HEAVY-DUTY ENGINE OIL CLASSIFICATION PANEL
OF
ASTM D02.B0.02
August 15, 2001
Holiday Inn – O'Hare International Hotel, Rosemont, IL

ACTION ITEMS

1.	**Get data to CAT regarding PC-9 / 1N.**	**All**
2.	**Used oil viscosity Task Force limits and procedure mtg.**	**D. Stehouwer**
3.	**Exit ballots, round two.**	**J. McGeehan**

MINUTES

1.0 Call to Order

1.1 Chairman Jim McGeehan called the meeting to order at 8:06 a.m. on August 15, 2001, in Ball Room 5 of the Holiday Inn – O'Hare International of Rosemont, IL. There were 14 members present or represented and approximately 32 guests present. The attendance list is shown as Attachment 2.

2.0 Agenda

2.1 The announced agenda (Attachment 1) was reviewed and agreed upon.

3.0 Previous Meeting Minutes

3.1 The minutes of the July 11, 2001 meeting were reviewed and the last sentence of paragraph 11.6 should be corrected to read: "ASTM specification D3244…". Also, the first line of the second bullet item on page 142 (Attachment 16, page 2) should have a "15" before the W-40. With these corrections / additions, the minutes of the previous meeting were approved as posted on the TMC website.

4.0 Membership

4.1 There were no changes in membership.

5.0 PC-9 Matrix Status

5.1 John Zalar reported on the status of the PC-9 matrix (Attachment 3). The T-10 and M-11 EGR matrix tests are all completed. Seventeen of eighteen 1R matrix tests are also done and the eighteenth test is running. It should finish by the end of August.

5.2 Steve Kennedy inquired about the status of approval for the revision to the MOA. Dick Clark responded that all approval signatures had not yet been received.

6.0 Mack T-10

6.1 Jim Rutherford reported on the statistical analysis of the T-10 matrix data (Attachment 4). This analysis of the data shows significant technology, lab and stand effects on lead; base oil and base oil / technology interaction effects on liner wear; technology, lab and stand effects on IR.

6.2 Joe Franklin reviewed the matrix IR data (Attachment 5). Method 5 was selected by the T-10 Task Force as the method of choice since it seemed to give better separation of the data.

6.3 Greg Shank gave an update on the T-10 status and changes (Attachment 6). He proposed that the T-10 test be accepted for use in the PC-9 category. Ralph Cherrillo seconded the motion. There was concern raised about accepting the test with limited calibrated stand availability, so a teleconference was scheduled for August 16, 2001, to review matrix stand calibration status. The motion passed with 14 for, 0 against, 0 abstain.

7.0 Used Oil Low Temperature Viscometrics

7.1 Jim Rutherford presented an addendum to the T-10 statistical analysis for the addition of MRV results from the 75 hour T-10 oil samples (Attachment 7). This analysis indicates technology, base oil and base oil / technology interaction all had significant effects on the low temperature viscosity of sooted oils. Dave Stehouwer proposed that the MRV TP-1 method (D4684) at 5°C above the fresh oil grade MRV temperature, be used to evaluate the 75 hour sample from the Mack T-10 test, for low temperature pumpability concerns. Greg Shank seconded the motion which passed with 14 for, 0 against, 0 abstain.

7.2 Ted Selby presented data on T-10 matrix oils generated using a scanning rotary viscometry technique (Attachment 8). This approach gives much more information about the low temperature viscosity behavior of soot containing oils and takes less time.

8.0 Mack T-10 Limits

8.1 Greg Shank presented the EMA agreed upon limits for the T-10 test (Attachment 9) and moved for their acceptance. Ralph Cherrillo seconded the motion. Pat Fetterman presented alternative limits suggested by Infineum (Attachment 10). There was considerable discussion on having both lead and IR oxidation as pass / fail parameters because of their correlation. Mack wants both to help ensure appropriate anti-oxidant levels. The motion passed with 11 for, 1 against, 2 abstentions and will proceed to an exit ballot.

9.0 Cummins M-11 EGR

9.1 Dennis Malandro presented the M-11 EGR matrix data statistical analysis (Attachment 11). For crosshead wear there were significant effects for labs and base oils. There were no significant effects for top ring weight loss or top ring gap increase and only lab effects for liner wear. Dennis noted that the units shown on the liner wear step slide are incorrect. The numbers are correct, but they reflect microns, not milligrams. Oil filter differential pressure showed a base oil / technology interaction effect. There were significant lab effects and base oil / technology interaction effects on average engine sludge. There were significant lab effects on injector adjusting screw weight loss. Lab and technology effects were both significant for rod bearing weight loss.

9.2 Dave Stehouwer presented an update on the M-11 EGR status (Attachment 12) and moved that the HDEOCP accept the test for use in the PC-9 category. Greg Shank seconded the motion which passed with 14 for, 0 against, 0 abstain.

9.3 Jim Newcombe announced that the ACC had accepted the T-10 and M-11 EGR into the “Code of Practice”, contingent on acceptance by the HDEOCP, and that registration of tests may start on Monday, August 20, 2001.

9.4 Dave Stehouwer presented the proposed M-11 EGR pass / fail limits (see Attachment 12) and moved for their adoption. Greg Shank seconded the motion. Pat Fetterman suggested dropping TRWL as a parameter and an alternate limit for average engine sludge (Attachment 13). The original motion passed with 11 for, 1 against, 2 abstentions, and will proceed to an exit ballot.

10.0 Caterpillar 1R

10.1 Dwayne Tharp reported on the 1R matrix status (Attachment 14) and indicated 17 of 18 tests had completed, with the final test expected to finish by the end of August.

10.2 Phil Scinto presented a ‘preliminary draft’ of the 1R matrix data statistical analysis based on the 12 test results available at the time (Attachment 15).

11.0 Category Demonstration Oil

11.1 Greg Shank wanted the record to show that the EMA can not provide a demonstration oil, but they will work with the oil / additive suppliers to come up with one. The NCDT agreed to help provide a demonstration oil.

12.0 “Exit” Ballots from the July 11, 2001 Meeting

12.1 1N

12.11 There were several concerns expressed about potentially higher ash PC-9 oils being able to pass the 1N CG-4 limits.
12.12 Oronite proposed using CH-4 (1K) limits.
12.13 Infineum proposed relaxed limits (Attachment 16).
12.14 ExxonMobil would agree to tighter oil consumption limits (0.27 g/hr) if the deposit limits were relaxed.
12.15 Caterpillar is concerned about stuck rings and backward compatibility.
12.16 Ethyl proposes TGF relief to the 25-30% region (Attachment 17).

12.2 Used Oil Viscometrics

12.21 Imperial Oil expressed concerns about the proposed limits for 10W-30 oils because of the reduced blend window imposed by the HTHS limit.
12.22 Oronite has concerns about having to re-run a T-10 to generate a 75 hour sample for the viscosity analysis.
12.23 ExxonMobil wants to know if “stay-in-grade” still applies.
12.24 Ethyl suggests that sample generation be de-coupled from the T-10 with perhaps a “flush and run” setup.
12.25 Chevron would like more background on how 25,000 cP was picked as the limit. Dave Stehouwer provided Attachment 18 to help answer that question.
12.26 After more discussion, it was suggested that a Task Force be formed to review the limits and procedure before the next meeting. Dave Stehouwer will head the Task Force and Bill Kleiser, Lew

Williams, Pat Fetterman, Tom Cousineau, Ralph Cherrillo and Steve Herzog agreed to participate.

12.3 Mack T-8E

12.31 Infineum made the point that the MRV test on the T-10 oil sample now replaces the need for the T-8E. However, they would support a 1.9 RV using 100% DIN shear (Attachment 19).
12.32 ExxonMobil would support 1.8 or 1.9 RV. They feel using 100% DIN shear can result in more than a 0.1 shift in RV.
12.33 Chevron doesn't feel 100% DIN shear is necessary, would support 50%.
12.34 Mack feels there is not enough data to permit dropping the T-8E or the MRV. They would move to 1.8 RV if 100% DIN shear accepted (Attachment 20).
12.35 Greg Shank moved that the T-8E Relative Viscosity limit for PC-9 be set at 1.8 for 4.8% soot, using 100% of the D6278 sheardown value. Steve Kennedy seconded the motion which passed with 14 for, 0 against, 0 abstain. This will be re-exit balloted.

12.4 High Temperature, High Shear

12.41 Lubrizol would change to affirmative for a limit of 3.3 or 3.4 cP.
12.42 ExxonMobil concerned that a critical limit of 3.3 might be more restrictive than a non-critical 3.5.
12.43 Infineum maintains that to get higher HTHS would require more polymer and would not necessarily result in higher film thickness (Attachment 21).
12.44 Pennzoil-Quaker State feels the HTHS should be a category requirement, not just for XW-30 oils.
12.45 EMA sticks by their proposal that the minimum fresh oil HTHS they want to see for their engines is 3.5 cP, as a non-critical parameter.

12.5 Volatility

12.51 Lubrizol feels that 15% is ok for 15W-40 oils but they would like to see 17% for XW-30 oils because they have customers whose base stocks would be effected. They could withdraw the negative.

12.6 Elastomers

12.61 Lubrizol is concerned that the review / adjudication process is not well enough defined. They would withdraw if a process were defined.
12.62 Ethyl presented a process (Attachment 22).

12.7 Next Round of "Exit" Ballots

12.71 Ballot 1.8% RV with 100% D6278 sheardown for T-8E.
12.72 Ballot both 3.5 cP, non-critical and 3.3 cP, critical, as HTHS limits, with 6V-92 base oil read across guidelines for the 3.3 option.

