HEAVY-DUTY ENGINE OIL CLASSIFICATION PANEL

OF

ASTM D02.B0.02

December 5, 2017

Houston Marriott Marquis – Houston, TX

ACTION ITEMS

MINUTES

1.0 Call to order

1.1 The Heavy Duty Engine Oil Classification Panel (HDEOCP) was called to order by Chairman Shawn Whitacre at 1:30 p.m. on Tuesday, December 5, 2017, in the Houston 1 Room of the Houston Marriott Marquis Hotel, Houston, TX.

1.2 There were 15 members present and 84 guests present. The attendance list is included as Attachment **2.**

2.0 Agenda

2.1 The agenda circulated prior was modified as attached. **Attachment 1, page 2.** The Anti-Trust Statement was presented. **Attachment 1, page 3.**

3.0 Minutes

3.1 The June meeting minutes were approved as written.

4.0 Membership

4.1 There were five membership changes. Ed Murphy replaced Josh Frederick for Valvoline, Matthew Hauschild replaced Robert Stockwell for Oronite, John Loop replaced Gail Evans for Lubrizol, Justin Mills replaced Don Smolenski for Evonik, and Abdul Cassim replaced Ken Chao for John Deere. There was one proxy: Mike Alessi of ExxonMobil was represented by Gordon Lee. **Attachment 1, page 4.**

5.0 CLOG Update

5.1 Thom Smith gave the update for CLOG (Category Life Oversight Group). **Attachment 3.** CLOG met 12/4/17. CLOG is responsible for keeping categories alive with tests becoming unavailable. Key tests for HDEOCP consideration are to use the IIIH for the IIIF and replace the EOAT with the COAT test. Equivalent limits in the IIIH for the IIIF were determined and CLOG recommended that the HDEOCP adopt the limits in the attachment. 70 hour limit would be interpolated because there is no 70 hour oil sample. An informal CLOG survey found 8 in favor, 2 not in favor with some concerns. There is not much difference using square root or natural log. The limits currently based on piston batch; limits would not change with different batches, but Industry Correction Factors could be used if necessary. Other equivalencies in presentation. Some recommendations did not have consensus, but all were sent to Lubes Group to decide. API voting members should vote. The COAT is working on other issues before recommending equivalent limits. CLOG recommends that the HDEOCP approve the limits for the IIIF to IIIH. EMA stated they did not have an opportunity to fully review the proposal.

6.0 Sequence IIIH to Sequence IIIF for API CH-4, CI-4, and CJ-4

6.1 Jim Rutherford presented statistical review of IIIH/IIIF analysis. **Attachment 4.** Three candidate data pairs were submitted along with matrix data. Statisticians did look at several ways to interpolate the 70 hour value. Further discussion on interpolation values as there is not a 70 hour sample. Unlikely that there will be more data. **CLOG moved to adopt the recommended limits. Discussion followed. Mary Gery seconded. There were 17 affirmative votes, 0 no votes, and 2 waives. Motion carries and this recommendation will be delivered to Sub B.**

7.0 Review of status of carry-over engine tests that support API CK-4, FA-4 and legacy categories

7.1 Sean Moyer gave a report combined with Mark Cooper's report. **Attachment 5.** CAT 1K/1N SP working through extending life of auxiliary stand components. CAT 1P crankshafts can be ordered. CAT C13 will introduce new liners with coordinated references in early 2018. COAT is having 3 measurement systems built by a single source for each lab to use starting in 2018. T-11/T-12. ISM no issues. ISB updated CF and LTMS. RFWT no change. IIIF/IIIG hardware is anticipated to run out this month. EOAT no update on COAT correlation. EOAT engine has enough hardware for one more rebuild extending its life. There was a request to extend the timeline beyond 2020 for the next report. IIIF/IIIG could actually extend to 1Q18.

8.0 Update on DD13 Scuffing Test

8.1 Suzanne Neal gave an update on the DD13 Scuffing Test. **Attachment 6.** Waiting on a new batch of liners. Will also have new rings and pistons.

9.0 Update on CAT Oil Aeration Test

9.1 Hind Abi-Akar updated the panel on the COAT. **Attachment 7.** There have been many meetings with small working group and full Surveillance Panel. The group visited Emerson to understand the flow meter better. One lab is building the 3 measurement systems so they are more alike. Another plea for data run in both the EOAT and COAT, otherwise a correlation will be based on only 1005.

10.0 Cummins ISB Correction Factors

10.1 Jim Moritz discussed the updated Industry Correction Factors (ICF) and new style LTMS introduced for the Cummins ISB test. **Attachment 8.**

11.0 Old Business

11.1 Update on Ford 6.7L Wear Test Development

11.1.1 Ron Romano gave an update on the latest Ford developed wear test. **Attachment 9.** The test is 200 hours run continuously. A High Wear Oil (HWO) and Low Wear Oil (LWO) have been run. Some tests had some parts replaced at 150 hours to get a comparison of 150 vs. 200 hours. Two other oils were developed and run which were modified versions of the 2 previous oils. There are 32 rocker arms and pushrods per engine. HWO and LWO separated. Six tests were conducted. Rocker arm weight loss includes 3 wear points on each rocker arm. Results suggest the test responds to chemistry and viscosity. One test had higher EOT soot. EOT soot is 6-7%. This level of soot is higher than seen in the field, which is approximately 3% soot. Push rod weight loss didn't show much. Higher soot was due to a dirty injector after 2 tests. New injectors are now used each time. Iron levels for HWO are higher than others. Test details have been shared with independent test labs. All 6 runs on same short block, with new heads and valve train for each test. Soot correction factors have not been looked at; will consider it. Similar soot levels in other test types. Injection timing is not adjusted, but soot is targeted based on time between 7-10 hours.

11.1.2 The next steps are to get other labs going, create an ASTM test method and ask for a category or supplement. A Task Force will be opened up to other stake-holders.

12.0 New Business

12.1 D4485 Definitions

12.1.1 Laura Birnbaumer had an update to D4485. **Attachment 10.** Removing Sequence VI and "Resource Conserving" uncovered some inconsistencies with D4485. **Laura moved to recommend to Sub B to change D4485 as shown in the attachment. Mary Dery seconded. There were 16 affirmative votes, 0 no votes, and 2 waives. Motion carries and this recommendation will be delivered to Sub B.**

12.2 Proposal to modify D4485 table structure

12.2.1 Laura also had a recommendation to change the table structure in D4485. **Attachment 11.** The HDEOCP is a technical body with responsibility of maintaining D4485. Table 3 is basically all categories in one table. Laura worked with ASTM publication department to update the document and improve it. A new grouping was proposed. API 1509 uses separate tables. ASTM is supportive of changing it. Why not CK-4 and FA-4 together since tests are same? Since FA-4 is not backward compatible, could be separate; could actually be 5 tables. Other categories could be added or removed easier. Mary Dery seconded. A ballot would have to show the table change. Exact table layout would be in the ballot. This would be a formal letter ballot through Sub B; need this group to reach consensus on moving forward. Seconder wants 5 tables. Laura accepts 5 tables. **Motion to make 5 tables; one per category. There were 18 affirmative votes, 0 no votes, and 0 waives. Motion carries and this recommendation will be delivered to Sub B.**

13.0 Next meetings

13.1 The next meeting will in Phoenix during the June 2018 ASTM Meeting.

14.0 The meeting was adjourned at 3:10 pm.

D02.B0.02.1 HDEOCP

Shawn Whitacre
Chairman
Heavy-Duty Engine Oil Classification Panel

December 5, 2017
Houston, TX USA

AGENDA
D02.B0.02.1
Heavy-Duty Engine Oil Classification Panel

Tuesday, December 5, 2017 1:30pm CST
Marriott Marquis Houston
Houston, Texas USA

1) **Call to Order/Anti-trust statement**

2) **Minutes –** Approval of Minutes from June 27, 2017 Meeting in Boston, MA, USA

3) **Membership**

   a) Review current panel membership

4) **Existing tests/categories**

   a) CLOG Update (Thom Smith, Valvoline)
   b) Sequence IIIH to Sequence IIIF for API CH-4, CI-4, and CJ-4 (Jim Rutherford, Chevron Oronite)
   c) Review of status of carry-over engine tests that support API CK-4, FA-4 and legacy categories (Sean Moyer, TMC/Mark Cooper, Oronite)
   d) Update on DD13 Scuffing Test (Suzanne Neal, DTNA)
   e) Update on CAT Oil Aeration Test (Hind Abi-Akar, Caterpillar)
   f) Cummins ISB Correction Factors (Jim Moritz, Intertek)

5) **Old Business**
   a) Update on Ford 6.7L Wear Test Development (Ron Romano, Ford)

6) **New Business**
   a) D4485 Definitions (Laura Birnbaumer, Chevron Oronite)
   b) Proposal to modify D4485 table structure (Laura Birnbaumer, Chevron Oronite)

7) **HDEOCP Adjournment (transition to DEOAP)**

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- **For a complete list of standards see** http://www.astm.org/COMMIT/SUBCOMMIT/D02B0.htm

ASTM-HDEOCP Membership

	Oil and Additive Companies		OEMs
1	Shawn Whitacre - Chevron	1	Greg Shank – Volvo Power Train
2	Mike Alessi- ExxonMobil*	2	Ryan Denton - Cummins Inc.
3	Dan Arcy - Shell	3	Mesfin Belay - Detroit Diesel
4	Corey Taylor - BP Castrol	4	Hind Abi-Akar - Caterpillar Inc.
5	Ed Murphy – Valvoline[1]	5	Heather DeBaun – Navistar
6	Mary Dery- BASF	6	Ken Chao - John Deere
7	Don Smolenski - Evonik	7	Eric Johnson- GM Powertrain
8	Cory Koglin – Afton	8	Jason Andersen- Paccar
9	Matthew Hauschild – Oronite [2]	9	Ron Romano - Ford
10	John Loop – Lubrizol[3]		
11	Robert Salgueiro - Infineum U.S.A.		
12	David Taber - Phillips 66 Lubricants		
13	Jim Linden, TOTAL Lubricants		

* Gordon Lee (EM) has proxy

1. Replacing Josh Frederick
2. Replacing Robert Stockwell
3. Replacing Gail Evans

HDEOCP Attendance: December 5, 2017

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HDEOCP Attendance: December 5, 2017

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CLOG Update to HDEOCP

Marriott Marquis
Houston, TX
2017.12.05

What is at risk

- The following categories may be in jeopardy if alternative tests and equivalent limits cannot be established

API HD Categories	API PC Categories	ILSAC Categories
CH-4	SJ	GF-5
CI-4	SL	
CJ-4	SM	
	SN	
	Resource Conserving	

Summary of Status

Current Test	Replacement Test	Status	Timing
IIIF	IIIH	Recommendations to be made to API LG and HDEOCP	Dec/Jan
IIIG	IIIH	Completed	Done
IIIGA	ROBO	Completed	Done
IIIGB	IIIHB	Completed	Done
IVA	IVB	Awaiting precision matrix	Jan/Feb 2018
VG	VH	Recommendations to be made to API LG	Jan/Feb 2018
VID	VIE	API LG gone to Ballot	Nov 2017 if approved
VID (XW-16)	VIF	Completed	Done
EOAT	COAT	Awaiting SP recomendation	1Q18

Current Status

- **Sequence IIIF deposits & Vis Increase**
  - Proposed S category Limits to be sent to API LG
  - Proposed C category limits to be sent to ASTM HDEOCP
  - IIIF Life expectancy: Q1 2018
  - IIIH Equivalency: to discuss today

	API	60 PVIS, max	80 PVIS, max	WPD, min	PSV, min
IIIF Limits	SJ	325	-	3.2	8.5
	SL	-	275	4.0	9.0
	CH-4	295	-	-	-
	CI-4	-	275	-	-
	CJ-4	-	275	-	-

Proposal	API	60 PVIS, max	70 PVIS, max	WPD, min	PSV, min
IIIH Limits	SJ	*120*	-	*1.9*	*6.6*
	SL	-	*370*	*2.3*	*7.2*
	CH-4	*110*	-	-	-
	CI-4	-	*370*	-	-
	CJ-4	-	*370*	-	-

CLOG IIIF / IIIH Equivalency Survey
November 2017

At the November 9 CLOG meeting the Statisticians Group put forward proposed Sequence IIIH limits to be used in place of the current Sequence IIIF limits for API categories CH-4, CI-4 and CJ-4. These are shown in the table below.

API Category	Current IIIF Parameter	Current IIIF Limit	Equivalent IIIH Parameter	Equivalent IIIH Limit
CH-4	60hr pVis	295 Max	60hr pVis	110 Max
CI-4	80hr pVis	275 Max	70hr pVis (interpolated)	370 Max
CJ-4	80hr pVis	275 Max	70hr pVis (interpolated)	370 Max

Please indicate below whether or not you agree that CLOG should review the proposal with HDEOCP and recommend this proposal to the API Lubricants Group.

Yes, I agree the HD proposal should be Reviewed with HDEOCP and recommended to API LSG
Yes = 8

No, the HD proposal should NOT be Reviewed with HDEOCP and recommended to APILSG
No = 2

Comments from Survey

With the uncertainty of the Sequence IIIH performance based on piston batch differences, and because the Sequence IIIF is still available, the establishment of equivalent limits for the IIIH to IIIF should not be completed until the IIIH piston batch issue is resolved.

CLOG needs to understand these issues before recommending limits for HDEOCP ballot.

- What is the impact of alternate interpolation methods (square root vs Log e) for determining the 70hr PVIS?
- Which method better describes the typical oxidation curve of a IIIF formulation?
- If Log e was used, what would the P/F limits be for CI-4/CJ-4?

- On Slide 6 the final bullet states that these limits are based on batch 4 pistons (unadjusted) and further suggests that the limits be corrected with subsequent IIIH batches. It would be impractical to have Pass/Fail limits that are piston batch specific.
- It is generally believed that Batch 4 pistons are mild, then if balloted as is, these limits would be unduly severe for future piston batches.

