of the changes listed above on **ASTM reference oil 300**, are included below:

- Decreased intake lifter wear.
- Decreased exhaust lifter wear.

- Decreased oil consumption.
- Helped maintain oil pressure throughout the entire test.
- Decreased Fe content.
- Based on decrease of Fe content, might have decreased liner and ring wear.
- Increased fuel dilution. I don't have an explanation for this change.
- No change to kinematic viscosity trend.
- No change to H_2O content trend.
- TAN increase stayed about the same through 50 hours, then decreased from 50 to 200 hours.
- TBN drop-off stayed about the same through 25 hours, then decreased from 25 to 200 hours.
- TAN/TBN Crossover occurred almost 50 hours later.
- Oxidation trend stayed about the same through 100 hours, then decreased from 100 to 200 hours.
- Nitration trend stayed about the same through 50 hours, then decreased from 50 to 150 hours, then increased from 150 to 200 hours.

Sequence IVB prove-out test IVB102-0-58, conducted on **ASTM reference oil 1012**, reached end of test on Sunday, 6/25/17, at 4:31am. Completed oil analysis is attached. **NO LOBE FAILURES OCCURRED!!!** I've also included data from prior prove-out and precision matrix tests, conducted on **ASTM reference oil 1012**, for comparison. A test report is also attached.

Key results for prove-out test IVB102-0-58 are as follows:

- Intake lifter average volume loss w/o Talc = **1.12 mm^3**
- Intake lifter average volume loss w/ Talc = **1.19 mm^3**
- Camshaft Lobe Failure = **NO**
- Intake Camshaft Average Heel to Toe Wear = 0.**5 µm**
- Fe Content = **153 ppm at 200 hours**
- H2O Content = **2339 ppm at 200 hours**
- TAN/TBN Crossover = **Between 100 and 125 hours**
- Oil Consumption = **469.4 grams**

My observations on the effects of the changes listed above on **ASTM reference oil 1012**, are included below:

- Decreased intake lifter wear.
- No change to exhaust lifter wear.
- No change to oil consumption.
- Helped maintain oil pressure throughout the entire test.
- Decreased Fe content.
- Based on decrease of Fe content, might have decreased liner and ring wear.
- Increased fuel dilution. I don't have an explanation for this change.
- No change to kinematic viscosity trend.
- No change to H_2O content trend.
- TAN increase stayed about the same throughout the entire test.

TBN drop-off slightly decreased throughout the entire test.

- TAN/TBN Crossover occurred approximately 25 hours later.
- Oxidation trend stayed about the same throughout the entire test.
- Nitration trend stayed about the same throughout the entire test.

Comparing Intertek prove-out and precision matrix test results from stands 102 and 165 on ASTM reference oils 300 and 1012, oil discrimination still exists with these changes applied. All data below is average data, if multiple data points exist, or single point data from Intertek stands 102 and 165.

Test Conditions	Pre-precision matrix prove-out	Precision matrix	Latest changes
Oil 300 ILAVL, mm^3	1.65	2.60	1.63
Oil 1012 ILAVL, mm^3	1.28	1.94	1.12
Separation ILAVL, mm^3	0.37	0.66	0.51

I am satisfied and encouraged with the outcome of these three tests and I believe that the changes applied to these three tests have merit in further investigating with testing at multiple labs and possibly in combination with the addition of the OHT chamfered test intake camshaft and the Lubrizol modified oil pan.

Regards,

William A. Buscher III
Principal Engineer
Automotive Research
Transportation Technology Business Line

Mobile (210)-240-8990
Office (210)-647-9489
www.intertek.com

intertek
Total Quality. Assured.

Intertek, 5404 Bandera Road San Antonio, Tx 78238