13.0 New Business

13.1 Lew Williams moved that passing PC-9 oils could be licensed as CH-4 oils prior to official CI-4 licensing. Bill Kleiser seconded the motion. Discussion included proposals that a passing T-10 could be used to satisfy a T-9 requirement, a passing M-11 EGR for an M-11 HST and a passing 1R for a 1P. By agreement, the motion was tabled until the next meeting.

14.0 Next Meeting

14.1 The next meeting was moved to September 12, 2001, same venue, starting at 8:00 a.m.

15.0 Adjournment

15.1 The meeting was adjourned at 2:56 p.m. on August 15, 2001.

Submitted by:

Jim Wells
Secretary to the HDEOCP

FINAL AGENDA

ASTM-HDEOCP

Holiday Inn O'Hare International
August 15th 2001
8:00 am –4:15 pm

Chairman/ Secretary: **Jim Mc Geehan/Jim Wells**
Purpose: **PC-9**
Desired Outcomes:
- **Matrix results in EGR tests**
- **AgreeTest limits on Cummins M11, Mack T-10 and Exit Criteria Ballots**

TOPIC	PROCESS	WHO	TIME
Coffee Agenda Review	• Desired Outcomes & Agenda	Group	7:30 a.m. 8:00 - 8:05
Minutes Approval	• July 11th 2001	Group	8:05 - 8:10
Membership	• Changes • Chairman's comments	Group Jim Mc Geehan	8:10 - 8:15
Matrix Status	• Mack T-10; Cummins M11-ERG; Cat 1R • Time line for PC-9	John Zalar	8:15 - 8:40
Cat 1R Approval	• Stack-holder approval of Cat 1R	Steve Kennedy	8:40 - 8:45
Coffee Break			8:45 - 9:00
Mack T-10 Up-date: new data	• Task Force recommendations • Ring-Liner wear • Bearing wt loss and lead increase • Oil consumption • IR oxidation of used oil • MRV TP-1 (75 hour sample) • Statistical analysis of data • Scanning Brookfield Analysis • Discussion • Motion on limits • Exit criteria ballot • Status of Research Report	Greg Shank Jim Rutherford Joe Frankline Ted Selby	9:00 - 10:00
Cummins M11 EGR	• Task force recommendations • Cross-head, injector screw and top-ring wear • Filter delta p	Dave Stehouwer Dennis Malandro	10:00 - 11:00

FINAL AGENDA

TOPIC	PROCESS	WHO	TIME
Cummins M11 EGR	• Sludge • New filter results • Statistical analysis of data • Discussion • Motion on limits • Exit criteria ballot • Status of Research Report		
Caterpillar 1R	• Matrix status • Timing of 17 test completion • Statistical design • Exit criteria ballot • Status of Research Report	Dwayne Tharp Phil Scinto	11:00 - 11:30
Lunch	• Lunch will be served in room • Collect money for lunch, coffee and room! • Approximate amount: $50.00 !	Jim McGeehan and Jim Wells	11:30 - 1:00
Demonstration Oil for PC-9	• Oil selected • Time of completion	Greg Shank	1:00 - 1:15
Results of Exit Criteria Ballots	• Mack T-8E • SAE 10W-30 –HT/HS • Used oil viscometrics • Elastomer compatibility • Volatility • Roller follower wear test • Aeration • Caterpillar 1N • High temperature corrosion • Foaming • Shear stability • Exit criteria ballots on failing ballots above	Jim Mc Geehan Group	1:15 - 4:00
Next Meeting	• Sept 5th • Issue B ballot Sept 10th	Jim McGeehan	4:00-4:15

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HEAVY DUTY ENGINE OIL CLASSIFICATION PANEL

ATTENDANCE LIST

AUGUST 2001

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Hope, Ken Chevron Phillips Chemical Co. LP 1862 Kingwood Dr. Kingwood, TX 77339	(281) 359-6519 hopekd@cpchem.com		
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Oliphant, Tom American Refining Group 77 N. Kendall Ave. Bradford, PA 16701	(814) 368-1353 (814) 368-1328 toliphant@amref.com		
Oliver, Rick RSI 2805 Beverly Dr. Flower Mound, TX 75022	(972) 726-2136 crickoliver@home.com		
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Parry, Barb Mohawk Lubricants Ltd. 130 Forester St. North Vancouver, BC VTH2M9	(604) 924-2703 (604) 929-8371 bparry@mohawklubes.com		
Patrick, Dick Citgo Petroleum Corporation P.O. Box 3758 Tulsa, OK 74102	(918) 495-5937 (918) 495-5935 rpatri1@citgo.com	RJP	☺
Pearse, Steven Castrol Technology Centre Whitchurch Hill Pangbourne Reading Berkshire, England RG8 7QR	44 (0) 118 976 5459 steven_pearse@burmahcastrol.com	SP	☺
Peckham, Jack Lubricants World 4545 Post Oak Place, #210 Houston, TX 77027	(713) 993-9320 jpeckham@phillips.com		
Place, William E. Oronite 30150 Telegraph Rd., Suite 416 Bingham Farms, MI 48025	(248) 540-3277 (248) 540-3279 wepl@chevron.com	BP	☺

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Name: Company: Address:		
Name: Company: Address:		
Name: Company: Address:		
Name: Company: Address:		
Name: Company: Address:		

Status of PC-9 Matrix Testing

Presented to HDEOCP

August 15, 2001

John L. Zalar

ATTACHMENT 3, 1 OF 5

T-10

- Planned Tests: 28
- Total Starts: 33
- Completed Tests
  - Verified and posted on TMC web site: 28
  - Aborted/Invalid/Rejected: 5
- Statistical analysis presented to T-10 Task Force

M11-EGR

- **Planned Tests: 26**
- **Total Starts: 28**
- **Completed Tests**
  - **Verified and posted on TMC web site: 26**
  - **Aborted/Invalid: 2**
- **Statistical analysis presented to M11-EGR Task Force**

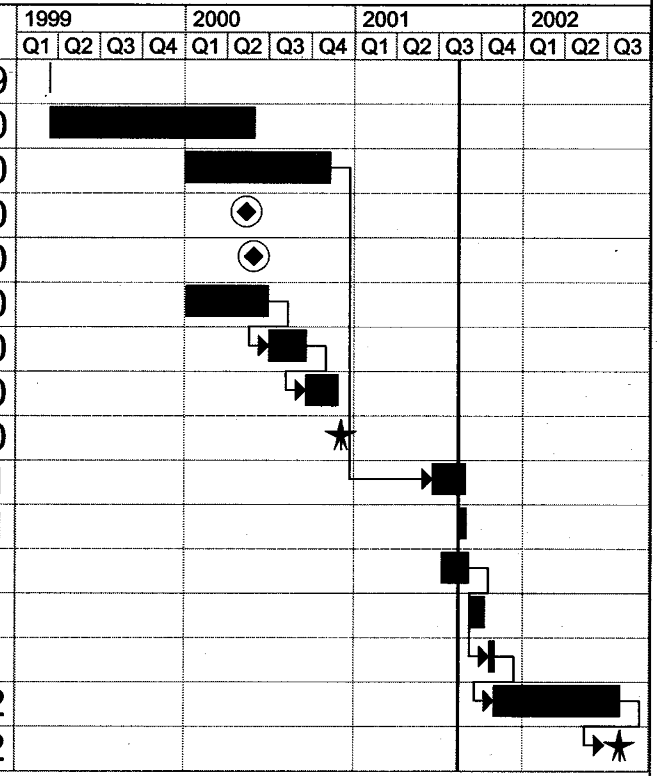
1R

- Planned Tests: 18
- Total Starts: 19
- Completed Tests
  - Posted on TMC web site: 12
  - EOT but not yet posted: 5
  - Aborted/Invalid: 1
- Tests Currently Running: 1
- Earliest EOT for Last Matrix Test: 8/29/01

Summary of Events Required for PC-9 Licensing

J. L. Zalar 8/15/01

ID	Task Name	Start	Finish
1	Define PC-9 Performance Parameters	3/16/99	3/16/99
2	Design Precison Matrix	3/17/99	5/31/00
3	PC-9 Funding MOA Signed	1/3/00	11/10/00
4	1Q & M11EGR Adequate for Oil Devel.	5/15/00	5/15/00
5	Finalize Base Oil Selections for Prec. Mtx.	5/31/00	5/31/00
6	Finalize Additive Selections for Prec. Mtx.	1/6/00	6/30/00
7	Base Oils Recd. by Additive Companies	7/3/00	9/20/00
8	Blend Matrix Oils > TMC > Labs	9/21/00	11/27/00
9	Final Acceptance of New Engine Tests	12/5/00	12/5/00
10	PC-9 Matrix Testing*	6/20/01	8/29/01
11	Precision Matrix Data Analysis (1R)	8/20/01	8/31/01
12	HDEOCP Post Matrix Test Acceptance	7/11/01	9/5/01
13	Subcommittee B Ballot	9/10/01	10/10/01
14	Finalize Pass/Fail Criteria (Sub B Mtg)	10/22/01	10/31/01
15	New Product Development	11/1/01	7/31/02
16	API Licensing Allowed	8/1/02	8/1/02



ATTACHMENT 3, 5 OF 5

* Last 1R Stand

DRAFT

Statistical Summary of the Mack T10 Precision/BOI Matrix

Summary

- This is a preliminary analysis. The statistician work group has not reviewed the presentation.
- Delta lead benefits from a natural log transformation.
- No other transformations were necessary.
- The matrix data have not been evaluated for ACC precision requirements.
- There was a significant positive correlation between delta lead from beginning to end of test and delta lead from 250 to 300 hours, between top ring weight loss and cylinder liner wear, and between method 5 IR and each of the delta lead measures.