Current Status

- **Sequence IIIG deposits & Vis Increase**
  - IIIH Limits for API SN/ILSAC GF-5 and SM approved by LG
  - IIIG Life Expectancy: Q1 2018

	API	ILSAC	EOT PVIS	WPD	Hot Ring Stick
IIIG Limits	API SN	GF-5	150 Max	4.0 Min	None
	API SM	-	150 Max	3.5 Min	None

Approved	API	ILSAC	EOT PVIS	WPD	Hot Ring Stick
IIIH Limits	API SN	GF-5	150 Max	3.7 Min	None
	API SM	-	150 Max	3.2 Min	None

Current Status

- **Sequence IIIGA used oil MRV**
  - API LG agreed that the ROBO could be used as a substitute test
- **Sequence IIIGB Phosphorus Retention**
  - API LG approved use of the IIIHB

	API	ILSAC	% P Retention
IIIGB Limits	API SN	GF-5	79% Min

Approved	API	ILSAC	% P Retention
IIIHB Limits	API SN	GF-5	81% Min

Current Status

- **Sequence IIIF, IIIG and VE wear**
  - It was determined that these parameters could be waived based upon a minimum P requirement of 0.06% and a Sequence IVA or IVB requirement.
- **Sequence IVA Cam wear**
  - Awaiting completion of the Sequence IVB precision matrix
  - Life expectancy of IVA: 2022
  - IVB equivalency: Q1 2018

	API	ILSAC	Average Cam Wear
Sequence IVA Limits	SN	GF-5	90µ max
	API SM	-	90µ max
	API SL	-	120µ max
	API SJ	-	120µ max

	API	ILSAC	Average Cam Wear
Sequence IVB Limits	API SN	GF-5	TBD
	API SM	-	TBD
	API SL	-	TBD
	API SJ	-	TBD

Current Status

- **Sequence VG Sludge and Varnish**
  - Stats Group and Ford recommendations to be sent to API LG
  - VID Life Expectancy: Q1 2018
  - VH Equivalency:

	API	ILSAC	AES	RAC	AEV	APV	OSC	Hot Stuck Rings
Sequence VG Limits	**SN**	**GF-5**	**8.0 min**	**8.3 min**	**8.9 min**	**7.5 min**	**15% max**	**None**
	SL, SM & SJ	**-**	**7.8 min**	**8.0 min**	**8.9 min**	**7.5 min**	**20% max**	**None**

Proposals	API	ILSAC	AES	RAC	AEV	APV	OSC	Hot Stuck Rings	
Sequence VH Limits	**SN**	**GF-5**	***7.2 min***	***7.7 min***	***8.6 min***	***7.4 min***	***TBD***	***None***	***Stats Group***
			7.6 min	***7.6 min***	***8.7 min***	***7.6 min***	***TBD***	***None***	***Ford***
	SL, SM & SJ	**-**	**TBD**	**TBD**	**TBD**	**TBD**	**TBD**	**TBD**	

Current Status

- **Sequence VID Fuel Economy - HTHS ≥ 2.6 cP**
  - API LG currently balloting an equivalency proposal
    - VID Life Expectancy: Ended
    - VIE Equivalency: Nov 2017 if ballot approved

			XW-20		XW-30		10W-30 and others	
Sequence VD Limits	**API**	**ILSAC**	**FEI 2**	**FEI Sum**	**FEI 2**	**FEI Sum**	**FEI 2**	**FEI Sum**
	SN/ RC	**GF-5**	**1.2 min**	**2.6 min**	**0.9 min**	**1.9 min**	**0.6 min**	**1.5 min**

Proposal being Ballotted			XW-20		XW-30		10W-30 and others	
Sequence VIE Limits	**API**	**ILSAC**	**FEI 2**	**FEI Sum**	**FEI 2**	**FEI Sum**	**FEI 2**	**FEI Sum**
	SN/ RC	**GF-5**	***1.5 min***	***3.2 min***	***1.2 min***	***2.5 min***	***1.0 min***	***2.2 min***

Current Status

- **Sequence VID Fuel Economy - HTHS ≥ 2.3 cP**
  - Sequence VIF equivalent limits approved by LG
    - VID Life Expectancy: Ended
    - VIF Equivalency: October 2017 if approved

		XW-16	
Sequence VID Limits	**API**	**FEI 2**	**FEI Sum**
	SN/ RC	**1.3 min**	**2.8 min**

Approved		XW-16	
Sequence VIF Limits	**API**	**FEI 2**	**FEI Sum**
	SN/ RC	**1.8 min**	**3.7 min**

Current Status

- **Engine Oil Aeration Test**
  - Proposal based solely on oil 1005 made
  - Request has gone out for data on other oils
  - Surveillance Panel is reviewing proposals
  - EOAT Life Expectancy: Q4 2018
  - COAT Equivalency: Q1 2018

	API	% Aeration
EOAT Limits	CJ-4	8.0 max
	CI-4	8.0 max
	CH-4	8.0 max

	API	% Aeration
COAT Limits	CJ-4	TBD
	CI-4	TBD
	CH-4	TBD

Chevron

Oronite

IIIH / IIIF Data Analysis

Analysis group

Update: 07 November 2017 for CLOG 09 November 2017

ADDING UP® For 100 Years

Chevron Oronite

Overview

- Need IIIH limits to replace IIIF limits in older categories:

Target Test & Parameter(s) for Tie-Back			Categories at Stake that Cannot Be Continued if Tie-Back Not Established					Potential Surrogate Tests for Tie-Back
Test	Parameters	Transformation	SJ	SL	CH-4	CI-4	CJ-4	
IIIF	60hr - %KV40 (55hr)	ln	✔ 325		✔ 295			IIIH pVis
IIIF	80hr - %KV40 (70hr)	1/sqrt		✔ 275		✔ 275	✔ 275	IIIH pVis
IIIF	80hr - WPD	na	✔ 3.2	✔ 4.0				IIIH WPD
IIIF	80hr - APV	na	✔ 8.5	✔ 9.0				IIIH APV

- IIIF will be unavailable early 2018? < 200 runs left
  – Some controversy about how many runs left and whether test will be available to all sponsors into 2018
- CLOG ran four IIIH tests with the current reference oil from IIIF (433-2) and a reference oil last used in IIIF in 2013 (1006-2)
- Two tests ran with batch 3 hardware and two ran with batch 4 hardware. The tests with batch 3 hardware were rerun by the lab with batch 4 hardware.
- The Surveillance Panel is working to bring the IIIH back to target severity.

ADDING UP For 100 Years

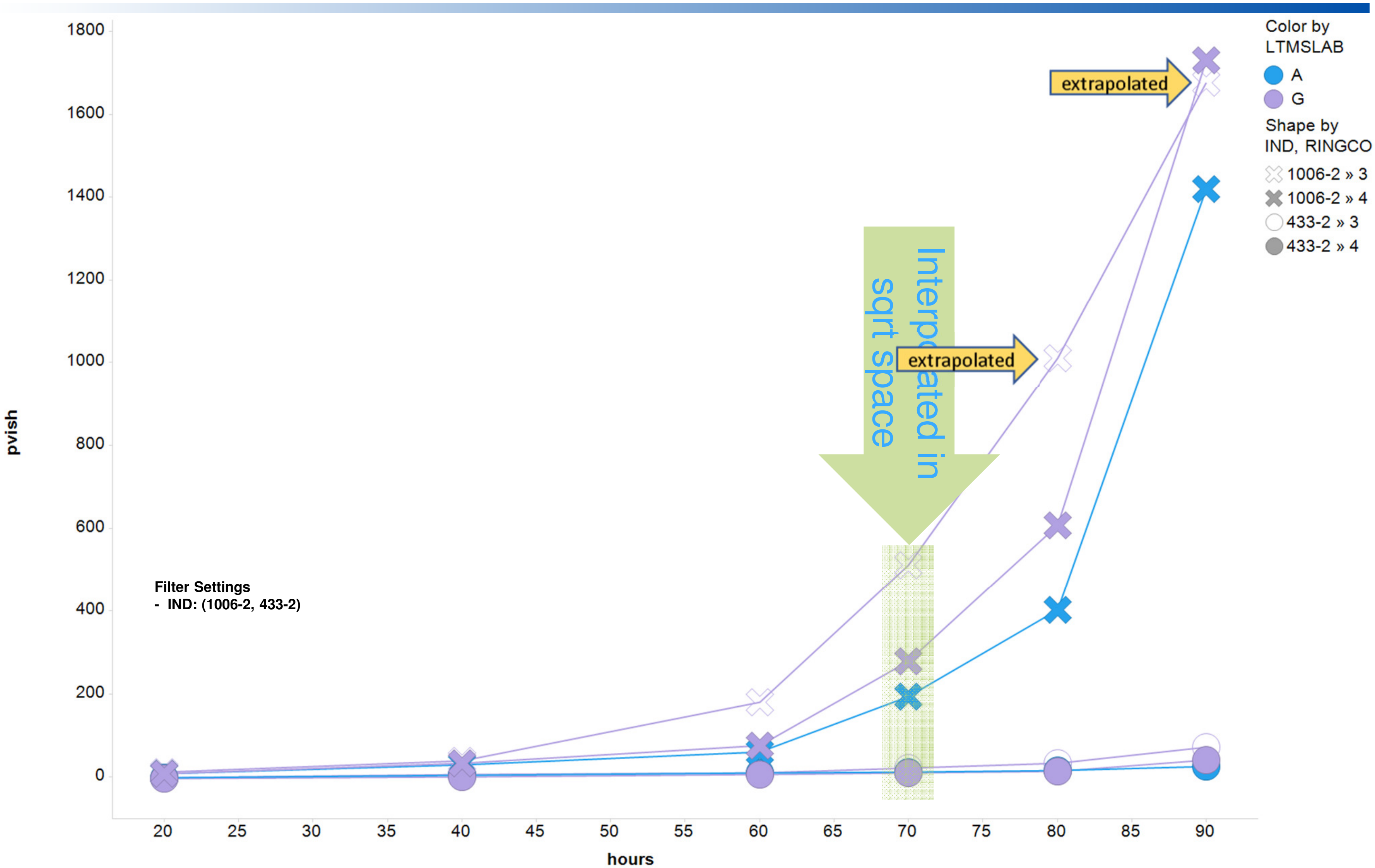
CLOG IIIH → IIIF Analysts Participants

- Elisa Santos
- Martin Chadwick
- Thom Smith
- Robert Stockwell
- Art Andrews
- Lisa Dingwell
- Abaigeal Ritzenthaler
- Todd Dvorak
- Rich Grundza
- Kevin O'Malley
- Travis Kostan
- Jo Martinez
- Jim Rutherford

Since CLOG September 25 Update

- Two new references since, one in stand G2
- Three candidate data pairs submitted
- We might look at different “WPD” than current rating.
  - More investigation could be done but not promising.
- Look at IR oxidation, metals, other used oil analyses.
  - No one reported anything.
- Looked at interpolations / extrapolation in square root space to produce following proposal because square root is in IIIF test method. Without 70 hour viscosity data in IIIH, we can’t evaluate what transformation would be most appropriate.
- If we use other criteria than PVIS90 and WPD in IIIH, they should be added as “non critical” criteria for ltms.
- APV in IIIH is average of UNWEIGHTED PISTON BOSS VARNISH AVERAGE PIS across six cylinders

IIIH CLOG tests with interpolation



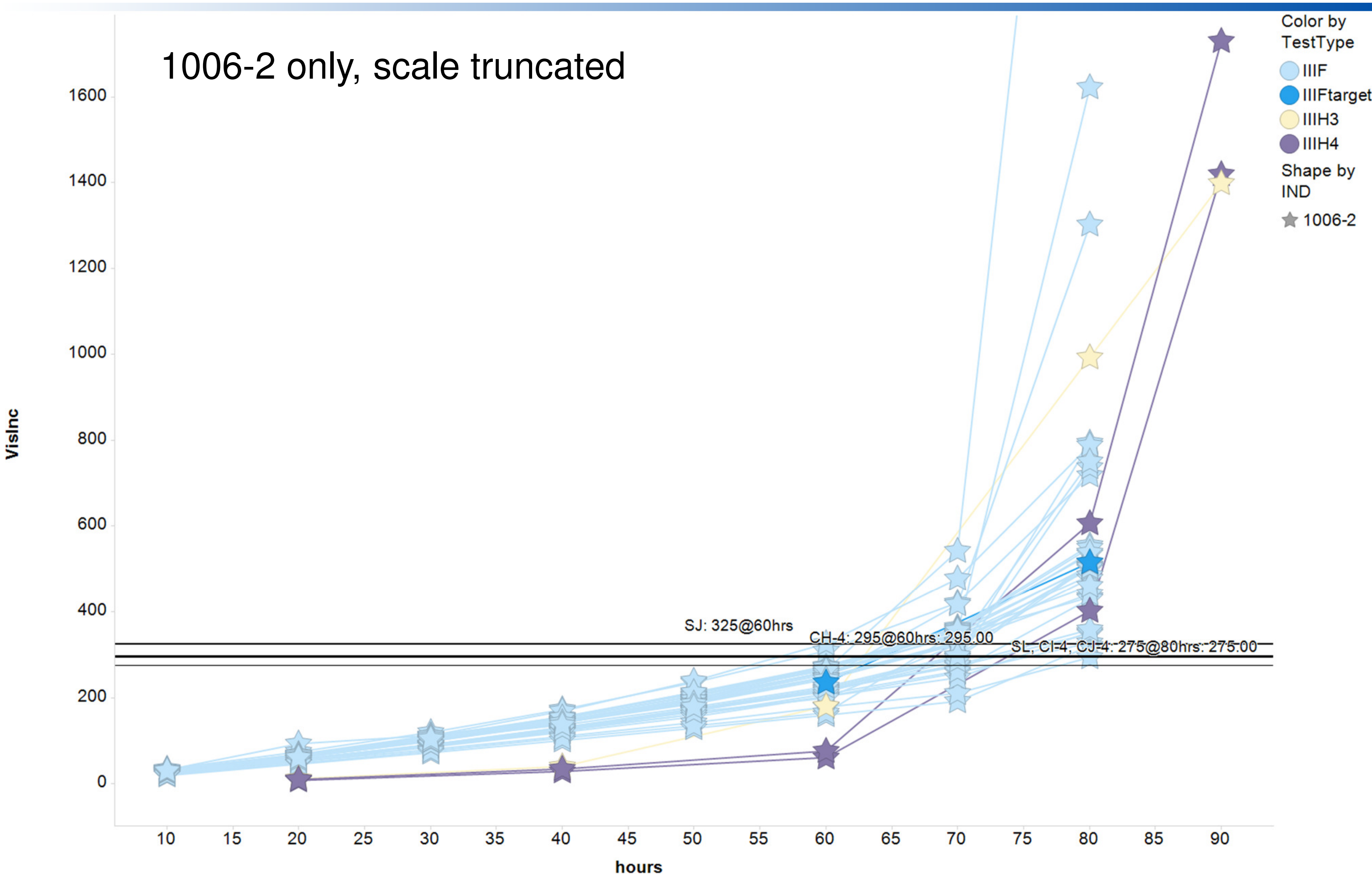
Current Proposal

Target Test & Parameter(s) for Tie-Back			Categories at Stake that Cannot Be Continued if Tie-Back Not Established					Potential Surrogate Tests for Tie-Back	IIIF outcomes in target datasets	Suggested limits to attain same probability of pass for 1006-2 and 433-2	data pairs	**Proposed Limits**
Test	Parameters	Transformation	SJ	SL	CH-4	CI-4	CJ-4					
IIIF	60hr %KV40	ln	✔ 325					IIIH pVis	433-1 nowhere near failing 1006-2 just barely fails SJ	=> 60hr PVIS 117 70hr interpolated PVIS 388 80hr PVIS 1300 calc 90hrPVIS 3600 sa90hrPVIS 5000 break between 60 and 80 hours	all 3 high prob pass ==>	**120 @ 60 hrs**
IIIF	60hr %KV40	ln			✔ 295			IIIH pVis	433-1 nowhere near failing 1006-2 2/30 fail CH-4	=> 60hr PVIS 106 70hr interpolated PVIS 386 80hr PVIS 1100 calc 90hrPVIS 3100 sa90hrPVIS 4300 break between 60 and 80 hours	all 3 high prob pass ==>	**110 @ 60 hrs**
IIIF	80hr %KV40	1/sqrt		✔ 275 (@70 hrs)		✔ 275 (@70 hrs)	✔ 275 (@70 hrs)	IIIH pVis	433-1 nowhere near failing 1006-2 all fail, limit slightly below lowest 1006-2	=> 60hr PVIS 60 80hr PVIS 400 calc90hrPVIS 1400 sa 90hr 1800 break between 60 and 80 hours	A-03 pp 275@70hrs ==>	**370 @ 70 hrs interpolated in square root space**
IIIF	80hr - WPD	na	✔ 3.2					IIIH WPD	433-1 easily passes 1006-2 just passes	=> calc WPD 1.9 saWPD 1.7		**=> calc WPD: 1.9**
IIIF	80hr - WPD	na		✔ 4.0				IIIH WPD	433-1 fails 9/31 1006-2 fails 19/30	=> calc WPD 2.3 saWPD 2.2		**=> calc WPD: 2.3**
IIIF	80hr - APV	na	✔ 8.5					IIIH Apv	433-1 easily passes 1006-2 easily passes	=> calc APV 6.6 saAPV 6.3		**=> calc APV: 6.6**
IIIF	80hr - APV	na		✔ 9.0				IIIH Apv	433-1 fails 5/31 1006-2 fails 3/30	=> calc APV 7.2 saAPV 6.8		**=> calc APV: 7.2**
IIIF	Hot Stuck Rings		none	none								**no hot stuck rings**

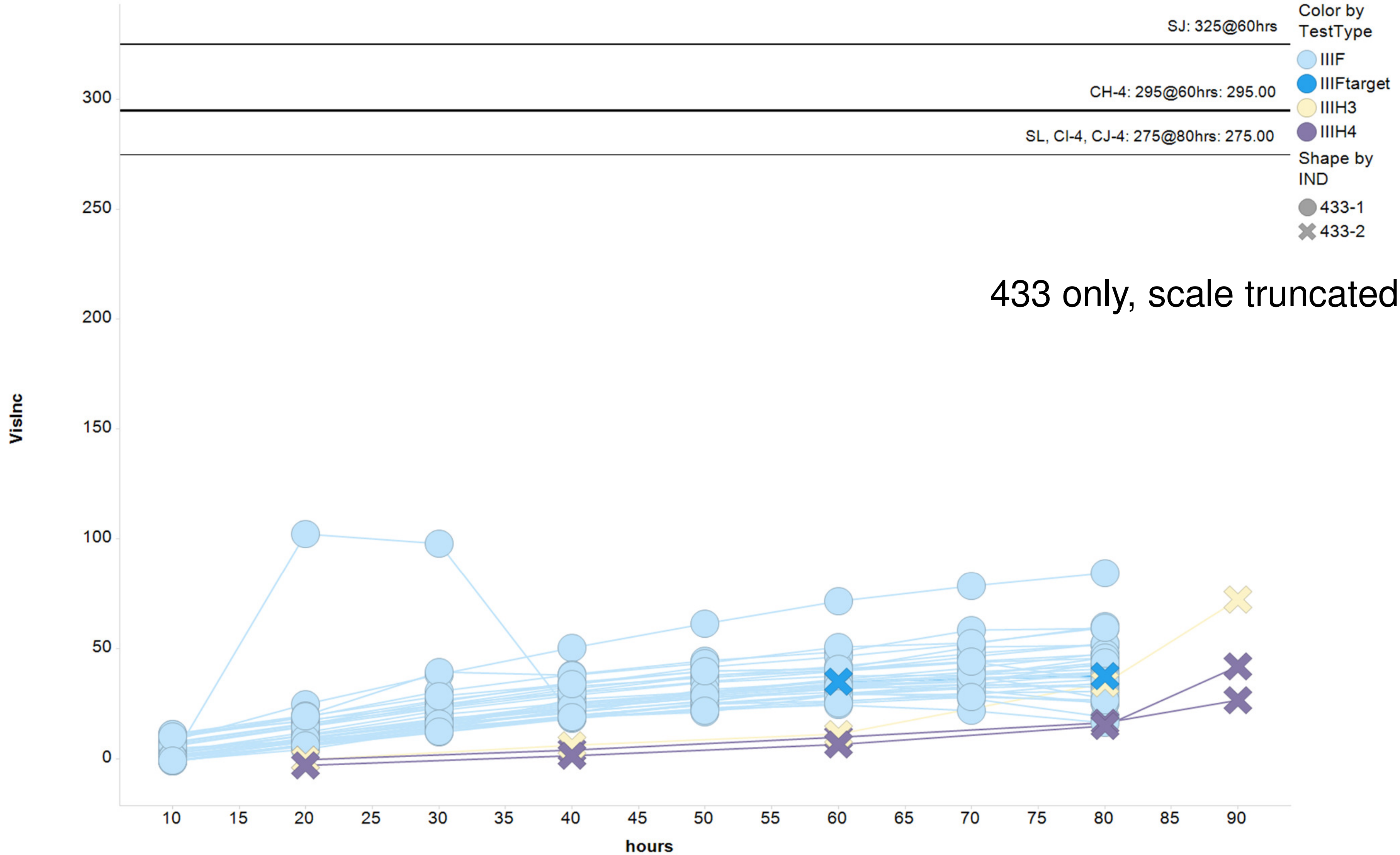
- OR – (1) measure viscosity at 70 hours in the IIIH
- OR – (2) use sensor to measure viscosity continuously
- OR – use above limits until 1 or 2 is done
- If we determine limits in IIIH batch 4 without severity adjustment, we could maybe readjust limits if the test is ever brought back to target.

Appendix

September 25, 2017 summary for CLOG



September 25, 2017 summary for CLOG



Candidate data pairs

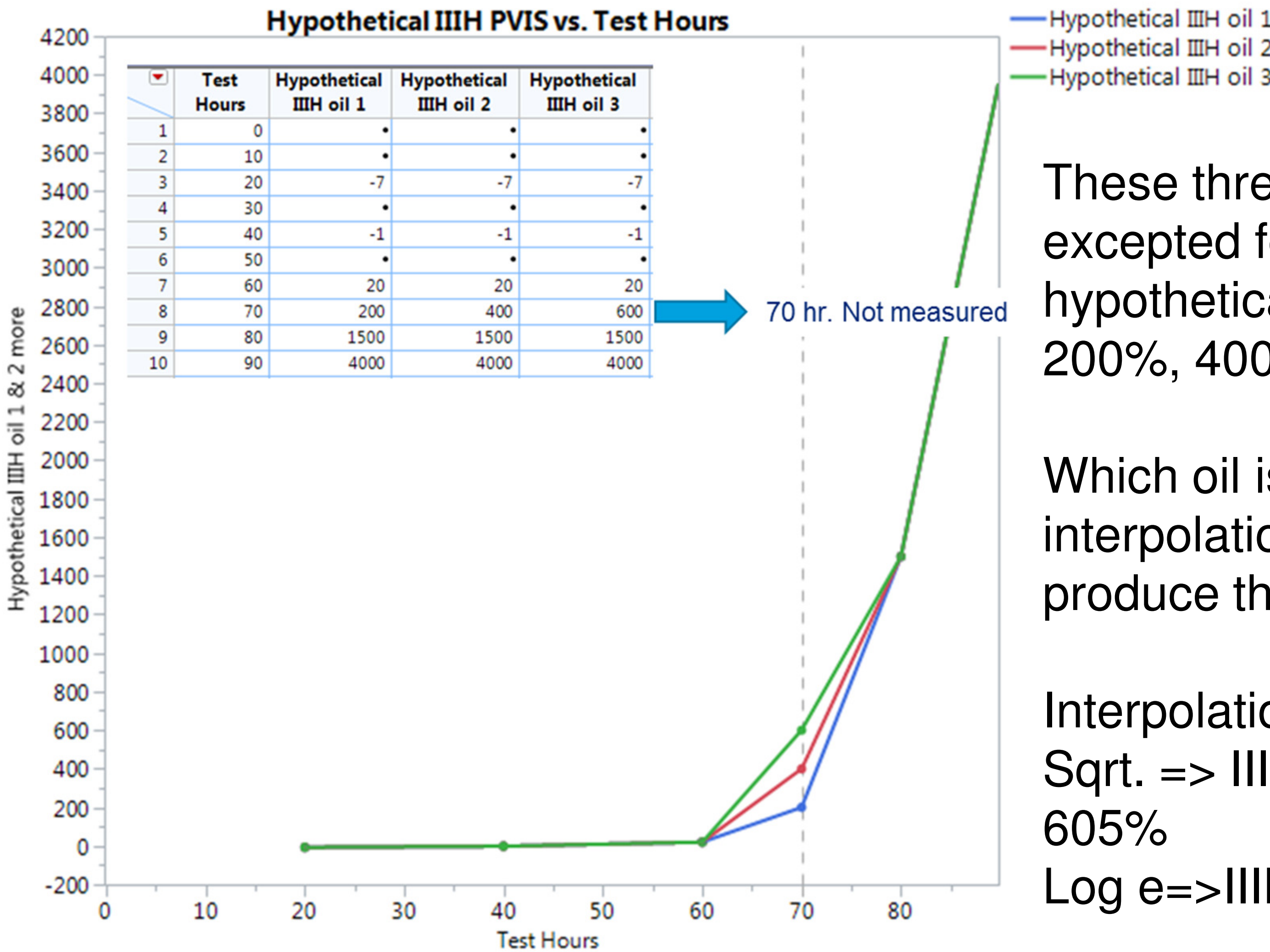
Chevron Oronite

Oil															
Oil Code	VISGrade	BOGroup	BOSaturates	BOSulfur	BOVI	FONoack									
				number	number	number									
A-01	15W40	2	98	0.0006	107	7									
A-02	15W40	2	95	0.0008	105	10									
A-03	15W40	1	81	0.0372	99	10									
Oil	IIIH														
Oil Code	EOTDate	PISTBAT	PVIS20	PVIS40	PVIS60	PVIS80	PVIS90	PVIS90	WPD	WPD	APV				
	date	string	number	number	number	number	number	final	unadjusted	final	final				
A-01	4/16/2017	4	-4.67	-2.37	3.41	297.98	955.2	1153.6	6.13	6.11	9.63				
A-02	6/13/2017	4	7.07	16.18	27.14	199.2	621.02	1093.4	6.26	6.1	9.82				
A-03	6/20/2017	4	1.43	8.33	66.97	922.07	7240.26	12748.1	5.83	5.67	9.95				
Oil	IIIF														
Oil Code	EOTDate	PISTBAT	PVIS10	PVIS20	PVIS30	PVIS40	PVIS50	PVIS60	PVIS70	PVIS80	PVIS80	WPD	WPD	APV	APV
	date	string	number	number	number	number	number	number	number	number	final	unadjusted	final	unadjusted	final
A-01	2/18/2016	1	6.58	12.25	17.12	22.34	26.49	30.09	24.14	145.68	24.1	6.3	6.3	9.84	9.49
A-02	2/18/2017	2	17.07	29.29	39.37	47.29	55.04	61.38	68.75	102.33	68.8	6.62	6.62	9.79	9.42
A-03	12/11/2015	1	17.38	29.79	39.45	46.81	46.7	109.95	290.25	1036.49	290.2	6.52	6.52	9.82	9.47

ADDING UP For 100 Years

Concern: There is no IIIH data at 70 hr. to properly evaluate the transformation selection used with the 70 hr. interpolation

Chevron Oronite



	Test Hours	Hypothetical IIIH oil 1	Hypothetical IIIH oil 2	Hypothetical IIIH oil 3
1	0	•	•	•
2	10	•	•	•
3	20	-7	-7	-7
4	30	•	•	•
5	40	-1	-1	-1
6	50	•	•	•
7	60	20	20	20
8	70	200	400	600
9	80	1500	1500	1500
10	90	4000	4000	4000

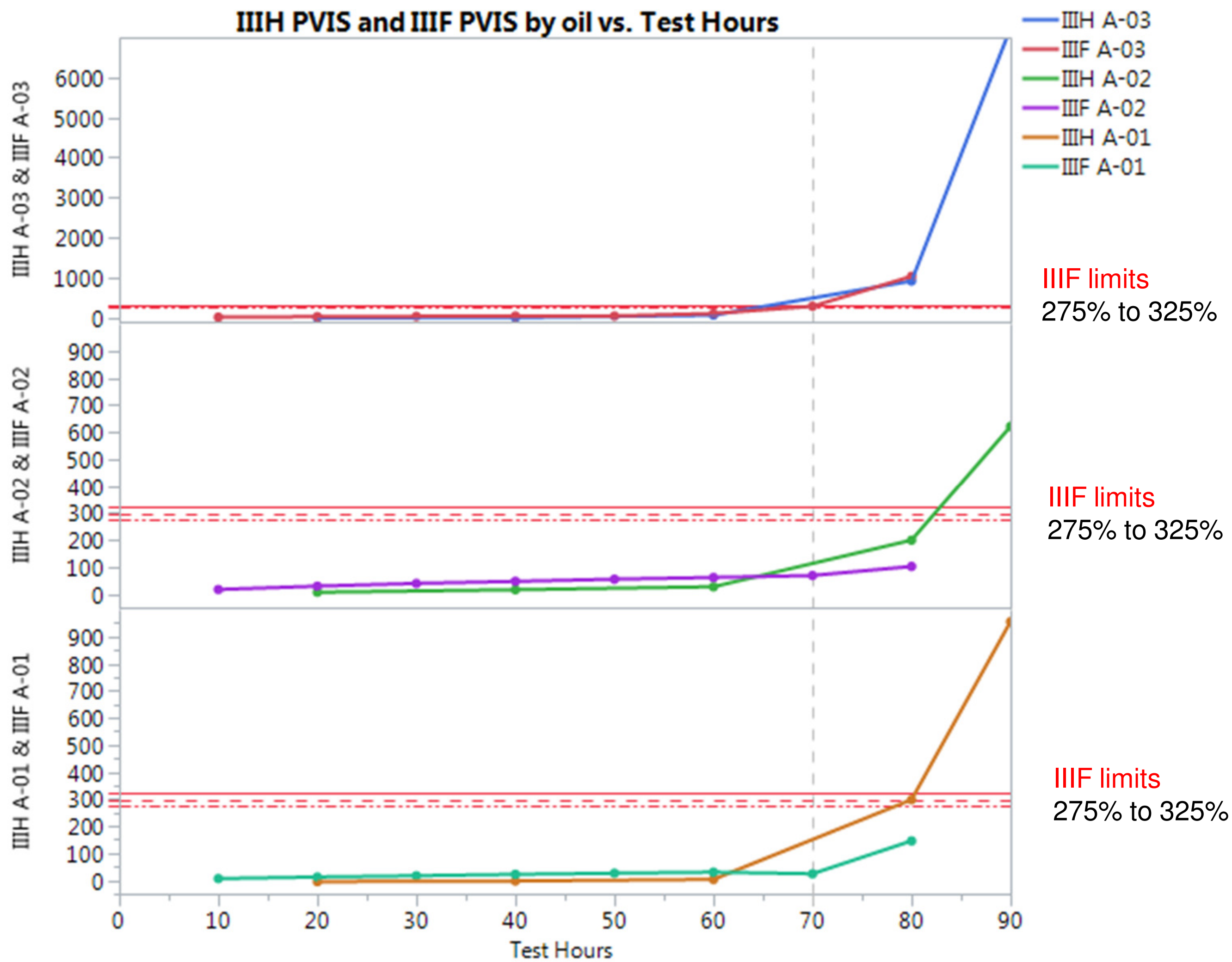
These three oils are identical, excepted for the 70 hr. hypothetical measurement: 200%, 400% or 600%.

Which oil is it? The interpolation will always produce the same number.