Summary
(continued)

- Labs had significant effects for both delta lead measures and IR. They were marginally significant for cylinder liner wear.
- Stand within Lab was significant for IR and marginally significant for both delta lead measures.
- The interaction between technology and base oil was significant for cylinder liner wear and marginally significant for top ring weight loss.

Summary
(continued)

- Technology had a significant effect for the delta lead measures and IR.
- Base Oil was significant effect for cylinder liner wear and marginally significant for top ring weight loss.
- No observations with large Studentized residuals (>3.0) remain in the data set.
- Oil means and standard deviations are given for potential use in LTMS.

Data Set

- Table 1 shows the design for the matrix.
- All operationally valid data with the exception of CMIR 38815 and CMIR 38946 are included.
- The T10 Task Force decided to eliminate the test with CMIR 38815 from the analysis.
  - This was an early test in Lab B on Oil A which had high silicon and aluminum in the used oil. It also had high ring weight loss with low cylinder liner wear. The lab ran Oil A again with non-anomalous results. The matrix remained intact as planned with the deletion of this test.
- The Task Force later decided to eliminate the test with CMIR 38946.
  - This was a test of Oil D in Stand 1 in Lab G that had high delta lead (206 ppm), low EGR rates, and a different relation between delta lead and upper rod bearing weight loss.

Table 1. Mack T10 Precision Matrix Plan

Base Oil	Technology X	Technology Y	Technology Z
Base Oil 1	PC-9A	PC-9D	PC-9G
Base Oil 2	PC-9B	PC-9E	PC-9H
Base Oil 3	PC-9C	PC-9F	PC-9J

Lab/Stand						
Lab A		Lab D	Lab G		Lab F	Lab B
1	2	1	1	2	6	7
A	A	A	A	A	A	A
G	A	G	~~D~~ *	A	A	D
E	E	B	H	E	H	B
C	J	F	C	J	F	J

* The Task Force eliminated this test from the completed data set.

Table 2. Mack T10 Precision Matrix Data

from TMC 07/16/01

Obs	TESTKEY	LTMSLAB	LTMSAPP	LTMSDATE	Oil	Tech	Base Oil	DPBFNL	DPb250300	ATRWLFNL	CLWFNL	OILCON	M5IR300	AvgSoot
1	38814	F	1	20001211	A	X	1	33	16	139	36.3	79.0	452	4.5
2	38809	A	1	20001219	A	X	1	23	8	158	33.3	52.3	348	4.7
3	38811	D	1	20001224	A	X	1	12	5	139	38.2	52.1	210	4.5
4	38945	D	1	20010215	F	Y	3	21	7	69	27.3	56.0	347	4.4
5	38953	F	1	20010217	H	Z	2	73	33	150	33.3	61.0	1042	4.2
6	38939	A	1	20010305	C	X	3	33	14	116	25.3	62.9	458	4.4
7	38810	A	2	20010313	A	X	1	19	7	168	38.0	46.5	334	4.9
8	38947	G	1	20010318	H	Z	2	115	58	156	34.0	64.0	1949	4.8
9	38937	A	1	20010329	E	Y	2	18	6	118	21.2	53.4	342	3.9
10	38951	G	2	20010330	A	X	1	37	14	125	33.0	53.3	497	4.5
11	38943	D	1	20010401	B	X	2	17	5	125	30.9	43.9	294	4.2
12	38957	B	1	20010403	D	Y	1	25	10	204	45.7	53.6	477	5.1
13	38942	A	2	20010408	A	X	1	16	2	87	27.4	40.5	280	4.1
14	38948	G	2	20010419	J	Z	3	90	27	119	35.4	46.9	1292	4.4
15	38952	F	1	20010419	F	Y	3	62	34	106	26.0	51.0	1244	4.4
16	38949	G	1	20010420	C	X	3	77	26	133	35.1	66.0	1454	5.4
17	38941	A	1	20010422	G	Z	1	71	38	107	29.0	52.3	910	4.4
18	38938	A	2	20010504	J	Z	3	44	16	153	31.4	57.7	980	4.8
19	38944	D	1	20010504	G	Z	1	27	10	154	39.4	46.7	348	4.4
20	38956	B	1	20010509	J	Z	3	50	16	127	29.5	34.5	1106	5.1
21	38950	G	2	20010512	E	Y	2	52	22	109	28.3	55.5	991	4.8
22	38940	A	2	20010528	E	Y	2	22	9	67	20.4	45.0	373	4.8
23	40919	B	1	20010529	B	X	2	34	17	121	23.6	53.9	415	4.3
24	40230	G	2	20010602	A	X	1	25	8	108	34.2	47.8	200	4.3
25	41135	F	1	20010611	A	X	1	28	10	128	26.4	60.2	482	4.6
26	41410	B	1	20010618	A	X	1	34	17	140	35.2	42.1	347	4.9
27	41412	G	1	20010703	A	X	1	66	30	123	39.4	64.4	1372	5.1

Transformations

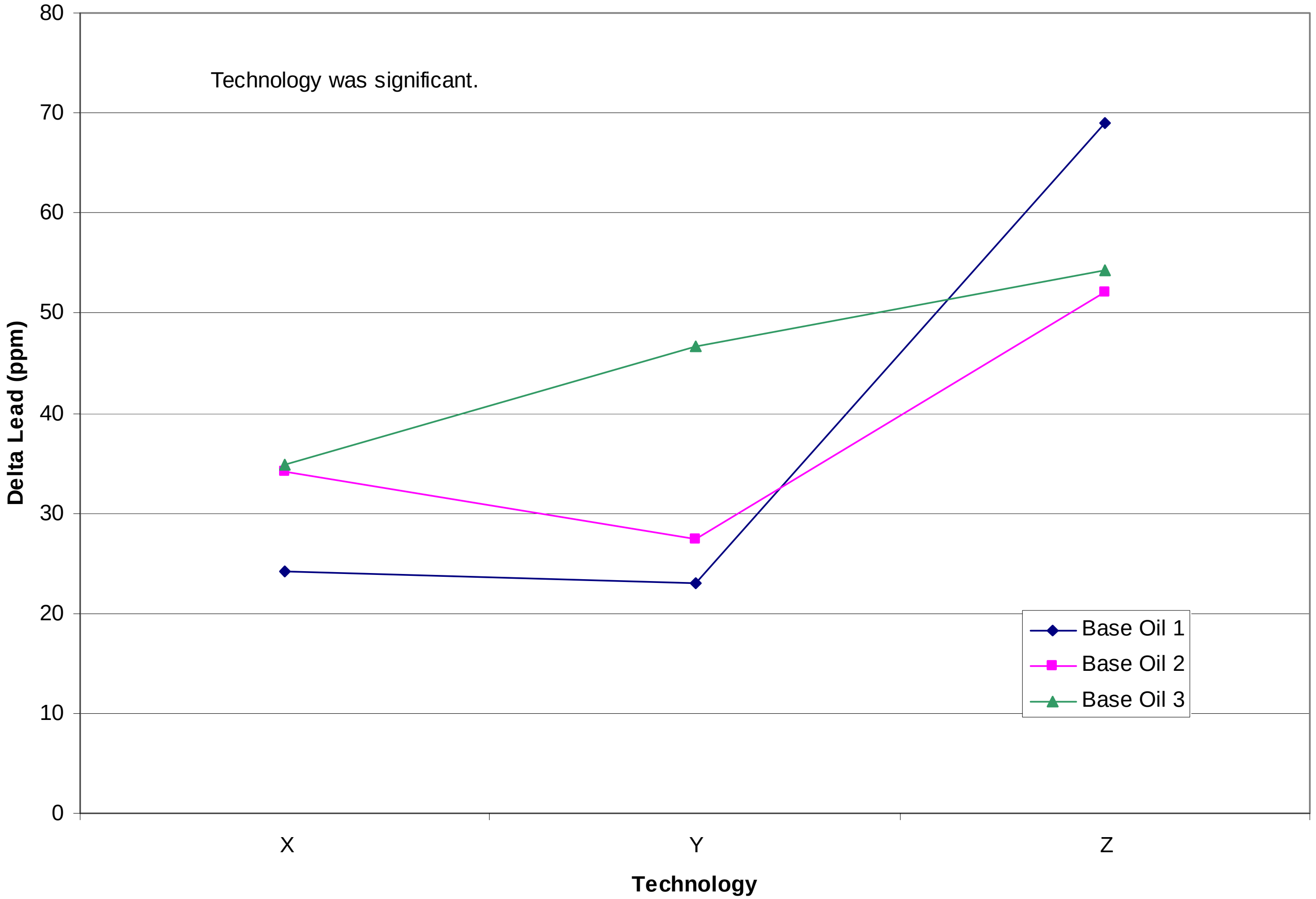
- Box-Cox procedure was applied using all matrix data.
- Delta lead benefits from a natural logarithm transformation.
- No data transformations are indicated for other responses analyzed.

Ln(Delta Lead)
Summary of Model Fit

- Model factors include Laboratory (A,B,D,F,G), Stand within Laboratory (A1,A2,G1,G2), Technology (X,Y,Z), Base Oil (1,2,3) and Technology by Base Oil interaction.