Interpolation based on:
Sqrt. => IIIH PVIS @70 = 605%
Log e=>IIIH PVIS @70 = 200%

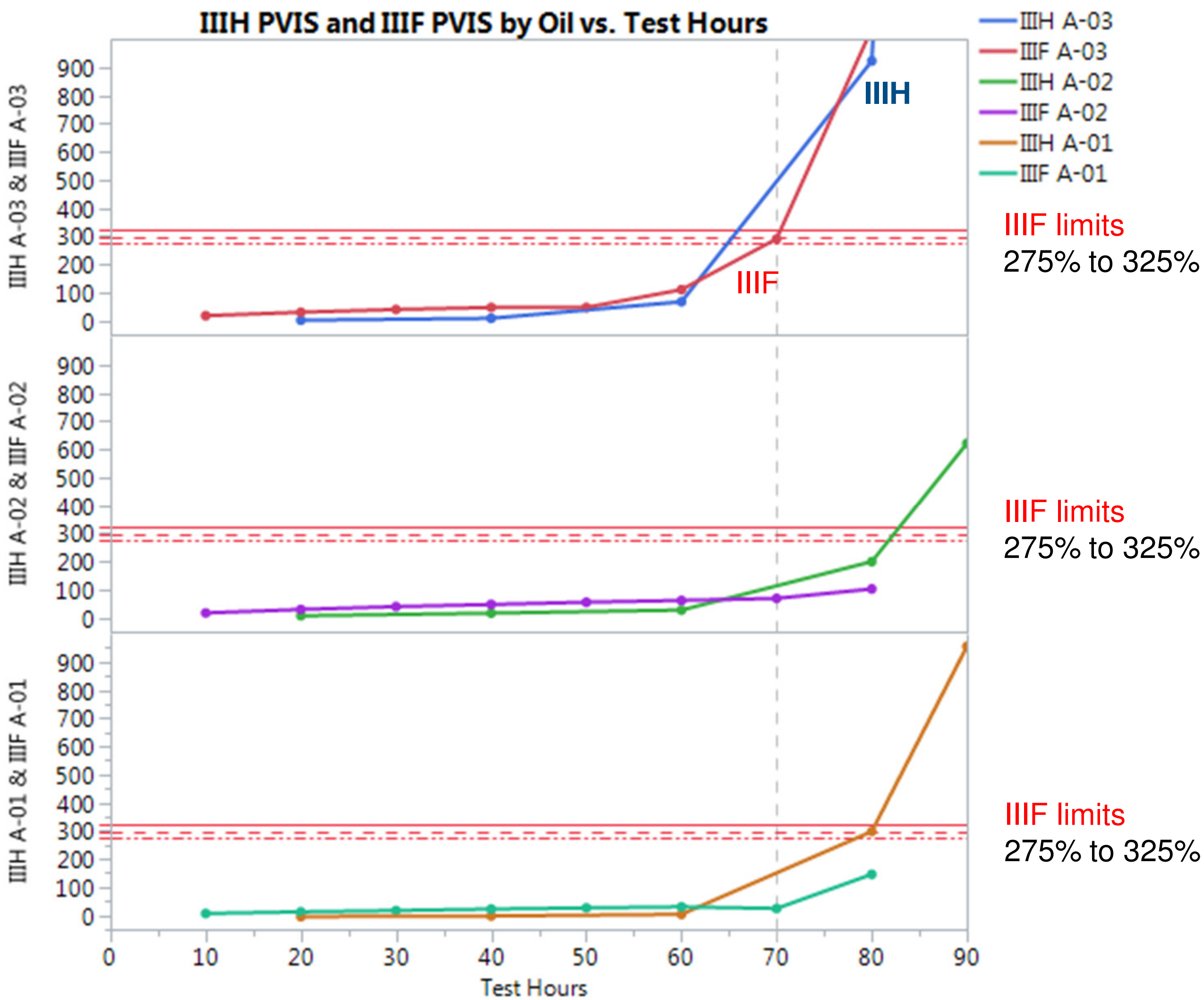
ADDING UP For 100 Years

Candidate data: Below there are three stacked panels Each panel shows a pair of hourly candidate data by Oil: PVIS IIIF vs. PVIS IIIH



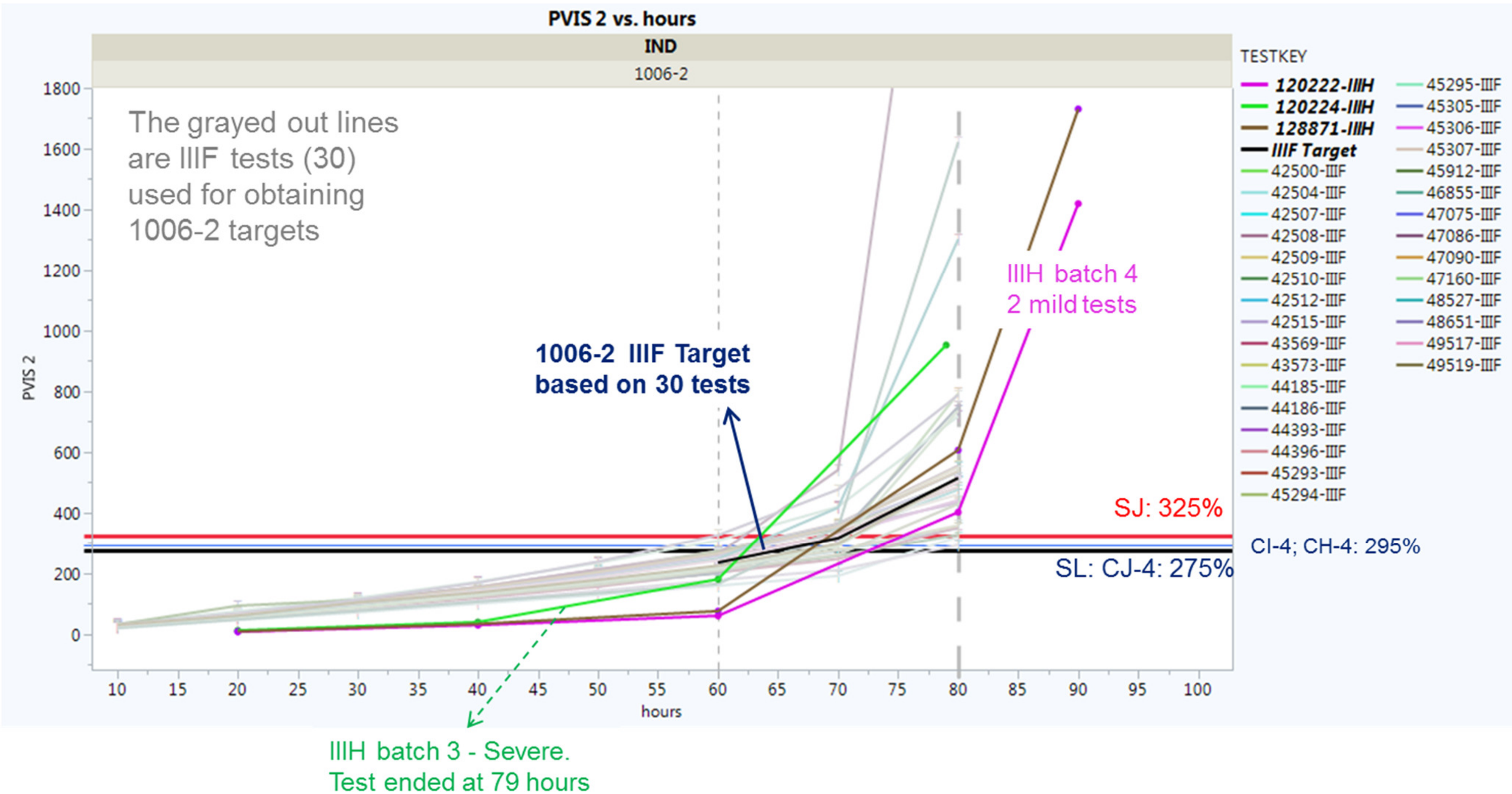
ADDING UP For 100 Years

Candidate data: PVIS IIIF vs. PVIS IIIH by Oil (common scale) Scales are truncated to show more detail for lower values



IIIF hourly PVIS: GF-2 Oil 1006-2

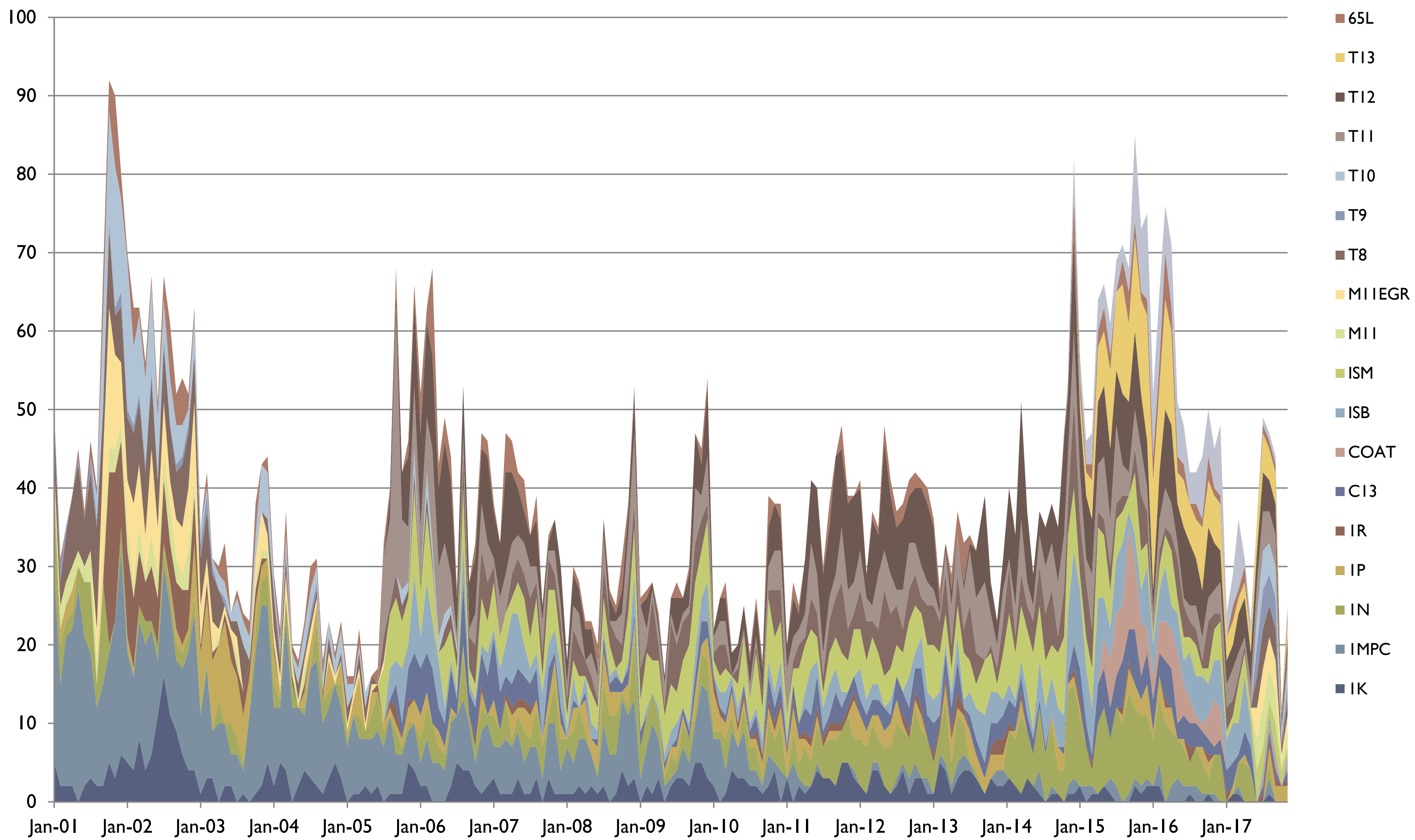
- 1006-2 IIIF Target (based on 30 tests listed on the legend) and three IIIH tests are highlighted below (two from batch 4 and one from batch 3 – this test ended at 79 hours
- The grayed out lines correspond to PVIS IIIF tests used for calculating the target for oil 1006-2 (the PVIS scale is truncated for test 47086)
- Note that IIIH samples every 20 hours, while the IIIF samples every 10 hours



D02.B0.02 Maintenance Report

December 2017

ALL TEST CANDIDATE ACTIVITY



Calibrated Labs and Stands*

Test	Labs	Stands
IK	1	1
IN	4	8
IM-PC	0	0
IP	3	3
IR	1	1
C13	3	3
ISB	3	5
ISM	5	5
EOAT	1	1
RFWT	2	2
T-8/E	2	4
T-11	1	1
T-12/T-12A	4/4	6/6
T-13	4	5
COAT	3	3
DD13	3	4

*As of 09/30/2017

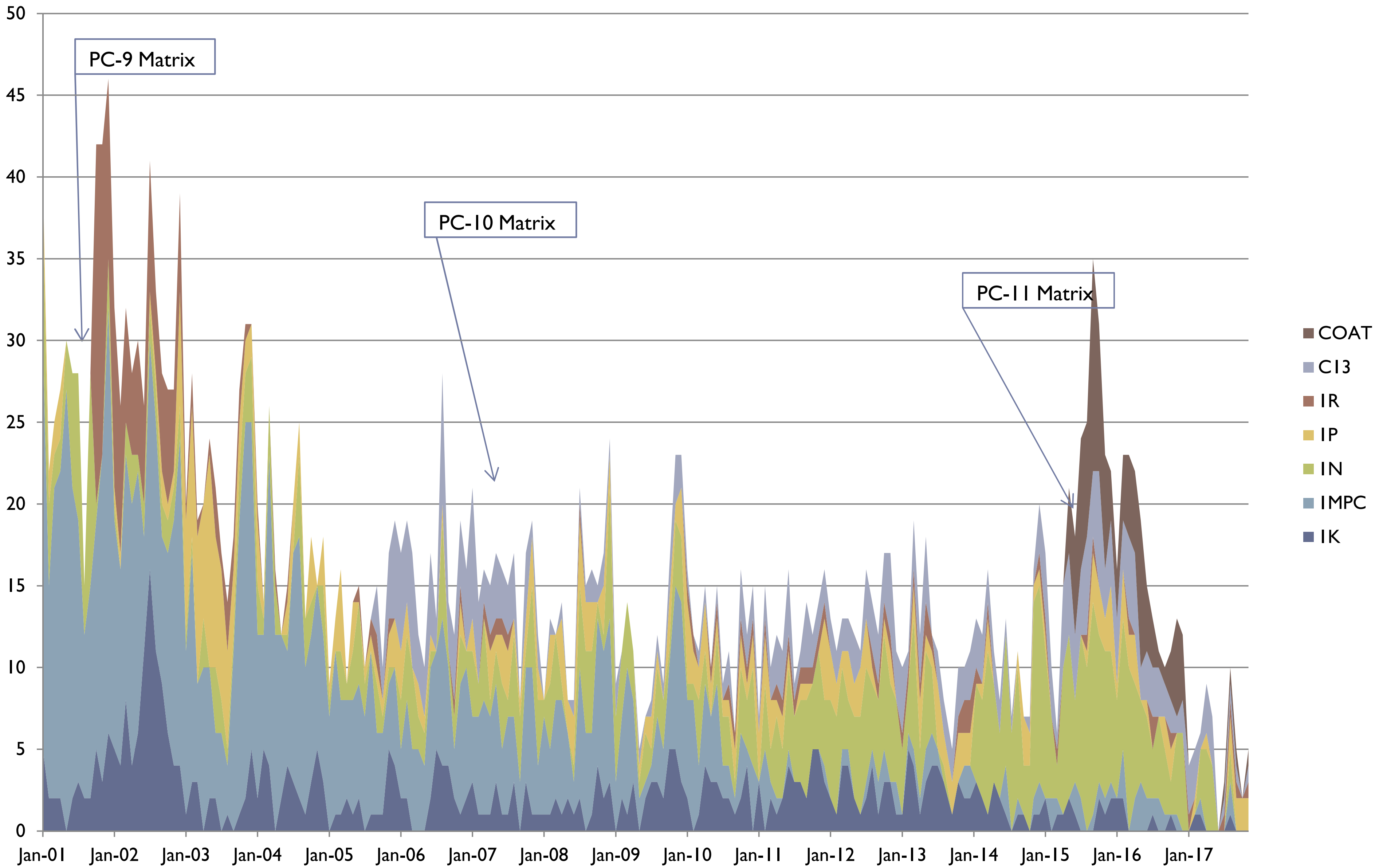
Availability of API CH-4 through CJ-4 Tests for PC-11

Test	Hardware Issues	Availability Through 2022	Notes
Cat 1K/1N	Auxiliary components	Likely	1980's vintage engine. Ongoing resolution of issues with auxiliary stand and miscellaneous components.
Cat 1P/1R	No current issues	Likely	1990's vintage engine. Crankshaft can be ordered. Rings and Liners backordered.
Cat C13	New liners – references anticipated January 2018	Likely	Engine block, injectors, turbos only available through reman. Liners with new material and processing but same specs will be introduced early 2018.

Additional Caterpillar Test Issues

- **Caterpillar Oil Aeration Test**
  - Surveillance panel working to create identical aeration measurement systems for each lab. Anticipated completion before end of the year. Introduction of new systems at each lab with reference tests anticipated beginning of 2018.