- Technology, and Lab were significant ($p<0.05$), and Stand within Lab was marginally significant ($0.05<p<0.10$).
  - Root MSE from the model was 0.21 (12 df).
  - The R^2 for the model was 0.94.
  - Figure 1 illustrates the least squares means by oil.
  - Figure 2 summarizes least squares means for stands within labs.
  - Stand within Lab significance was driven by the two stands in Lab G which were almost significantly different from each other. Both stands were higher (in many cases significantly) than all other stands.
  - Log transformation was appropriate.
  - No observations had large Studentized residuals.

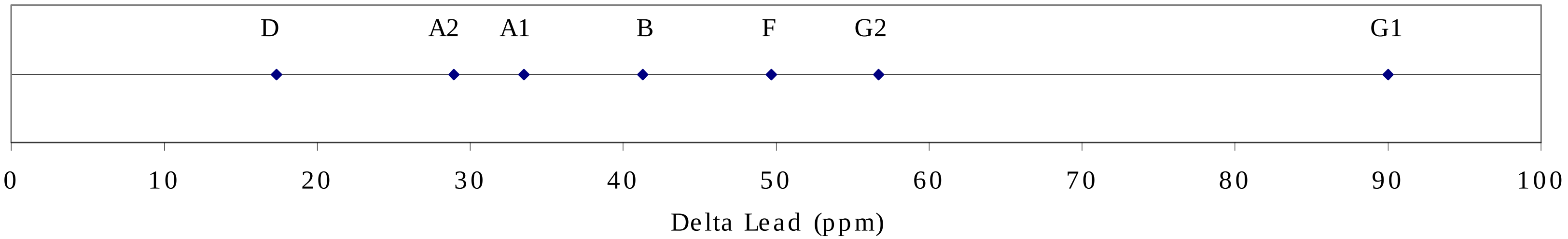
Figure 1
Least Squares Means for Oils



Technology	Least Squares Mean	p-value for test of equal means (Tukey)		
		vs X	vs Y	vs Z
X	31		0.33	0.00
Y	31	0.33		0.07
Z	58	0.00	0.07	

Figure 2
Least Squares Means for Stand within Lab
Delta Lead (ppm)

Lab/ Stand	LS Mean	p-value for test of equal means (Tukey)						
		vs A1	vs A2	vs B	vs D	vs F	vs G1	vs G2
A1	34		0.97	0.93	0.03	0.37	0.00	0.10
A2	29	0.97		0.46	0.15	0.10	0.00	0.01
B	41	0.93	0.46		0.01	0.96	0.04	0.59
D	17	0.03	0.15	0.01		0.00	<.0001	0.00
F	50	0.37	0.10	0.96	0.00		0.07	0.99
G1	90	0.00	0.00	0.04	<.0001	0.07		0.29
G2	57	0.10	0.01	0.59	0.00	0.99	0.29	

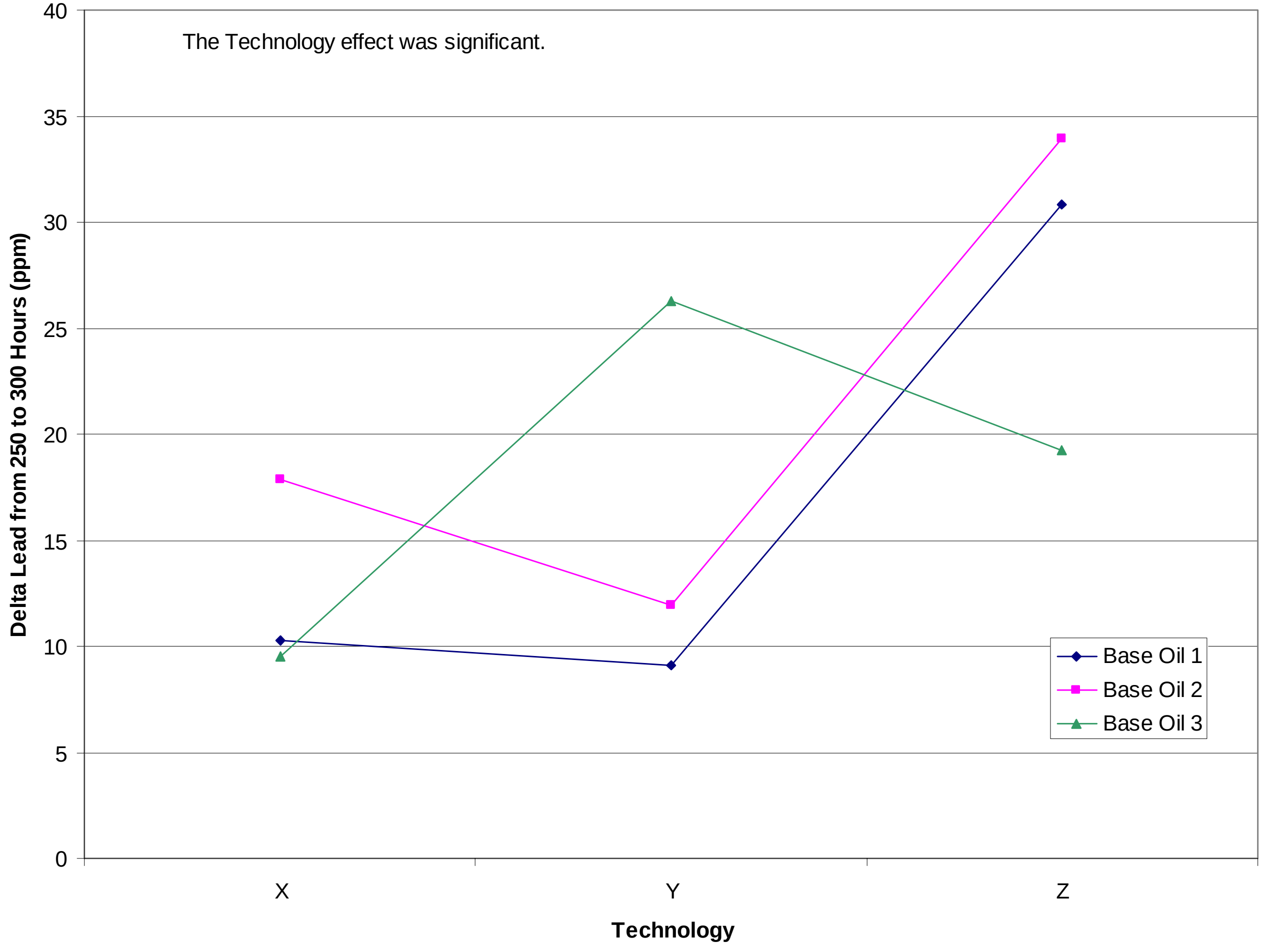


Delta Lead from 250 to 300 Hours
Summary of Model Fit

- Model factors include Laboratory (A,B,D,F,G), Stand within Laboratory (A1,A2,G1,G2), Technology (X,Y,Z), Base Oil (1,2,3) and Technology by Base Oil interaction.

- Technology, and Lab were significant ($p<0.05$), and Stand within Lab was marginally significant ($0.05<p<0.10$).
  - Root MSE from the model was 6 (12 df).
  - The R^2 for the model was 0.88.
  - Figure 3 illustrates the least squares means by oil.
  - Figure 4 summarizes least squares means for stands within labs.
  - Stand within Lab significance was driven by the two stands in Lab G which were almost significantly different from each other. Both stands were higher (in many cases significantly) than all other stands.
  - No observations had large Studentized residuals.

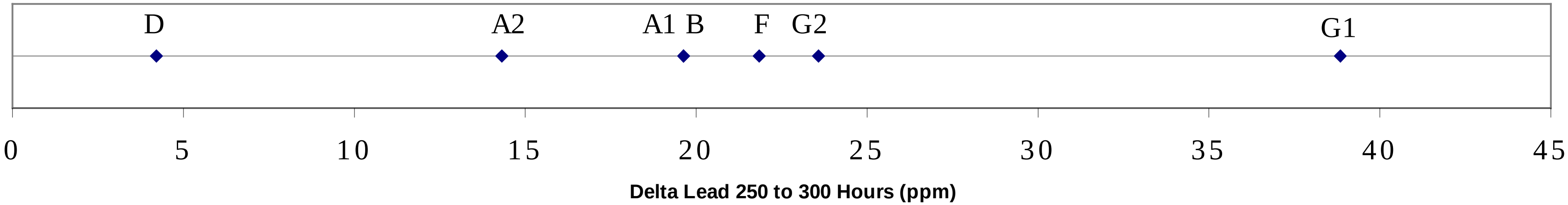
Figure 3
Least Squares Means for Oils



Technology	Least Squares Mean	p-value for test of equal means (Tukey) vs X	vs Y	vs Z
X	13		0.70	0.00
Y	16	0.70		0.03
Z	28	0.00	0.03	

Figure 4
Least Squares Means for Stands within Labs
Delta Lead from 250 to 300 Hours (ppm)

Lab/ Stand	LS Mean	p-value for test of equal means (Tukey)						
		vs A1	vs A2	vs B	vs D	vs F	vs G1	vs G2
A1	20		0.94	1.00	0.14	1.00	0.06	0.98
A2	14	0.94		0.95	0.56	0.79	0.02	0.45
B	20	1.00	0.95		0.16	1.00	0.13	0.99
D	4	0.14	0.56	0.16		0.06	0.00	0.05
F	22	1.00	0.79	1.00	0.06		0.10	1.00
G1	39	0.06	0.02	0.13	0.00	0.10		0.22
G2	24	0.98	0.45	0.99	0.05	1.00	0.22	



Top Ring Weight Loss
Summary of Model Fit

- Model factors include Laboratory (A,B,D,F,G), Technology (X,Y,Z), Base Oil (1,2,3) and Technology by Base Oil interaction.

- Base Oil and Interaction between Technology and Base Oil were marginally significant.
  - Root MSE from the model was 25 (14 df).
  - The R^2 for the model was 0.62.
  - Figure 5 illustrates the least squares means by oil.
  - Figure 6 illustrates the least squares means for laboratories.
  - No observations had large Studentized residuals.

Figure 5
Least Squares Means for Oils

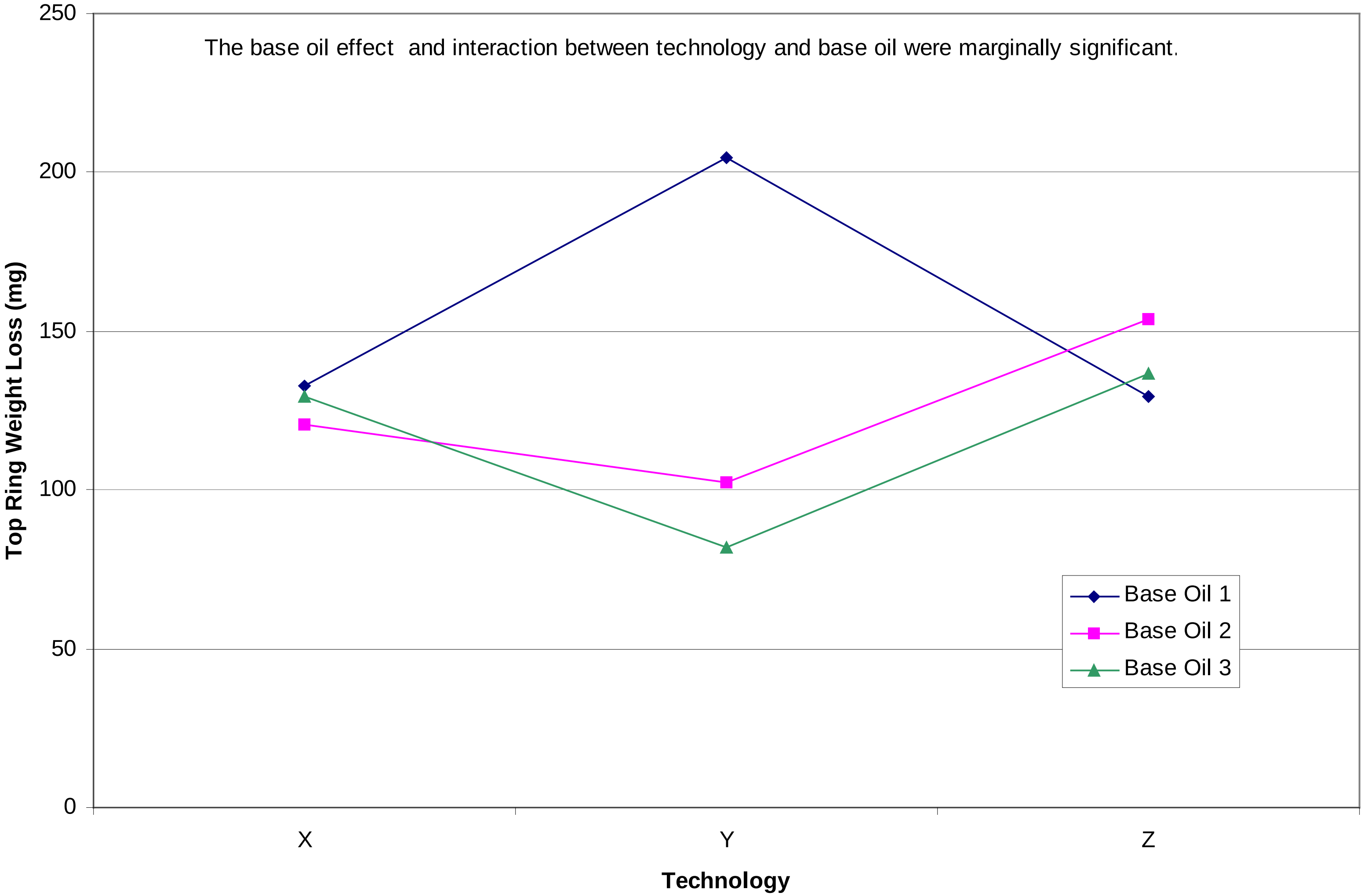
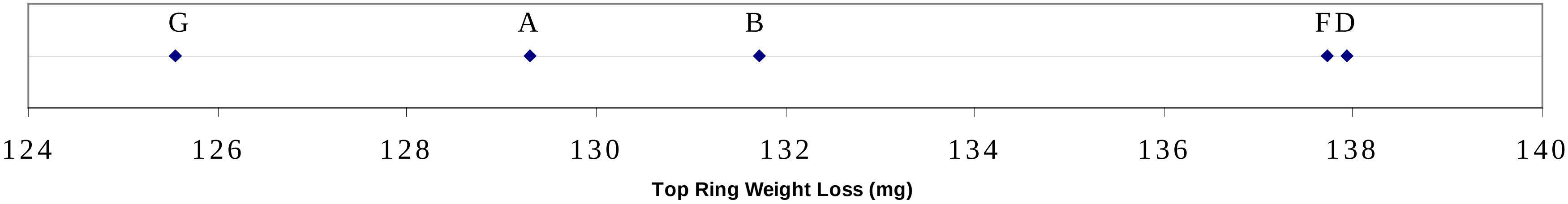


Figure 6
Lab Least Squares Means
Top Ring Weight Loss (mg)

Lab	LS Mean	p-value for test of equal means (Tukey)				
		vs A	vs B	vs D	vs F	vs G
A	129		1.00	0.99	0.99	1.00
B	132	1.00		1.00	1.00	1.00
D	138	0.99	1.00		1.00	0.96
F	138	0.99	1.00	1.00		0.95
G	126	1.00	1.00	0.96	0.95	

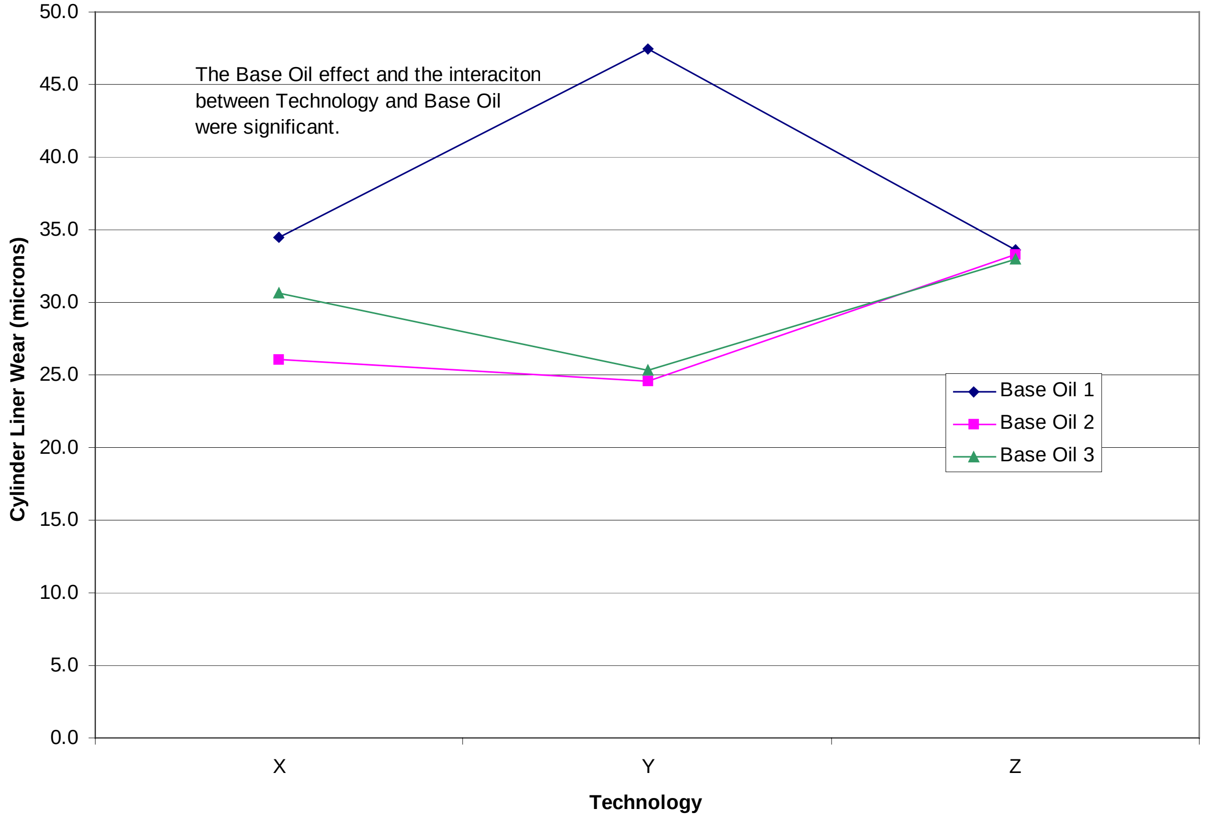


Cylinder Liner Wear
Summary of Model Fit

- Model factors include Laboratory (A,B,D,F,G), Technology (X,Y,Z), Base Oil (1,2,3) and Technology by Base Oil interaction.

- The Base Oil effect and the interaction between Technology and Base Oil was significant. Lab was marginally significant.
  - Root MSE from the model was 3.7 (14 df).
  - The R^2 for the model was 0.80.
  - Figure 7 illustrates the least squares means by oil.
  - Figure 8 shows least squares means for base oils and labs.
  - There were no large Studentized residuals.