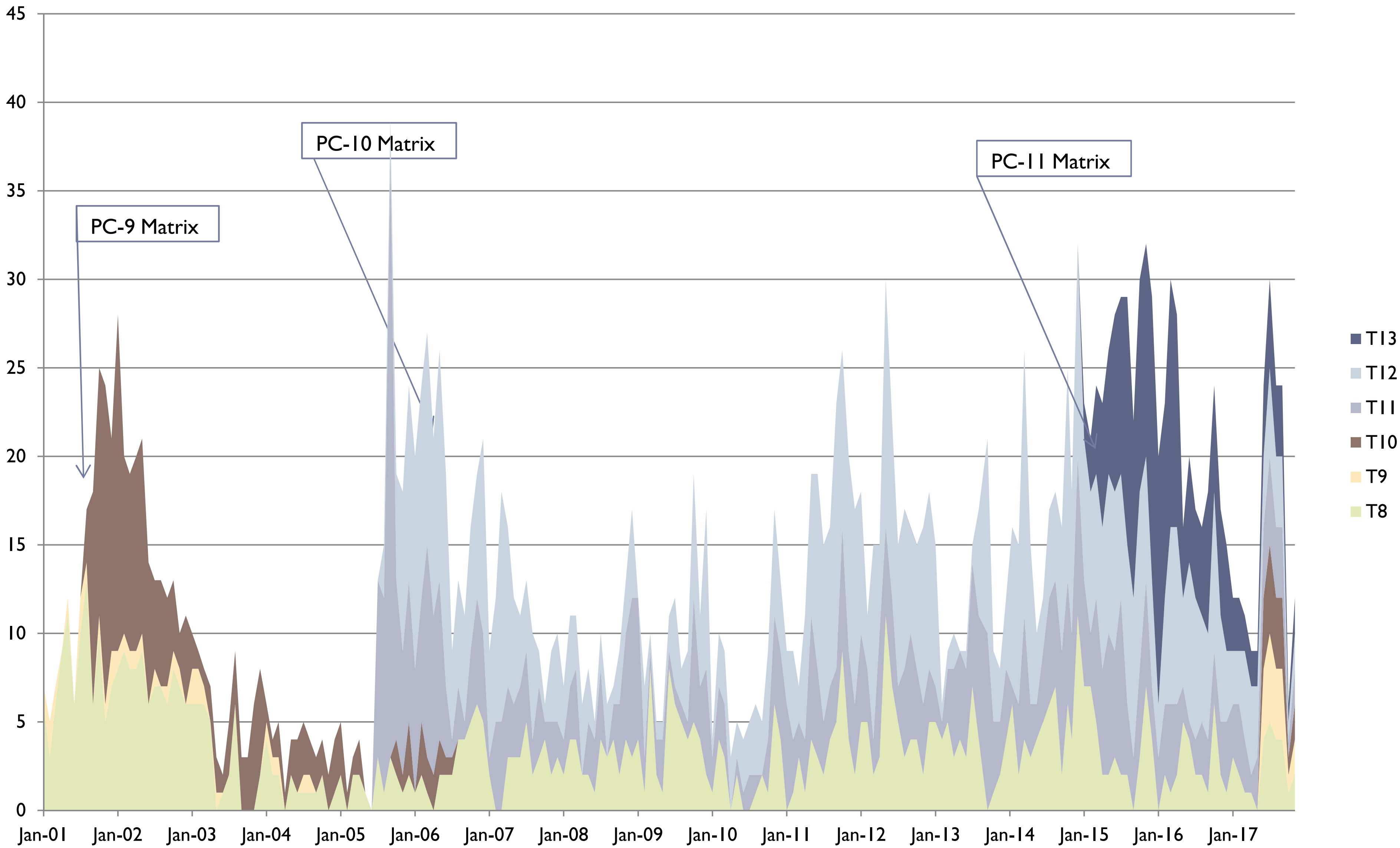
CATERPILLAR CANDIDATE ACTIVITY



Availability of API CH-4 through CJ-4 Tests for PC-11

Test	Hardware Issues	Availability Through 2022	Notes
Mack T-11	Oil Consumption	Likely	Engine production ended 2006. Finite number of engine blocks. Engine build life issues with oil consumption.
Mack T-12	Oil Consumption, head gasket	Likely	Engine production ended 2006. Low demand.

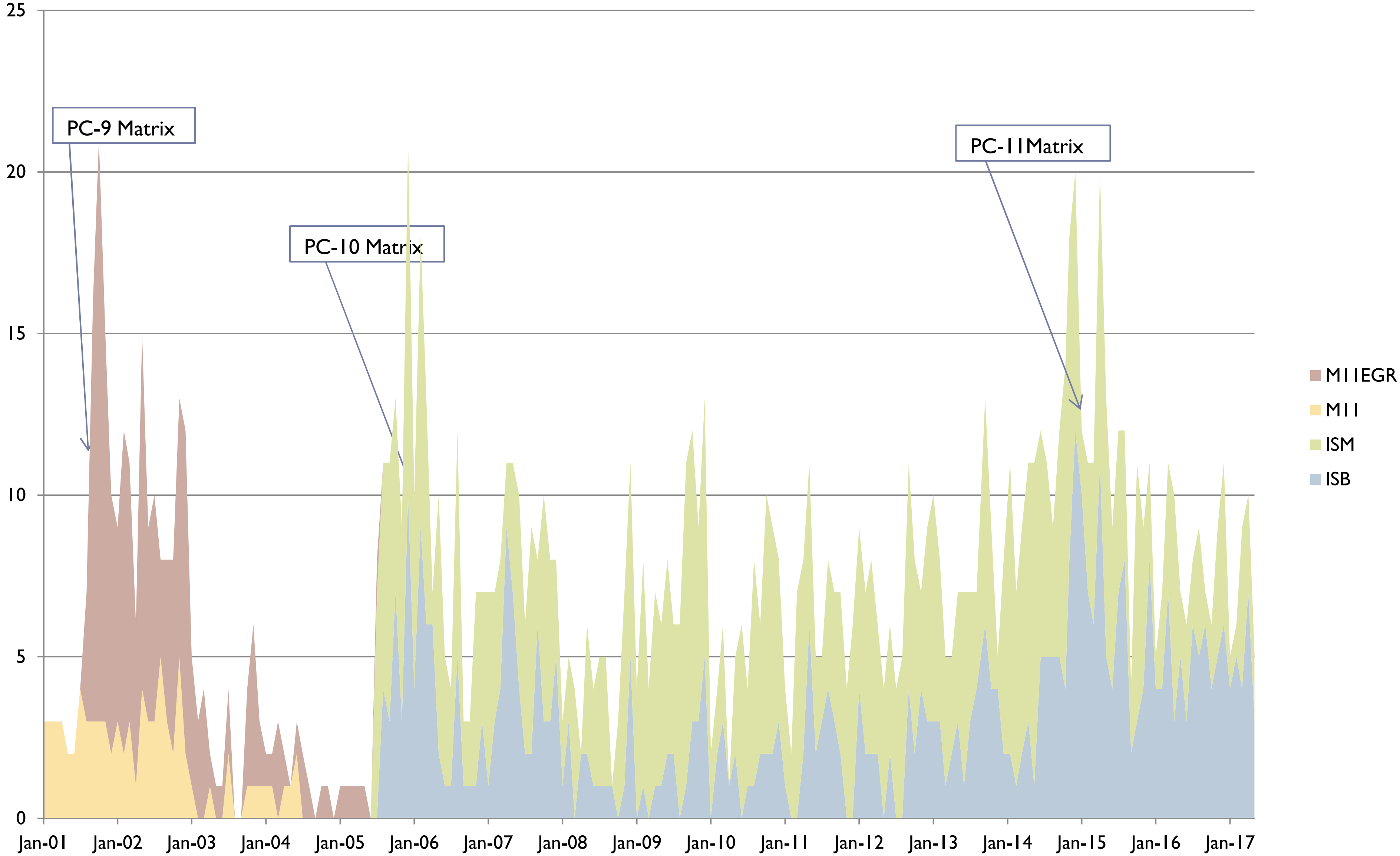
MACK CANDIDATE ACTIVITY



Availability of API CH-4 through CJ-4 Tests for PC-11

Test	Hardware Issues	Availability Through 2022	Notes
Cummins ISM	No current issues	Likely	None
Cummins ISB	No current issues	Likely	Update correction factors for both tappet weight loss and camshaft wear. LTMS updated in November.

CUMMINS CANDIDATE ACTIVITY



Availability of API CH-4 through CJ-4 Tests for PC-11

Test	Hardware Issues	Availability Through 2022	Notes
RFWT	None	Likely	Long term supply of test parts at CPD. 6.5 L engine no longer in production at AM General, but available through supply network. Injection pump still available.
Seq IIIF/IIIG	Hardware depletion Dec 2017	No	Hardware depletion projected 4Q 2017. IIIH to IIIG limits to be defined by industry.
EOAT	Using last known hardware	No	Oil Temperature runs higher w/ current EOAT engine. Still no official EOAT / COAT correlation. Engine hardware available for one rebuild.

B2 Action Items

- **No Action Items**
- **Comments**

DAIMLER

ASTM 8074 - DD13 Scuffing Test
Suzanne Neal & Patrick Joyce
December 5th, 2017

Daimler Trucks

Daimler Surveillance Panel

Initiated	ASTM June 2016
Chairman	Patrick Joyce – Lubrizol Corporation
Secretary	Jose Starling – Southwest Research Institute
OEM Representative	Suzanne Neal – Daimler
TMC Representative	Sean Moyer
Next Meetings	To be determined – waiting on shipment of liners to arrive.

Test Status & Parts Availability

- **Status of the Test**
  - Available,
  - Test labs are planning reference more test stands. Waiting for all batched parts to be available.
- **Parts Availability**
  - Referencing new batch of top rings
    - ~ 2200
    - ~ 366 Engine Builds (6 Top Rings per engine)
  - Referencing new batch of Pistons
    - ~ 1600 Pistons
    - ~ 266 Engine Builds (6 Pistons per engine)
  - *In Progress - Batched liners to TEI*
    - ~ Ordered 2000 Batched Liners – waiting on shipment
    - ~ 333 Engine Builds (6 Liners per engine)

Caterpillar Oil Aeration Test Updates

Hind Abi-Akar

HDEOCP Meeting

Dec 5, 2017

Houston, TX

COAT Status

Meetings:

- Working group and Surveillance panel
  - Multiple remote meetings and face-to-face meeting
  - Meeting with Flow meter supplier Emerson, Aug 2017

Test is available for candidate testing

- One stand is referenced and available for testing

Current activities Goal: decrease variability and variation among labs

- Based on an analysis and statistical models of the test matrix, no changes to the current standard deviations were required
- TMC: additions to data dictionary (Form 6) and to the Test Summary (Form 4)

COAT IMPROVEMENT PLAN

Caterpillar Surveillance Panel goal: Improve the current COAT test and bring all labs closer to target

Evaluate options for density measurements

Applied lessons learned and Emerson recommendations

Agreed upon one path to measure density at consistent temperature of the MM

Planning

Plan developed to align stand setups, correct operational differences and have uniform calibration procedure

New hardware is being built to maximize consistency, will be validated before use, and then used by all labs

Implementation

Implementation and shakedown are planned

Calibration testing will follow and completion is expected at end of Dec 2017

CAT

Cummins ISB Industry Correction Factor changes and LTMS Update

Effective		Condition	Description
From	To		
21-Apr-11	18-Oct-17	All tests using batch B tappets with batch E, F, and G cams	Multiply ATWL by 0.637; Add -9.5 to ACSW
11-Dec-11	12-Nov-12	All tests using batch C tappets with batch H cams	Multiply ATWL by 0.637; Add -9.5 to ACSW
13-Nov-12	18-Oct-17	All tests using batch C tappets with batch H and J cams	Multiply ATWL by 0.711; Add -5.6 to ACSW
None	18-Oct-17	All test using batch D tappets and batch K cams	Multiply ATWL by 1; Add -11.3 to ACSW
19-Oct-17	***	All test using batch D tappets, batch K cams, and batch E crossheads	Multiply ATWL by 0.7851; Add -18.5 to ACSW

Also, the Cummins Surveillance Panel adopted the 'newer' style LTMS for the ISB test and Severity Adjustments (stand based) for the first time. This is currently out for 2 week review.

Jim Moritz, Cummins Surveillance Panel Chairman, December 5, 2017

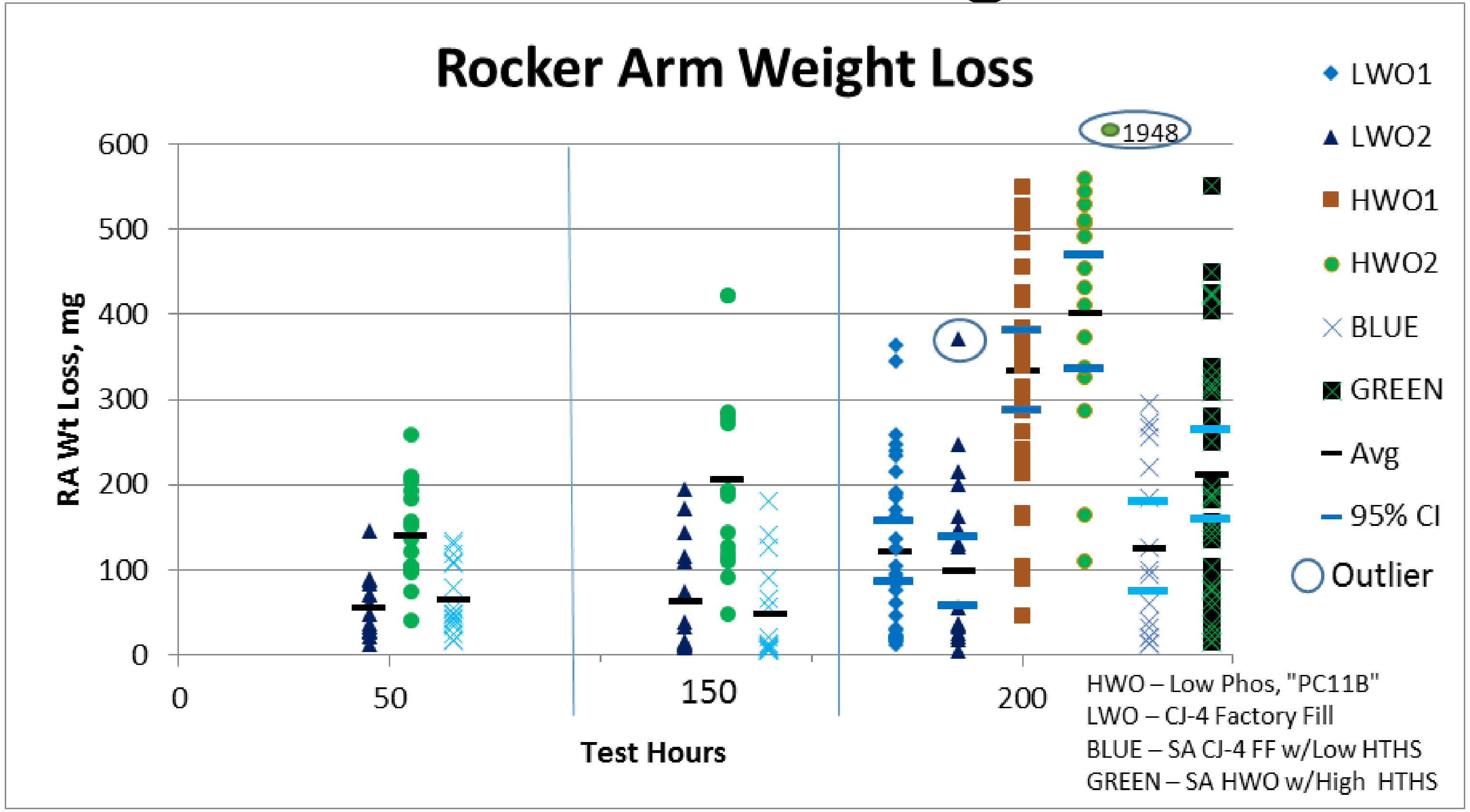
6.7L Valvetrain Wear Test Update

Ron Romano
December 5, 2017

6.7L Valvetrain Wear Test

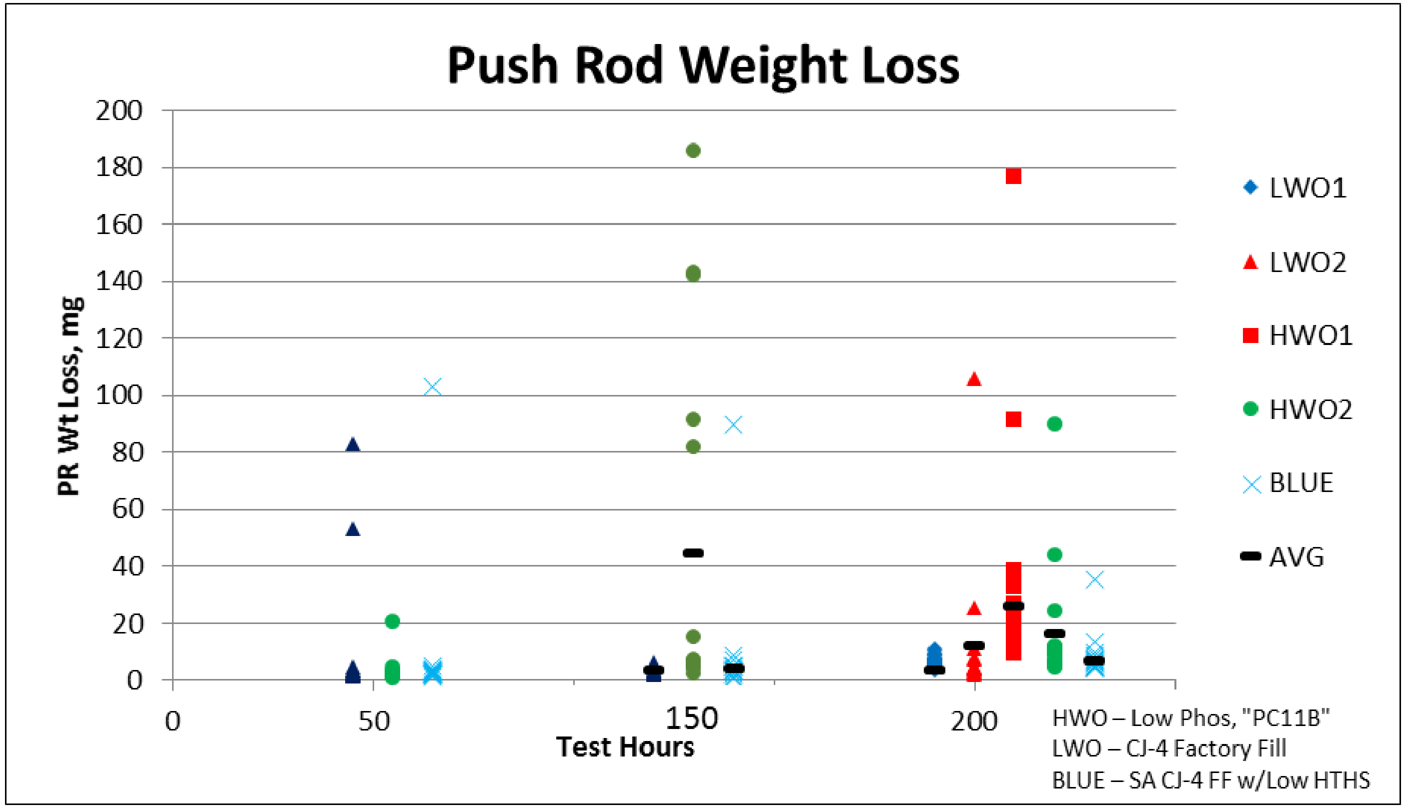
- Procedure
  - 7-10 hour soot stage – 2600 rpm/WOP (740 Ft-#) – Target 2-2.5% soot
  - 200 hour wear stage – Peak Power - 2800 rpm/825 Ft-#
  - 1st High Wear Oil (HWO), Low Wear Oil (LWO) and Green tests ran 200 hours on all the Valve Train (VT) components
  - 2nd HWO, LWO and Blue oil ran 200 hours on right VT components and 150 hours on left VT components. (to observe time effect)
- Oils tested
  - HWO – “PC11B”
    - 3.0 HTHS150
    - 800 ppm phosphorus
  - LWO – CJ-4 Factory Fill
    - 3.5 HTHS150
    - 1100 ppm phosphorus
  - Blue – S/A CJ-4 Factory Fill w/Low HTHS150
    - 3.0 HTHS150
    - 1100 ppm phosphorus
  - Green – S/A HWO w/High HTHS150
    - 3.5 HTHS150
    - 800 ppm phosphorus

Rocker Arm Weight loss



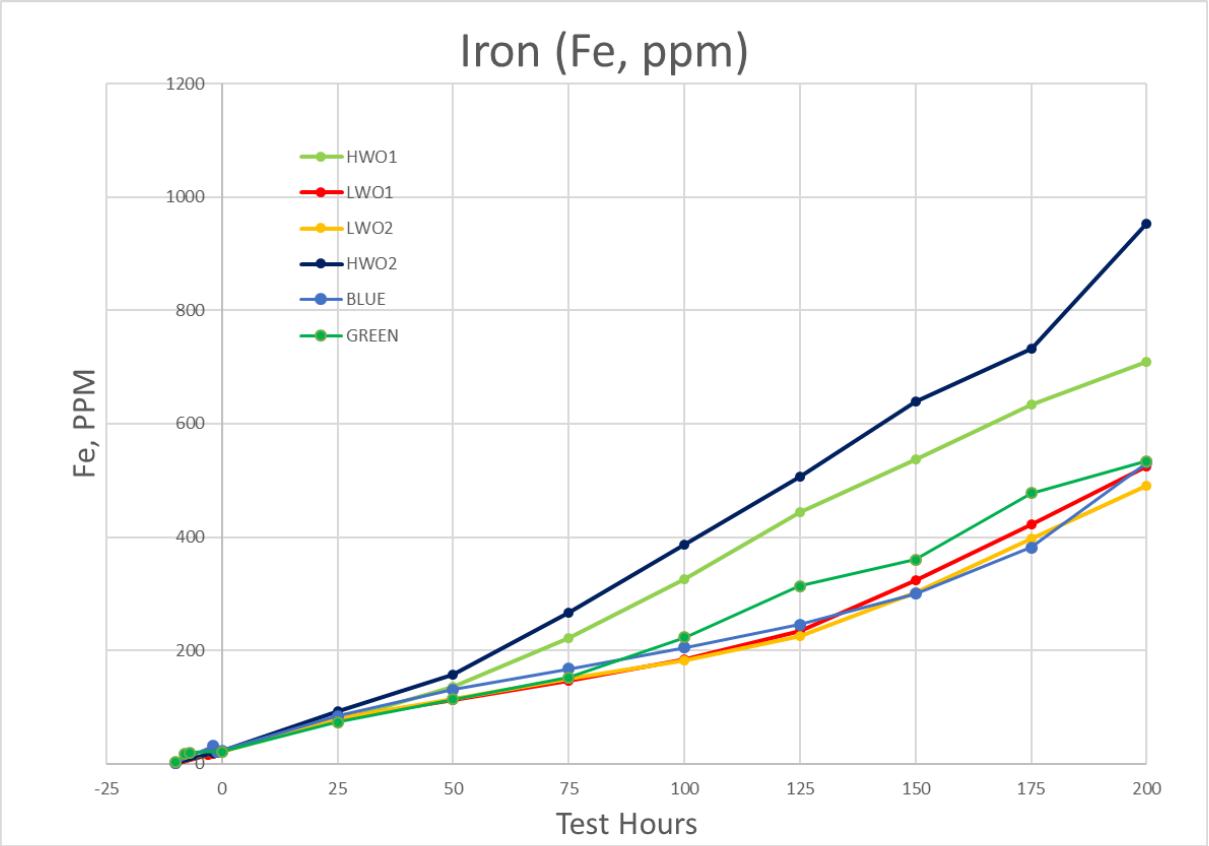
- 200 hours
  - Good separation on average weight loss between the HWO and LWO
  - Good repeatability between tests
  - Acceptable overlap between HWO and LWO on the individual Rocker Arm weight loss.
  - Considered good measurement criteria
  - Blue oil provided similar wear results to the LWO indicating that the test responds to anti-wear chemistry
  - Green oil results were between LWO and Blue oils and the HWO indicating that test responds to viscosity
- 150 hours
  - Showed good separation on the average weight loss but not as much as 200 hour components
  - Unacceptable overlap in the data between the HWO and LWO. HWO only having a few (6) data point outside the LWO range

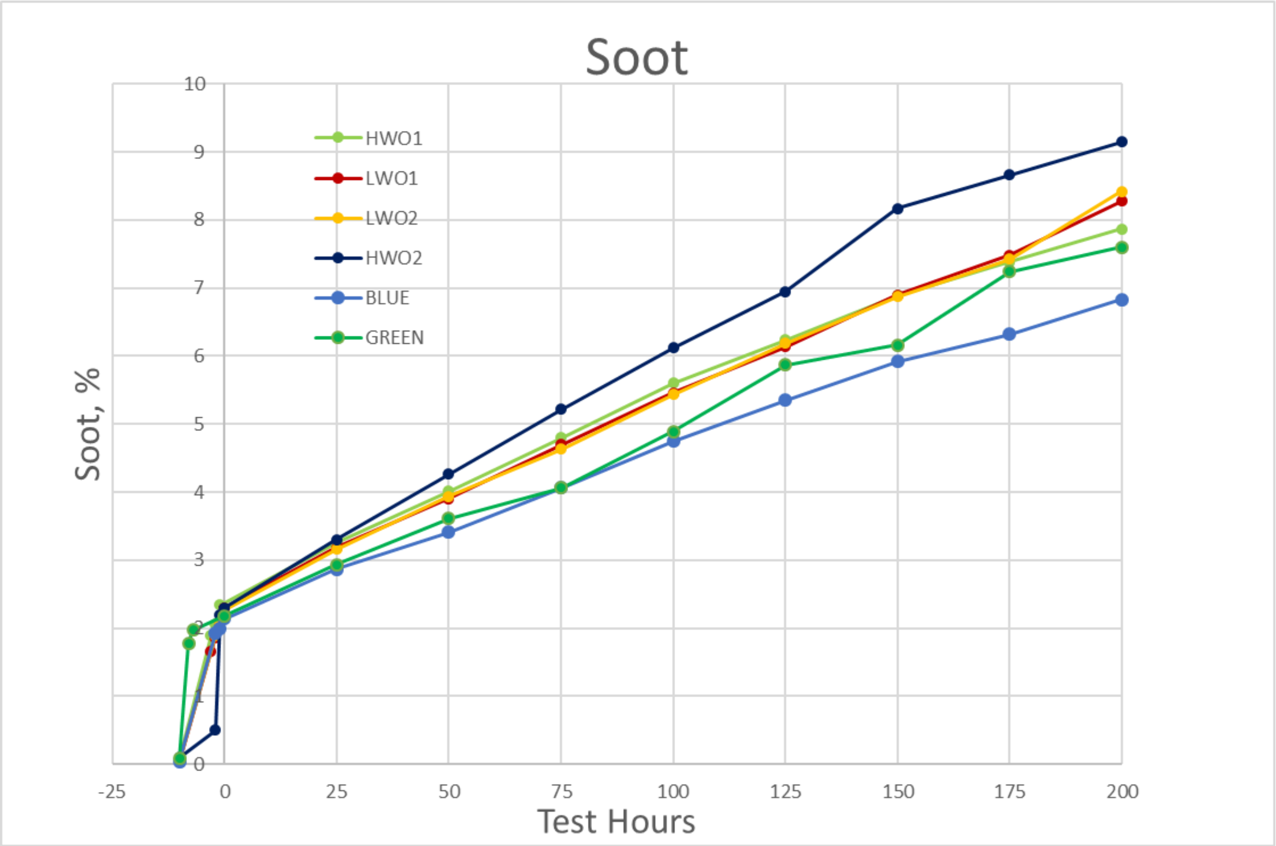
Push Rod Weight Loss



- Push rod wear showed large variation in wear throughout the engine
  - Only a small number of rods in each engine showed high wear in the HWO making the average wear relatively meaningless.
- The high variation led to poor discrimination between the HWO and LWO
- Due to large variability in wear within the engine, push rod wear was eliminated as a measurement criteria

Oil Analysis





- Iron levels were repeatable
- Soot levels were repeatable. Blue and green oil tests used new injectors for both these tests. Injectors were replaced after the 4th test (HWO@ due to higher soot than the previous tests.
- Blue oil provided similar iron levels to the LWO again indicating that the test responds to anti-wear chemistry.
- Green oil test showed slightly higher iron levels than the LWO and Blue oil tests correlating with the increased rocker arm wear

Questions

ASTM D4485 3 Terminology & 4 Performance Classification

Laura Birnbaumer
Automotive Engine Oil Product Qualification

ASTM
Houston, TX

December 4-6, 2017

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For 100 Years

ASTM D4485 3 Terminology & 4 Performance Classification

WK59621 to align D4485 with API 1509 reveled some surprises with missing entries and the incorrect labeling of some examples:

I move the following changes be made to D4485 Sections 3 and 4

1. Remove "Resource Conserving" from 3.1.2 *category,*
2. Add 3.1.X *supplementary classification, n-in engine oils*, a designation, such as Resource Conserving and SN Plus, for a given level of performance beyond that of a category in specified engine and bench tests.
3. Add 3.2.X *Resource Conserving supplementary classification, n*-the group of engine oils that have demonstrated fuel economy benefits, greater emission system and turbocharger protection and help protect engines operating on ethanol-containing fuels up to E85.
4. Add 3.2.X *F category, n*-a group of certain XW-30 oils specifically formulated for use in diesel engines designed to meet 2017 model year on-highway greenhouse gas (GHG) emission standards.
5. Add "F" and "Resource Conserving" to 4.1 after "S," and "C," and change the "three" to "four."

ASTM D4485 3 Terminology & 4 Performance Classification

Adobe Acrobat Document

3.1.2 *category, n—in engine oils*, a designation such as SJ, SL, SM, SN, CH-4, CI-4, CJ-4, CK-4, FA-4, Energy Conserving, Resource Conserving, and so forth, for a given level of performance in specified engine and bench tests.

3.1.3 *classification, n—in engine oils*, the systematic arrangement into categories in accordance with different levels of performance in specified engine and bench tests.

3.1.4 *heavy duty, adj—in internal combustion engine operation*, characterized by average speeds, power output, and internal temperatures that are generally close to the potential maximums.

3.1.5 *heavy-duty engine, n—in internal combustion engine types*, one that is designed to allow operation continuous at or close to its peak output.

3.1.6 *light-duty, adj—in internal combustion engine operation*, characterized by average speeds, power output, and internal temperatures that are generally much lower than the potential maximums.

3.1.7 *light-duty engine, n—in internal combustion engine types*, one that is designed to be normally operated at substantially less than its peak output.

3.1.7.1 *Discussion*—This type of engine is typically installed in automobiles and small trucks, vans, and buses.

3.1.8 *lugging, adj—in internal combustion engine operation*, characterized by a combined mode of relatively low-speed and high-power output.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *C category, n*—the group of engine oils that are intended primarily for use in diesel and certain gasoline-powered vehicles.

3.2.2 *Energy Conserving category, n*—the group of engine oils that have demonstrated fuel economy benefits and are intended primarily for use in automotive gasoline engine applications, such as passenger cars, light-duty trucks, and vans.