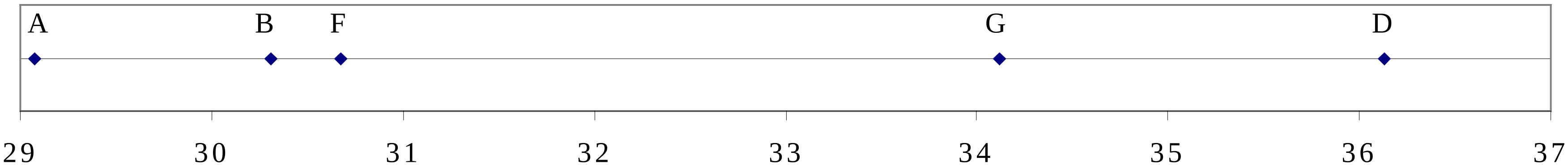
Figure 7
Least Squares Means for Oils



Tech	Base Oil	LS Mean	p-value for test of equal means (Tukey)								
			vs X1	vs X2	vs X3	vs Y1	vs Y2	vs Y3	vs Z1	vs Z2	vs Z3
X	**1**	34.5		0.29	0.92	0.18	0.03	0.17	1.00	1.00	1.00
X	**2**	26.1	0.29		0.97	0.01	1.00	1.00	0.61	0.75	0.64
X	**3**	30.7	0.92	0.97		0.11	0.69	0.92	1.00	1.00	1.00
Y	**1**	47.4	0.18	0.01	0.11		0.01	0.02	0.26	0.25	0.12
Y	**2**	24.6	0.03	1.00	0.69	0.01		1.00	0.31	0.37	0.25
Y	**3**	25.3	0.17	1.00	0.92	0.02	1.00		0.49	0.55	0.58
Z	**1**	33.7	1.00	0.61	1.00	0.26	0.31	0.49		1.00	1.00
Z	**2**	33.3	1.00	0.75	1.00	0.25	0.37	0.55	1.00		1.00
Z	**3**	33.0	1.00	0.64	1.00	0.12	0.25	0.58	1.00	1.00	

Figure 8
Lab Least Squares Means
Cylinder Liner Wear (microns)

Lab	LS Mean	p-value for test of equal means (Tukey)				
		vs A	vs B	vs D	vs F	vs G
A	29.1		0.99	0.13	0.97	0.14
B	30.3	0.99		0.38	1.00	0.69
D	36.1	0.13	0.38		0.39	0.95
F	30.7	0.97	1.00	0.39		0.67
G	34.1	0.14	0.69	0.95	0.67	



Oil Consumption
Summary of Model Fit

- Model factors include Laboratory (A,B,D,F,G), Technology (X,Y,Z), Base Oil (1,2,3) and Technology by Base Oil interaction.

- No effects were significant.
  - Root MSE from the model was 8.9 (14 df).
  - The R^2 for the model was 0.51.
  - Figure 9 illustrates the least squares means by oil.
  - Figure 10 show least squares means for labs.
  - There were no large Studentized residuals.

Figure 9
Least Squares Means for Oils

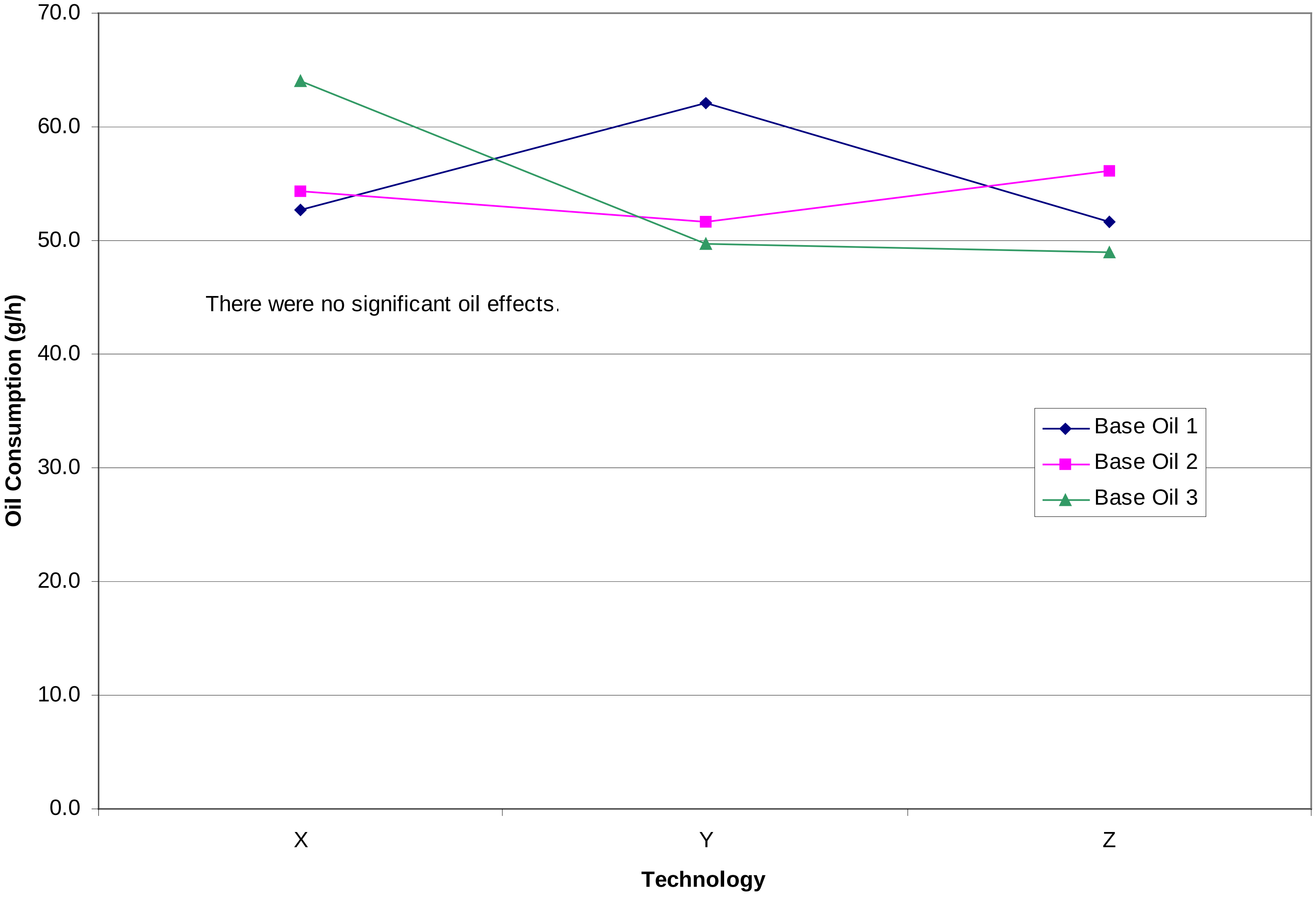
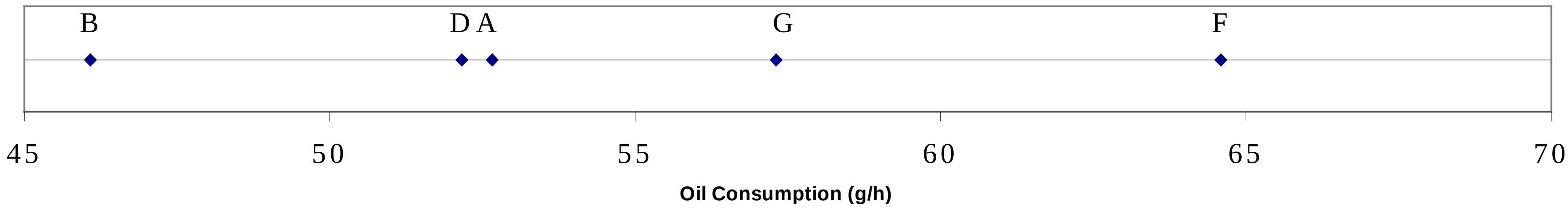


Figure 10
Lab Least Squares Means
Oil Consumption (g/h)

Lab	LS Mean	p-value for test of equal means (Tukey)				
		vs A	vs B	vs D	vs F	vs G
A	52.7		0.87	1.00	0.39	0.87
B	46.1	0.87		0.93	0.19	0.52
D	52.2	1.00	0.93		0.44	0.94
F	64.6	0.39	0.19	0.44		0.76
G	57.3	0.87	0.52	0.94	0.76	