3.2.3 *engine oil, n*—a lubricating liquid with additives that reduces friction or wear, or both, between the moving parts within an engine; removes heat, serves as a combustion-gas sealant for piston rings; and reduces potentially harmful effects such as rusting, deposit formation, oil oxidation, and foaming resulting from engine operation.

3.2.4 *S category, n*—the group of engine oils that are intended primarily for use in automotive gasoline engine applications, such as passenger cars, light-duty trucks, and vans.

4. Performance Classification

4.1 Automotive engine oils are classified in three general arrangements, as defined in 3.2; that is, S, C, and Energy Conserving. These arrangements are further divided into categories with performance measured as follows:

4.1.1 *SJ*—Oil meeting the performance requirements measured in the following gasoline engine tests and bench tests:

4.1.1.1 Test Method D5844, the Sequence IID, gasoline engine test has been correlated with vehicles used in short-trip service prior to 1978,[5,8] particularly with regard to rusting. (An alternative is Test Method D6557, the Ball Rust Test.)

4.1.1.2 Test Method D5533, the Sequence IIIE gasoline engine test, has been correlated with vehicles used in high-temperature service prior to 1988,[9] particularly with regard to oil thickening and valve train wear. (Alternatives are Test Method D6984, the Sequence IIIF test, or Test Method D7320, the Sequence IIIG test.)

4.1.1.3 Test Method D5302, the Sequence VE gasoline engine test, has been correlated with vehicles used in stop-and-go service prior to 1988,[10] particularly with regard to sludge and valve train wear. (An alternative is the combination of Test Method D6593, the Sequence VG test, and Test Method D6891, the Sequence IVA test.)

4.1.1.4 Test Method D5119, the L-38 gasoline engine test, is used to measure copper-lead bearing weight loss under high-temperature operating conditions. (An alternative is Test Method D6709, the Sequence VIII test.)

(1) Test Method D5119 (or Test Method D6709) is also used to determine the ability of an oil to resist permanent viscosity loss due to shearing in an engine.

4.1.1.5 In addition to passing performance in the engine tests, specific viscosity grades shall also meet bench test requirements (see Table 1), which are discussed in the following subsections:

(1) The volatility of engine oils is one of several factors that relates to engine oil consumption.

(2) Test Method D6795, the EOFT screens for the formation of precipitates and gels that form in the presence of water and can cause oil filter plugging.

(3) Phosphorus compounds in excessive amounts can cause glazing of automotive catalysts and exhaust gas oxygen sensors and, thereby, deactivate them. Control of the phosphorus level in the engine oil may reduce this tendency.

(4) The flash point may indicate if residual solvents and low-boiling fractions remain in the finished oil.

(5) Excessive foaming in engine oil can cause valve lifter collapse and a loss of lubrication due to the presence of air in the oil. Test Methods D892 and D6082 empirically rate the foaming tendency and stability of oils.

(6) Test Method D6922, the H and M Test indicates the compatibility of an oil with standard test oils.

(7) Newer engines designed to provide increased power and improved driveability and to meet future federal emissions and fuel economy requirements may be sensitive to internal deposits caused by elevated engine operating temperatures. Test Method D6335, the TEOST test, may be useful in determining the deposit control of oils recommended for these engines.

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[8] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1473. Contact ASTM Customer Service at service@astm.org.

[9] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1471. Contact ASTM Customer Service at service@astm.org.

[10] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1273. Contact ASTM Customer Service at service@astm.org.

Chevron Oronite

ASTM D4485 Table 3

Laura Birnbaumer
Automotive Engine Oil Product Qualification

ASTM Heavy Duty Class Panel
Houston, TX

December 5, 2017

ASTM D4485 Table 3

All of the current API C Service Categories are contained within the same table in ASTM D4485 – presently Table 3.

During the last update to Table 3, the addition of CK-4 and FA-4, Jessica L. Barrett, Manager of ASTM Standards Publications was quoted as saying "This was a doozy, and I'm sorry it took me so long to get it to you. The tables were a lot of work, and they're still very messy. I think you could consider breaking Table 3 into several smaller tables and be just fine." [Barrett, Jessica L. " RE: Finally, review of ASTM D4485-16, item #53 and 54 on D021604", message to Lyle Bowman, Birnbaumer, Laura, Fick, Alyson 2/17/2017 E-mail]

This is because physically "Table 3 is really a collection of several smaller tables." [2/27/2017] "it's basically 8ish different tables scotch-taped together." [2/22/2017] "It was already a complicated table to begin with and became more complicated for me to include new information". [2/22/2017]

ASTM D4485 Table 3

Ms. Barrett's perspective is from an editorial/publication standpoint and her comments more "about how unwieldy the table" [2/22/2017] is. She is leaving it up to us "technical experts" to decide how to group the API C Service Categories.

I propose the following grouping of the API C Service Categories in ASTM D4485 Tables:

The first table: CH-4 and CI-4
The second table: CJ-4 and CK-4
The third table: FA-4.

ASTM D4485 Table 3

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Document

Designation: D4485 – 16

Standard Specification for Performance of Active API Service Category Engine Oils[1]

This standard is issued under the fixed designation D4485; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

INTRODUCTION

This specification covers all the currently active American Petroleum Institute (API) engine oil performance categories that have been defined in accordance with the ASTM consensus process. There are organizations with specifications not subject to the ASTM consensus process, such as the International Lubricant Standardization and Approval Committee (ILSAC), American Petroleum Institute (API – SM, SN Specifications), and the Association des Constructeurs Europeans d'Automobiles (ACEA). Certain of these specifications, which have been defined primarily by the use of current ASTM test methods, have also been included in the Appendixes for information.

In the ASTM system, a specific API designation is assigned to each category. The system is open-ended, that is, new designations are assigned for use with new categories as each new set of oil performance characteristics are defined. Oil categories may be referenced by engine builders in making lubricant recommendations, and used by lubricant suppliers and customers in identifying products for specific applications. Where applicable, candidate oil programs are conducted in accordance with the American Chemistry Council (ACC) Petroleum Additives Product Approval Code of Practice.

Other service categories not shown in this document have historically been used to describe engine oil performance (SA, SB, SC, SD, SE, SF, SG, SH and CA, CB, CC, CD, CD-II, CE, CF, CF-2, CF-4, CG-4) (see 3.1.2). SA is not included because it does not have specified engine performance requirements. SH is not included because it was a category that could not be licensed for gasoline engine oil use in the API Service Symbol after Dec. 2, 2010. (Note—The SH category has been included in Appendix X8 as relevant information in combination with "C" categories.) The others are not included because they are based on test methods for which engine parts, test fuel, or reference oils, or a combination thereof, are no longer available. Also, the ASTM 5-Car and Sequence VI Procedures are obsolete and have been deleted from the category Energy Conserving and Energy Conserving II (defined by Sequence VI). Information on excluded older categories and obsolete test requirements can be found in SAE J183.

1. Scope*

1.1 This specification covers engine oils for light-duty and heavy-duty internal combustion engines used under a variety of operating conditions in automobiles, trucks, vans, buses, and off-highway farm, industrial, and construction equipment.

1.2 This specification is not intended to cover engine oil applications such as outboard motors, snowmobiles, lawn mowers, motorcycles, railroad locomotives, or oceangoing vessels.

1.3 This specification is based on engine test results that generally have been correlated with results obtained on reference oils in actual service engines operating with gasoline or diesel fuel. As it pertains to the API SL engine oil category, it is based on engine test results that generally have been correlated with results obtained on reference oils run in gasoline engine Sequence Tests that defined engine oil categories prior to 2000. It should be recognized that not all aspects

[1] This specification is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.B0 on Automotive Lubricants.

Current edition approved Dec. 15, 2016. Published March 2017. Originally approved in 1985. Last previous edition approved in 2015 as D4485 – 15a. DOI: 10.1520/D4485-16.

*A Summary of Changes section appears at the end of this standard

TABLE 3 C Engine Oil Categories

Category	Test Method	Rated or Measured Parameter	Primary Performance Criteria		
			One-test	Two-test[A]	Three-test[A]
CH-4	D6681 (1P)[B]	Weighted demerits (WDP), max	350	378	390
		Top groove carbon (TGC), demerits, max	36	39	41
		Top land carbon (TLC), demerits, max	40	46	49
		Average Oil Consumption, g/h (0 h – 360 h), max	12.4	12.4	12.4
		Final Oil Consumption, g/h (312 h – 360 h), max	14.6	14.6	14.6
		Piston, ring, and liner scuffing	none	none	none[C]
	D6750 (1K)[D]	Weighted demerits (WDK), %, max	332	347	353
		Top groove fill (TGF), %, max	24	27	29
		Top land heavy carbon (TLHC), %, max	4	5	5
		Average Oil Consumption, g/kWh (0 h – 252 h), max	0.54	0.54	0.54
		(g/MJ) (0 h – 252 h), max	(0.15)	(0.15)	(0.15)
		Piston, ring, and liner scuffing	none	none	none[C]
	D6483 (T-9)	Average Liner Wear, normalized to 1.75 % soot, μm max	25.4	26.6	27.1
		Average Top Ring Mass Loss, mg max[E]	120	136	144
		EOT Used Oil Lead Content less New Oil Lead Content, mg/kg, max	25	32	36
	or, D6987/D6987M (T-10)	Liner wear, μm, max	32	34	35
		Ring wear, mg, max	150	159	163
		Lead content at EOT, mg/kg, max	50	56	59
	or, D7422 (T-12)	Liner wear, μm, max	30.0	30.8	31.1
		Top Ring Mass Loss, mg, max	120	132	137
		Lead content at EOT, mg/kg, max	65	75	79
	D5966 (RFWT)	Average Pin Wear, mils, max	0.30	0.33	0.36
		(μm) max	(7.6)	(8.4)	(9.1)
	D6838 (M11)[F]	Rocker Pad Average Mass Loss, normalized to 4.5 % soot, mg max	6.5	7.5	8.0
		Oil Filter Differential Pressure at EOT, kPa max	79	93	100
		Average Engine Sludge, CRC Merits at EOT, min	8.7	8.6	8.5
	or, D7468 (ISM)	Crosshead wear, mg, max	7.5	7.8	7.9
		Oil filter delta pressure, at 150 h, kPa, max	79	95	103
		Sludge rating, CRC merits, min	8.1	8.0	8.0
	D5967 (Ext. T-8E)[G]	Relative Viscosity at 4.8 % Soot by TGA, max	2.1	2.2	2.3
		Viscosity increase at 3.8 % Soot by TGA, mm^2/s, max	11.5	12.5	13.0
	D6984 (Sequence IIIF)	60 h Viscosity at 40 °C, increase from 10 min sample, % max	295	295 (MTAC)[H]	295 (MTAC)[H]
	or D7320 (Sequence IIIG)[I]	Kinematic viscosity, % increase at 40 °C max	150	150 (MTAC)	150 (MTAC)
	D6894 (EOAT)[J]	Aeration, volume, % max	8.0	8.0 (MTAC)[H]	8.0 (MTAC)[H]
	D6594 (135 °C, HTC BT)	Used Oil Elemental Concentration			
		Copper, mg/kg increase, max	20		
		Lead, mg/kg increase, max		120	
		Tin, mg/kg increase		report	
		Copper strip rating,[K] max		3	
	D892 (Option A not allowed)	Foaming/Settling,[L] mL, max			
		Sequence I	10/0		
		Sequence II	20/0		
		Sequence III	10/0		
			SAE 10W-30	SAE 15W-40	
	D5800 or	percent volatility loss at 250 °C, max	20	18	
	D6417	percent volatility loss at 371 °C, max	17	15	
	D6278	Kinematic Viscosity after shearing,	SAE XW-30	SAE XW-40	
		mm^2/s, min	9.3	12.5	
			One-test	Two-test[M]	Three-test[M]
CI-4	D6923 (1R)	Weighted demerits (WDR), max	382	396	402
		Top groove carbon (TGC), demerits, max	52	57	59
		Top land carbon (TLC), demerits, max	31	35	36
		Initial oil consumption (IOC), (0 h – 252 h), g/h, average	13.1	13.1	13.1
		Final oil consumption, (432 h – 504 h), g/h, average, max	IOC + 1.8	IOC + 1.8	IOC + 1.8
		Piston, ring, and liner distress	none	none	none
		Ring sticking	none	none	none
	or, D6681 (1P)	Weighted demerits (WDP), max	350	378	390
		Top groove carbon (TGC), demerits, max	36	39	41
		Top land carbon (TLC), demerits, max	40	46	49
		Average oil consumption, g/h (0 h – 360 h), max	12.4	12.4	12.4
		Final oil consumption, g/h (312 h – 360 h), max	14.6	14.6	14.6
		Piston, ring, and liner scuffing	none	none	none
	D6987/D6987M (T-10)	Merit rating,[M] min	1000	1000	1000
	or the T-12 (T-10) test	Merit rating,[M] min	1000	1000	1000
	D6975 (M11 EGR)	Average crosshead mass. loss, mg, max	20.0	21.8	22.6

TABLE 3 *Continued*

Category	Test Method	Rated or Measured Parameter	Primary Performance Criteria		
		Average top ring mass loss, mg	report	report	report
		Oil filter differential pressure at 250 h, kPa, max	275	320	341
		Average engine sludge, CRC merits at EOT, min	7.8	7.6	7.5
	or, D7468 (ISM)	Crosshead wear, mg, max	7.5	7.8	7.9
		Oil filter Δ pressure at 150 h, kPa, max	55	67	74
		Sludge rating, CRC Merits, min	8.1	8.0	8.0
	D5967 (Ext. T-8E)[G]	Relative viscosity at 4.8 % soot[N]	1.8	1.9	2.0
	D6984 (Sequence IIIF)[O]	Kinematic viscosity (at 40 °C), percent increase, max	275	275 (MTAC)	275 (MTAC)
	or D7320(Sequence IIIG)[I]	Kinematic viscosity, percent increase at 40 °C max	150	150 (MTAC)	150 (MTAC)
	D6750[P] (1K)	Weighted demerits (WDK), max	332	347	353
		Top groove fill (TGF), %, max	24	27	29
		Top land heavy carbon (TLHC), %, max	4	5	5
		Average oil consumption, g/kWh (0 h – 252 h), max	0.54	0.54	0.54
		(g/MJ) (0 h – 252 h), max	(0.15)	(0.15)	(0.15)
		Piston, ring, and liner scuffing	none	none	none
	D5966 (RFWT)	Average pin wear, mils, max	0.30	0.33	0.36
		or (µm), max	(7.6)	(8.4)	(9.1)
	D6894 (EOAT)[J]	Aeration, volume percent, max	8.0	8.0 (MTAC)[H]	8.0 (MTAC)[H]

CI-4 Bench Tests	Measured Parameter	Primary Performance Criteria
D4683 (High temperature/High shear) or D4741 or D5481[Q]	Viscosity after shear,[R] min	3.5 mPa·s
D4684 (MRV-TP-1)	The following limits are applied to SAE viscosity grades 0W, 5W, 10W and 15W:	
	Viscosity of 75 h used oil sample from T-10 test (or T-10A[S] test), or 100 h used oil sample from T-12 test (or T-12A[T] test, tested at −20 °C, mPa·s, max	25 000
	If yield stress is detected, use modified D4684[U] (external preheat), then mPa·s, max	25 000
	and yield stress, Pa	<35
D5800 (Noack)	Evaporative loss at 250 °C, %, max	15
D6594 (135 °C HTCBT)	Copper, mg/kg increase, max	20
	Lead, mg/kg increase, max	120
	Tin, mg/kg increase	report
	Copper strip rating,[K] max	3
D6278	Kinematic viscosity after shearing, mm^2/s, min	SAE XW-30 / SAE XW-40 9.3/12.5
D892 (Option A not allowed)	Foaming/settling,[L] mL, max	
	Sequence I	10/0
	Sequence II	20/0
	Sequence III	10/0

CI-4 Bench Tests, cont'd—D7216 (Elastomer Compatibility)

Unadjusted Specification Limits for Elastomer Compatibility

Note—These are the *unadjusted specification limits* for elastomer compatibility. Candidate oils shall, however, conform to the *adjusted specification limits*, the calculation of which is described in Annex A4.