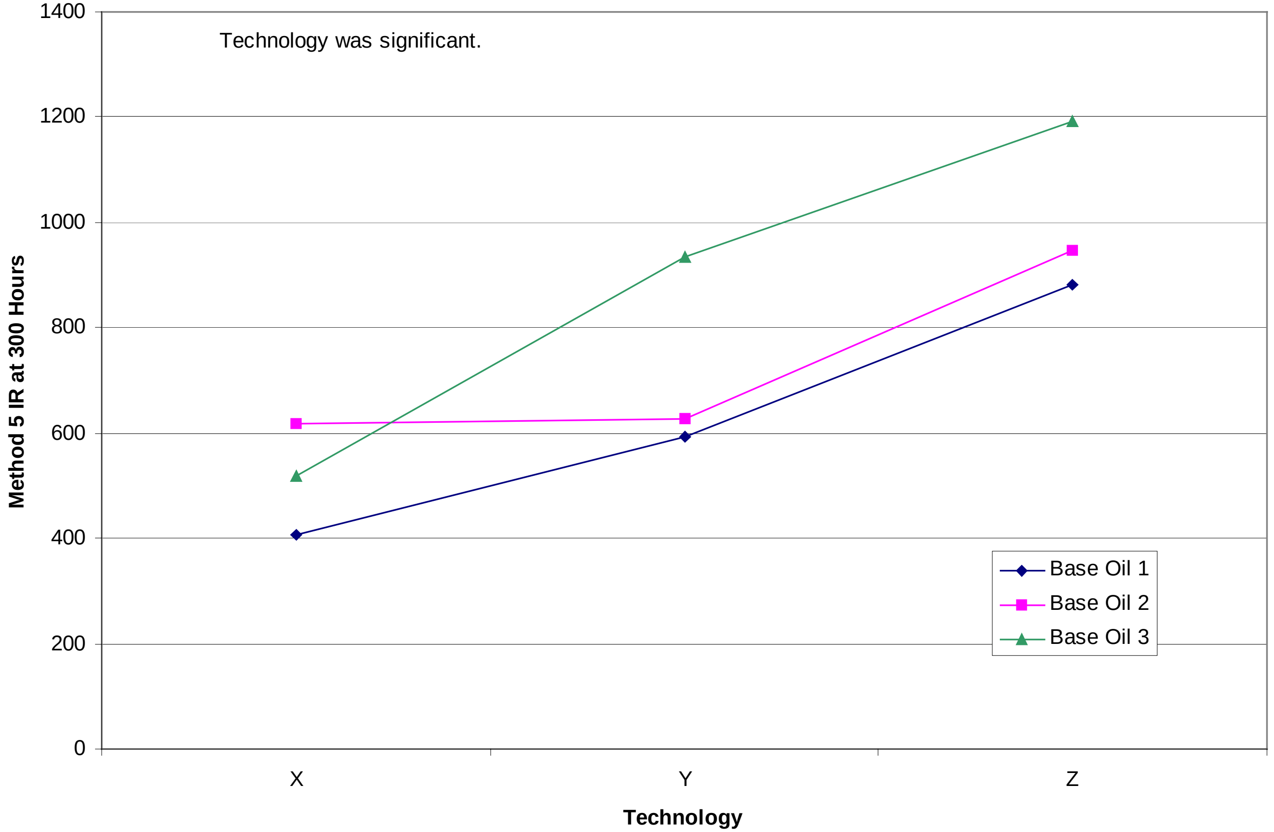


Method 5 IR at 300 Hours Summary of Model Fit

- Model factors include Laboratory (A,B,D,F,G), Stand within Laboratory (A1,A2,G1,G2), Technology (X,Y,Z), Base Oil (1,2,3) and Technology by Base Oil interaction.

- Technology, and Lab, and Stand within Lab were significant.
  - Root MSE from the model was 181 (12 df).
  - The R^2 for the model was 0.93.
  - Figure 11 illustrates the least squares means by oil.
  - Figure 12 summarizes least squares means for stands within labs.
  - Stand within Lab significance was driven mainly by one stand in Lab G that was significantly higher than all other stands.
  - No observations had large Studentized residuals.

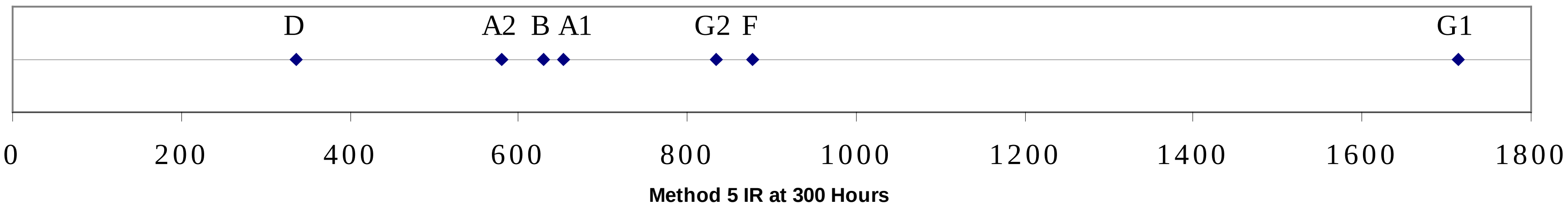
Figure 11
Least Squares Means for Oils



Technology	Least Squares	p-value for test of equal means (Tukey)		
		vs X	vs Y	vs Z
X	515		0.19	0.00
Y	719	0.19		0.06
Z	1007	0.00	0.06	

Figure 12
Least Squares Means for Stand within Lab
Method 5 IR at 300 Hours

Lab/ Stand	LS Mean	p-value for test of equal means (Tukey)						
		vs A1	vs A2	vs B	vs D	vs F	vs G1	vs G2
A1	652		1.00	1.00	0.41	0.76	0.00	0.86
A2	580	1.00		1.00	0.70	0.47	0.00	0.47
B	630	1.00	1.00		0.52	0.74	0.00	0.82
D	336	0.41	0.70	0.52		0.04	<.0001	0.08
F	877	0.76	0.47	0.74	0.04		0.00	1.00
G1	1714	0.00	0.00	0.00	<.0001	0.00		0.00
G2	833	0.86	0.47	0.82	0.08	1.00	0.00	



Correlations Among the Criteria

Raw Data	ln(Delta Pb)	DPb250300	TRWL	CLW	OC	M5IR300
ln(Delta Pb)	1.00	**0.91**	0.08	0.09	0.33	**0.91**
DPb250300	**0.91**	1.00	0.10	0.08	0.37	**0.88**
TRWL	0.08	0.10	1.00	**0.73**	0.18	0.10
CLW	0.09	0.08	**0.73**	1.00	0.14	0.11
OC	0.33	0.37	0.18	0.14	1.00	0.31
M5IR300	**0.91**	**0.88**	0.10	0.11	0.31	1.00

Residuals	ln(Delta Pb)	URBWL	TRWL	CLW	OC	M5IR300
ln(Delta Pb)	1.00	**0.75**	0.12	**0.40**	0.19	**0.68**
DPb250300	**0.75**	1.00	0.09	0.23	0.14	**0.76**
TRWL	0.12	0.09	1.00	**0.67**	0.22	0.22
CLW	**0.40**	0.23	**0.67**	1.00	0.19	0.24
OC	0.19	0.14	0.22	0.19	1.00	-0.18
M5IR300	**0.68**	**0.76**	0.22	0.24	-0.18	1.00

Oil LS Means	ln(Delta Pb)	URBWL	TRWL	CLW	OC	M5IR300
ln(Delta Pb)	1.00	**0.86**	-0.28	-0.25	-0.42	**0.82**
DPb250300	**0.86**	1.00	-0.21	-0.22	-0.41	**0.70**
TRWL	-0.28	-0.21	1.00	**0.94**	0.61	-0.13
CLW	-0.25	-0.22	**0.94**	1.00	0.50	-0.11
OC	-0.42	-0.41	0.61	0.50	1.00	-0.54
M5IR300	**0.82**	**0.70**	-0.13	-0.11	-0.54	1.00

Oil Least Squares Means and Standard Deviations

Oil	lnDeltaPb	DPb250300	TRWL	CLW	OilCon	M5IR300
A	3.1884	10	133	34.5	52.6	407.4
B	3.5301	18	121	26.1	54.3	618.1
C	3.5515	10	130	30.7	64.0	519.6
D	3.1351	9	205	47.4	62.1	593.3
E	3.3099	12	102	24.6	51.6	626.7
F	3.8439	26	82	25.3	49.7	935.6
G	4.2338	31	129	33.7	51.7	881.7
H	3.9526	34	154	33.3	56.1	946.6
J	3.9949	19	137	33.0	48.9	1191.3
Std Dev	0.2946	6	25	3.7	8.9	181