Note—TMC 1006 is the designation for the reference oil used in this test method. This designation represents the original blend or subsequent approved re-blends of TMC 1006.

Elastomer	Volume Change, %	Hardness Change, Points	Tensile Strength Change, %	Elongation at Break Change, %
Nitrile (NBR)	(+5, -3)	(+7, -5)	(+10, -TMC 1006)	(+10, -TMC 1006)
Silicone (VMQ)	(+TMC 1006, -3)	(+5, -TMC 1006)	(+10, -45)	(+20, -30)
Polyacrylate (ACM)	(+5, -3)	(+8, -5)	(+18, -15)	(+10, -35)
Fluoroelastomer (FKM)	(+5, -2)	(+7, -5)	(+10, -TMC 1006)	(+10, -TMC 1006)

Category	Test Method	Rated or Measured Parameter	Primary Performance Criteria		
			One-test	Two-test	Three-test
CJ-4	D7422 (T-12)	Merit rating,[V] min	1000	1000	1000
	D7468 (ISM)	Merit rating,[V] min	1000	1000	1000
		Top ring mass loss, mg, max	100	100	100
	D7549 (C13)	Merit rating,[V] min	1000	1000	1000
		Hot-stuck piston ring	none	none	none
	D7156 (T-11)	TGA % Soot at 4.0 mm^2/s increase, at 100 °C, min	3.5	3.4	3.3
		TGA % Soot at 12.0 mm^2/s increase, at 100 °C, min	6.0	5.9	5.9
		TGA % Soot at 15.0 mm^2/s increase, at 100 °C, min	6.7	6.6	6.5
	D7484 (ISB)	Slider tappet mass loss, mg, average, max	100	108	112
		Cam lobe wear, µm, average, max	55	59	61
		Crosshead mass loss, mg, average	report	report	report
	D6750 (1N)	Weighted demerits (WDN), max	286.2	311.7	323.0
		Top groove fill (TGF), %, max	20	23	25

TABLE 3 *Continued*

Category	Test Method	Rated or Measured Parameter	Primary Performance Criteria		
		Top land heavy carbon (TLHC), %, max	3	4	5
		Oil consumption, g/kWh, (0 h – 252 h), max	0.54	0.54	0.54
		(g/MJ) (0 h – 252 h), max	(0.15)	(0.15)	(0.15)
		Piston, ring, and liner scuffing	none	none	none
		Piston ring sticking	none	none	none
	D5966 (RFWT)	Average pin wear, mils, max	0.30	0.33	0.36
		(µm) max	(7.6)	(8.4)	(9.1)
	D6984 (Sequence IIIF)	Kinematic viscosity (at 40 °C), % increase, max	275	275 (MTAC)	275 (MTAC)
	or, alternately, D7320 (Sequence IIIG)[I]	Kinematic viscosity (at 40 °C), % increase, max	150	150 (MTAC)	150 (MTAC)
	D6894 (EOAT)	Aeration, volume, %, max	8.0	8.0 (MTAC)	8.0 (MTAC)

same for III H

CJ-4 Bench Tests	Measured Parameter	Primary Performance Criteria
D4683 (High temperature/High shear) or D4171 or D5481	Viscosity at 150 °C, mPa-s, min	3.5
D6594 (135 °C HTCBT)	Copper, mg/kg increase, max	20
	Lead, mg/kg increase, max	120
	Copper strip rating, max	3
D7109	Kinematic viscosity after 90 pass shearing, mm²/s at 100 °C, min	SAE XW-30 / SAE XW-40 9.3/12.5
D5800 (Noack)	Evaporative loss at 250 °C, %, max (Viscosities other than SAE 10W-30)	13
	Evaporative loss at 250 °C, %, max (SAE 10W-30 viscosity)	15
D892	Foaming/settling, mL, max	
	Sequence I	10/0
	Sequence II	20/0
	Sequence III	10/0
D6896 (MRV TP-1)	Viscosity of the 180 h used oil drain sample from a T-11 test, tested at –20 °C, mPa-s, max	25 000
	If yield stress is detected, use the modified test method (external preheat), then measure the viscosity, mPa-s, max	25 000
	Measure the yield stress, Pa	<35
	Chemical Limits (non-critical)	
D874	Mass fraction sulfated ash, %, max	1.0
D4951	Mass fraction phosphorus, %, max	0.12
D4951	Mass fraction sulfur, %, max	0.4

CJ-4 Bench Tests, cont'd—D7216 (Seal Compatibility)

Unadjusted Specification Limits for Elastomer Compatibility

Note—These are the *unadjusted specification limits* for elastomer compatibility. Candidate oils shall, however, conform to the *adjusted specification limits*, the calculation of which is described in Annex A4.

Note—TMC 1006 is the designation for the reference oil used in this test method. This designation represents the original blend or subsequent approved re-blends of TMC 1006.

Elastomer	Volume Change, %	Hardness Change, Points	Tensile Strength Change, %	Elongation at Break Change, %
Nitrile (NBR)	(+5, -3)	(+7, -5)	(+10, -TMC 1006)	(+10, -TMC 1006)
Silicone (VMQ)	(+TMC 1006, -3)	(+5, -TMC 1006)	(+10, -45)	(+20, -30)
Polyacrylate (ACM)	(+5, -3)	(+8, -5)	(+18, -15)	(+10, -35)
Fluoroelastomer (FKM)	(+5, -2)	(+7, -5)	(+10, -TMC 1006)	(+10, -TMC 1006)
Vamac G	(+TMC 1006, -3)	(+5, -TMC 1006)	(+10, -TMC 1006)	(+10, -TMC 1006)

Category	Test Method	Rated or Measured Parameter	Primary Performance Criteria		
			One-test	Two-test[M]	Three-test[M]
CK-4 or FA-4	D7422 (T-12)	Top Ring Mass Loss, mg, max	105	105	105
		Cylinder Liner Wear, µm, max	24.0	24.0	24.0
	D8048 (T-13)	IR Peak at EOT, Abs., cm^{-1}	125	130	133
		Kinematic Viscosity Increase at 40 °C, % max	75	85	90
		Avg. Oil Consumption, 48 h to 192 h, g/h, max	Report	Report	Report
	D7156 (T-11)	TGA % Soot at 4.0 mm²/s increase, at 100 °C, min	3.5	3.4	3.3
		TGA % Soot at 12.0 mm²/s increase, at 100 °C, min	6.0	5.9	5.9
		TGA % Soot at 15.0 mm²/s increase, at 100 °C, min	6.7	6.6	6.5
	D7549 (C13)	Merit rating,[M] min	1000	1000	1000
	D8047 (COAT)	Average Aeration,[M] 40 h to 50 h, %	11.8	11.8	11.8
	D7484 (ISB)	Slider tappet mass loss, mg, average, max	100	108	112
		Cam lobe wear, µm, average, max	55	59	61
		Crosshead mass loss, mg, average	Report	Report	Report
	D7468 (ISM)	Top Ring Mass Loss, mg, max	100	100	100
		Merit Rating,[M]	1000	1000	1000
	D6750 (IN)	Weighted demerits (WDN), max	286.2	311.7	323.0
		Top groove fill (TGF), %, max	20	23	25
		Top land heavy carbon (TLHC), %, max	3	4	5

	Oil consumption, g/kWh, (0 h to 252 h), max (g/MJ) (0 h to 252 h), max	0.54 (0.15)	0.54 (0.15)	0.54 (0.15)
	Piston, ring, and liner scuffing	none	none	none
	Piston ring sticking	none	none	none
D5966 (RFWT)	Average pin wear, mils, max (µm) max	0.30 (7.6)	0.33 (8.4)	0.36 (9.1)

CK-4 and FA-4 Bench Tests	Primary Performance Criteria	
Measured Parameter	CK-4	FA-4
SAE J300 Viscosity Grade	xW-30, xW-40	xW-30
D4683 (High temperature/High shear) or D4741 or D5481		
Viscosity at 150 °C, mPa·s		
xW-30 Grades min	3.5	2.9
xW-30 Grades max	n/a	3.2
xW-40 Grades	Meet SAE J300	n/a
D6594 (135 °C HTCBT)		
Copper, mg/kg increase, max	20	20
Lead, mg/kg increase, max	120	120
Copper strip rating, max	3	3
D7109 Kinematic viscosity after 90 pass		
Shearing, mm²/s at 100 °C, min		
xW-30	9.3	9.3
0W-40	12.5	n/a
Other xW-40	12.8	n/a
HTHS Viscosity (see above methods) at 150 °C, min xW-30 Grades	3.4	2.8
D5800 (Noack) Evaporative loss at 250 °C, %, max	13	13
D892 Foaming/settling, mL, max		
Sequence I	10/0	10/0
Sequence II	20/0	20/0
Sequence III	10/0	10/0
D6896 (Sooted Oil MRV TP-1) (D7156 Engine test required)		
Viscosity, 180 h used oil sample from a T-11/T-11A test, tested at −20 °C, mPa·s, max	25 000	25 000
Yield stress of the 180 h used oil sample above, Pa max	≤35	≤35
Chemical Limits (non-critical)		
D874 Mass fraction sulfated ash, %, max	1.0	1.0
D4951 Mass fraction phosphorus, %, max	0.12	0.12
D4951 Mass fraction sulfur, %, max	0.4	0.4

CK-4 and FA-4 Bench Tests, continued—D7216 (Seal Compatibility)

Unadjusted Specification Limits for Elastomer Compatibility

Note—These are the *unadjusted specification limits* for elastomer compatibility. Candidate oils shall, however, conform to the *adjusted specification limits*, the calculation of which is described in Annex A4.

Note—TMC 1006 is the designation for the reference oil used in this test method. This designation represents the original blend or subsequent approved re-blends of TMC 1006.

Elastomer	Volume Change, %	Hardness Change, Points	Tensile Strength Change, %	Elongation at Break Change, %
Nitrile (NBR)	(+5, −3)	(+7, −5)	(+10, −TMC 1006)	(+10, −TMC 1006)
Silicone (VMQ)	(+TMC 1006, −3)	(+5, −TMC 1006)	(+10, −45)	(+20, −30)
Polyacrylate (ACM)	(+5, −3)	(+8, −5)	(+18, −15)	(+10, −35)
Fluoroelastomer (FKM)	(+5, −2)	(+7, −5)	(+10, −TMC 1006)	(+10, −TMC 1006)
Vamac G (AEM)	(+TMC 1006, −3)	(+5, −TMC 1006)	(+10, −TMC 1006)	(+10, −TMC 1006)

[A] See Annex A2 for additional information.
[B] Refer to RR:D02-1441.
[C] If three or more operationally valid tests have been run, the majority of these tests shall not have scuffing. The scuffed tests are considered uninterpretable, and all data from these tests are eliminated from averaging.
[D] Refer to RR:D02-1273.
[E] Refer to RR:D02-1440.
[F] Refer to RR:D02-1439.
[G] A passing T-11 (TGA % soot at 12.0 mm²/s increase, at 100 °C, min)—6.00 (first test), 5.89 (second test), and 5.85 (third test)—can be used in place of a T-8E in the applicable categories. This is not intended to indicate equivalence.
[H] See Annex A1; use method without transformations.
[I] The Sequence IIIG limits shown are more restrictive than the corresponding limits in Sequence IIIF, and are not intended to indicate equivalence. Results meeting the Sequence IIIG criteria stated can be used in lieu of Sequence IIIF.
[J] Refer to RR:D02-1379.
[K] The rating system in Test Method D130 is used to rate the copper coupon in Test Method D6594.
[L] Ten minutes for Sequence I, II, and III.
[M] See Annex A6 for additional information.
[N] Relative Viscosity (RV) = viscosity at 4.8 % soot/viscosity of new oil sheared in Test Method D6278.
[O] Refer to RR:D02-1391.

[P] Refer to RR:D02-1273. Alternatively, Test Method D6750 (1N) can be used; if this test method is used, the measured parameters and primary performance criteria are the same as those shown for Test Method D6750 (1N) in the CJ-4 category.
[Q] Tests as allowed in SAE J300.
[R] Noncritical specification as defined by Practice D3244; may be superseded only by applicable higher limits set by SAE J300.
[S] The T-10A test is the name given to a T-10 test run for 75 h to generate the sample for measurement by Test Method D4684.
[T] The T-12A test is the name given to a T-12 test run for 100 h to generate the sample for measurement by Test Method D4684.
[U] Refer to RR:D02-1517.
[V] See Annex A5 for additional information.

ANNEXES

(Mandatory Information)

A1. MULTIPLE TEST ACCEPTANCE CRITERIA

A1.1 Multiple Test Acceptance Criteria (MTAC) is any data-based approach for evaluation of the quality and performance of a formulation where more than one test may be run. Generally for a candidate tested once, test data for each criterion shall be a pass. For a candidate tested twice, the mean (average) value of each result shall be a pass. For a candidate tested three or more times, one test might be declared an outlier and thus discarded and the mean (average) value of retained test data for each result shall be a pass. Data are rounded in accordance with the procedures specified in Practice E29.

TABLE A1.1 Parameters to Be Transformed and Averaged in Determination of MTAC

Test Method	Rated Parameter	Transformation
D5844 (Sequence IID)	Average engine rust	NA[A]
D5533 (Sequence IIIE)	Viscosity increase[B] (h to 375 %)	NA
	Average engine sludge	−LN (10-AES)
	Average piston varnish	NA
	Oil ring land deposits	NA
	Average camshaft plus lifter wear[C]	LN (ACLW)
	Maximum camshaft plus lifter wear[C]	LN (MCLW)
	Oil-related ring sticking	NA
D6984 (Sequence IIIF - as used in CH-4)	Percent viscosity increase at 60 h	LN
D6894 (EOAT)	Aeration, volume %	NA
D6984 (Sequence IIIF)	Viscosity, % increase	1/square root of the % viscosity increase at 80 h
	Average piston varnish	NA
	Weighed piston deposits	NA
	Screened average camshaft plus lifter wear	NA
	Hot stuck rings	NA
	Oil Consumption	NA
D7320 (Sequence IIIG)	Viscosity, % increase	LN
D6891 (Sequence IVA)	Cam wear	NA
D5302 (Sequence VE)	Average engine sludge	−LN (9.65 − AES)
	Rocker cover sludge	−LN (9.65 − RCS)
	Average piston varnish	NA
	Average engine varnish	NA
	Average camshaft wear	Square root of ACW
	Maximum camshaft wear	NA
	Oil screen clogging	NA
	Ring sticking	NA
D6593 (Sequence VG)	Average engine sludge	NA
	Rocker arm cover sludge	NA
	Average piston skirt varnish	NA
	Average engine varnish	NA
	Oil screen clogging	LN (Oil screen clogging + 1)
	Hot stuck compression rings	NA
D6202 (Sequence VIA)	Fuel economy improvement	NA
D6837 (Sequence VIB)	Fuel economy improvement	NA
D5119 (L-38)	Total bearing weight loss	NA
D6709 (Sequence VIII)	Total bearing weight loss	NA

[A] NA stands for Not Applicable.
[B] For tests reaching 375 % viscosity increase after 64 h, estimated hours = 64 + (6.163-LN (viscosity increase at 64 h + 100)/0.072). For tests reaching 375 % viscosity increase before 64 h, estimated hours are determined by a straight line interpolation between the two nearest 8 h points.
[C] When more than one test is run and if maximum wear is more than six times the average wear on any one test, the highest mating cam lobe/lifter result can be discarded and the remaining eleven combinations used to calculate a new maximum and average wear. This can only be done for one retained test.