T10 FTIR UPDATE 8/15/01

METHOD 2 DATA

Method 2 FTIR data			FTIR	FTIR	FTIR	FTIR	FTIR	FTIR	FTIR	FTIR	FTIR	FTIR	FTIR	FTIR	FTIR	
CMIR	LAB	OIL	NEW	25	50	75	100	125	150	175	200	225	250	275	300	
38809	A	A	0	14	152	184	276	478	644	874	930	1050	1172	1342	1520	
38810	A	A	0	148	160	270	440	640	990	906	1130	1186	1446	1350	1592	
38942	A	A	0	120	186	376	492	558	694	738	984	1080	1128	1198	1368	
38815	B	A	0	94	208	332	276	750	724	848	892	1042	1160	1172	1418	
41410	B	A	0		215	267	522	672	964	988	1156	1172	1370	1383	1557	
38811	D	A	0	98	202	350	522	526	760	840	1122	1142	1156	1094	1320	
38813	G	A	0	88	167	229	527	733	890	1027	1190	1269	1427	1743	2069	
38814	F	A	0	74	186	498	378	524	780	962	1100	1258	1546	1660	2048	
38954	F	A	0	64	178	252	518	622	900	1078	1188	1400	1648	1772	2280	
38951	G	A	0	102	135	312	506	543	873	898	1173	1257	1522	1435	1741	
40230	G	A	0	116	178	314	466	532	702	780	924	1026	1144	1124	1378	PE
40230	G	A	0	59	150	184	488	561	623	761	951	929	1119	1211	1607	SWRI
41412	G	A	0	109	206	265	761	1040	1225	1403	1850	2008	2441	2870	3547	
41135	F	A	0	76	160	302	490	660	840	954	1188	1300	1466	1620	1876	
38943	D	B	0	56	170	236	422	486	750	774	1026	1040	1168	1174	1376	
40919	B	B	0	116	232	246	549	581	717	978	1022	1215	1476	1535	1671	
38939	A	C	0	82	208	212	468	624	816	922	1108	1212	1448	1508	1750	
38949	G	C	0	36	134	194	336	642	913	1156	1704	1806	2075	3002	3696	SWRI
38949	G	C	0	96	192	260	534	696	1070	1248	1616	1956	2496	2544	3450	PE
38937	A	E	0	104	212	344	490	592	764	846	1040	1094	1230	1248	1550	
38940	A	E	0	129	265	433	584	714	910	1033	1153	1169	1414	1457	1639	
38950	G	E	0	168	276	346	696	728	786	956	1208	1358	1734	1852	2434	PE
38950	G	E	0	180	202	243	545	846	1057	1255	1358	1575	2012	2119	2771	SWRI
38945	D	F	0	106	216	312	558	650	824	898	1042	1202	1358	1392	1674	
38952	F	F	0	76	173	235	500	765	704	1073	1604	1539	1849	2157	3041	
38941	A	G	0	110	216	424	412	510	814	878	1060	1252	1566	1774	2300	
38944	D	G	0	94	272	200	378	410	602	670	782	804	1074	1178	1346	
38953	F	H	0	86	166	252	382	480	730	902	1092	1284	1574	1810	2326	
38947	G	H	0	91	174	259	427	810	1138	1267	1470	1998	2660	3103	3923	SWRI
38947	G	H	0	76	94	98	180	240	384	464	936	1324	1592	1704	2418	PE
38938	A	J	0	138	208	372	556	578	830	1048	1292	1488	1938	1908	2418	
38956	B	J	0	132	306	370		747	885	1069	1302	1411	1800	2158	2308	
38948	G	J	0	216	336	604	638	942	864	1412	1664	2204	2742	2450	2952	
38957	B	D	0	335	415	614	681	837	933	1136	1368	1524	1738	1811	1917	
38946	G	D	0	14	156	312	606	716	1182	1272	1920	2248	3904		6724	PE
38946	G	D	0	132	322	462	769	895	893	1441	2105	2623	4109		7555	SWRI

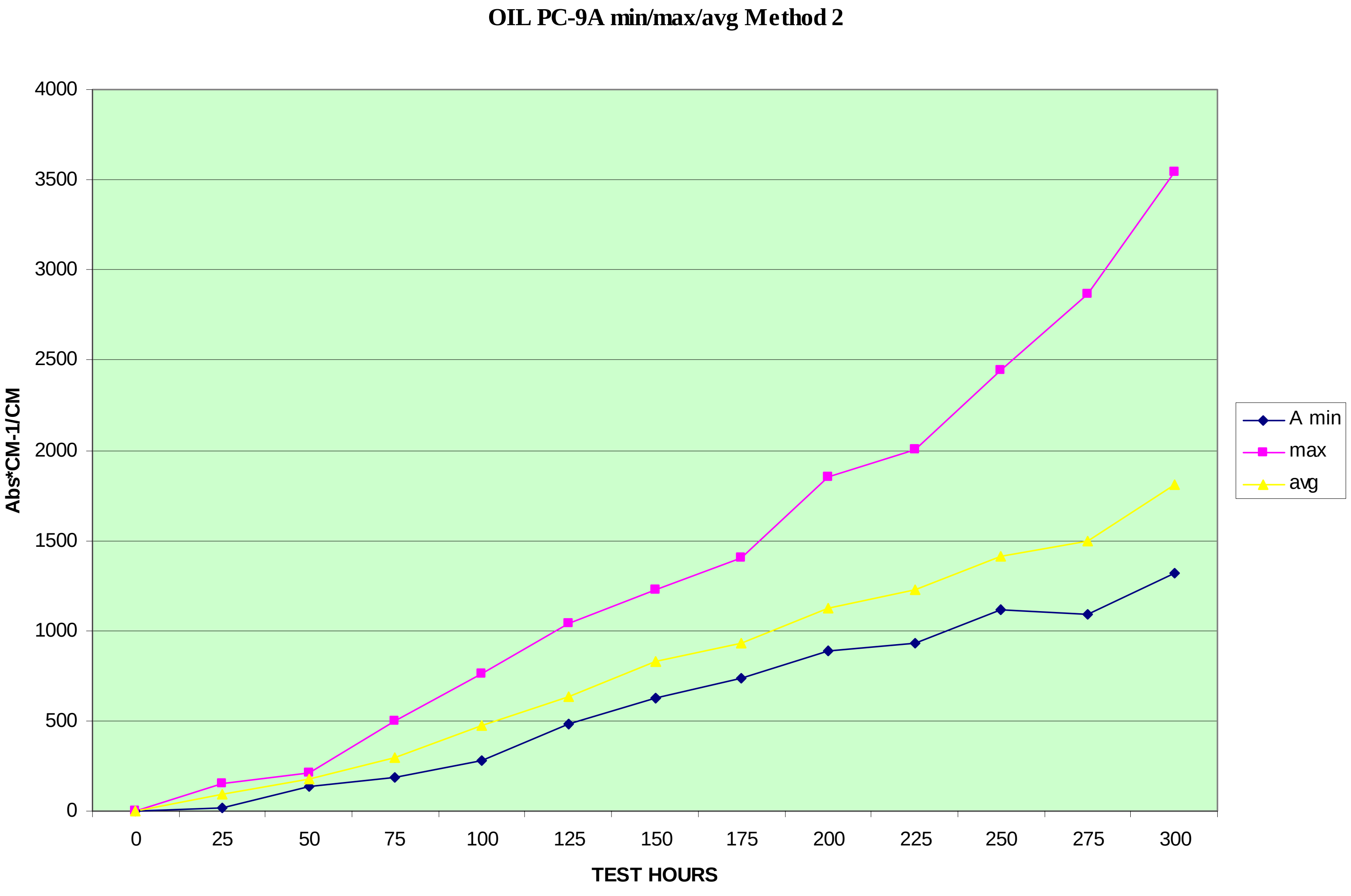
NOT AVAILABLE

METHOD 5 DATA

Method 5 FTIR data			FTIR	FTIR	FTIR	FTIR	FTIR	FTIR	FTIR	FTIR	FTIR	FTIR	FTIR	FTIR	FTIR	
CMIR	LAB	OIL	NEW	25	50	75	100	125	150	175	200	225	250	275	300	
38809	A	A	0	-34	-60	-92	-62	-16	46	72	106	178	238	240	348	
38810	A	A	0	-4	-68	-88	-64	30	30	66	148	126	200	260	334	
38942	A	A	0	-26	-32	-62	6	20	62	56	134	156	194	218	280	
38815	B	A	0	-28	-50	-58	-116	-40	-14	-8	26	64	118	126	156	
41410	B	A	0		-44	-69	-32	36	72	103	141	203	224	256	347	
38811	D	A	0	-13	-45	-61	-18	-12	15	46	95	127	165	166	210	
38813	G	A	0	-11	-25	-69	-16	17	109	130	215	253	329	404	525	
38814	F	A	0	-24	-42	-52	6	-6	86	158	150	224	306	326	452	
38954	F	A	0	-32	-66	-92	-28	10	66	152	212	226	352	368	606	
38951	G	A	0	-30	-38	-39	-3	37	84	137	215	238	332	370	497	
40230	G	A	0	-25	-122	-95	-39	-28	11	18	67	96	139	176	200	
41412	G	A	0	-43	-88	-82	12	130	234	341	500	588	868	950	1333	PE
41412	G	A	0	-13	-54	-54	42	141	270	349	522	573	843	946	1372	SWRI
41135	F	A	0	-4	-40	-90	-6	46	100	138	204	232	330	370	482	
38943	D	B	0	-46	-60	-90	-38	0	34	70	116	152	224	214	294	
40919	B	B	0	-48	-55	-63	-6	33	75	141	192	216	331	352	415	
38939	A	C	0	-20	-44	-58	-36	10	94	130	184	246	318	332	458	
38949	G	C	0	-175	-203	-236	-177	-127	216	243	432	555	770	1050	1454	SWRI
38949	G	C	0	-38	-60	-72	28	72	198	252	422	514	854	946	1372	PE
38937	A	E	0	-18	-42	-56	-52	-32	18	50	96	108	196	214	342	
38940	A	E	0	-24	-57	-84	-68	-35	8	62	93	148	181	235	373	
38950	G	E	0	-6	-35	-38	3	55	132	193	267	363	552	663	991	
38945	D	F	0	-34	-64	-86	-80	-48	-6	66	100	128	202	210	346	
38952	F	F	0	-12	-60	-33	-24	21	135	96	270	334	503	634	1244	
38941	A	G	0	-32	-18	-26	-50	12	84	124	228	298	446	588	910	
38944	D	G	0	4	-54	-100	-32	-44	12	42	74	132	194	238	348	
38953	F	H	0	34	4	-28	16	60	104	188	334	432	648	738	1042	
38947	G	H	0	25	3	-63	-9	99	190	308	535	695	1152	1469	1949	SWRI
38947	G	H	0	-78	-136	-156	-110	-58	24	86	392	606	700	914	1280	PE
38938	A	J	0	-4	-38	-46	34	72	186	202	366	478	674	766	980	
38948	G	J	0	160	137	121	207	274	158	409	603	734	1083	1036	1292	
38956	B	J	0	27	3	-33		89	158	251	367	473	669	820	1106	
38957	B	D	0	-31	-88	-85	-50	15	12	99	146	161	285	279	477	
38946	G	D	0	-19	-51	-99	-16	52	63	235	617	912	1771		3551	

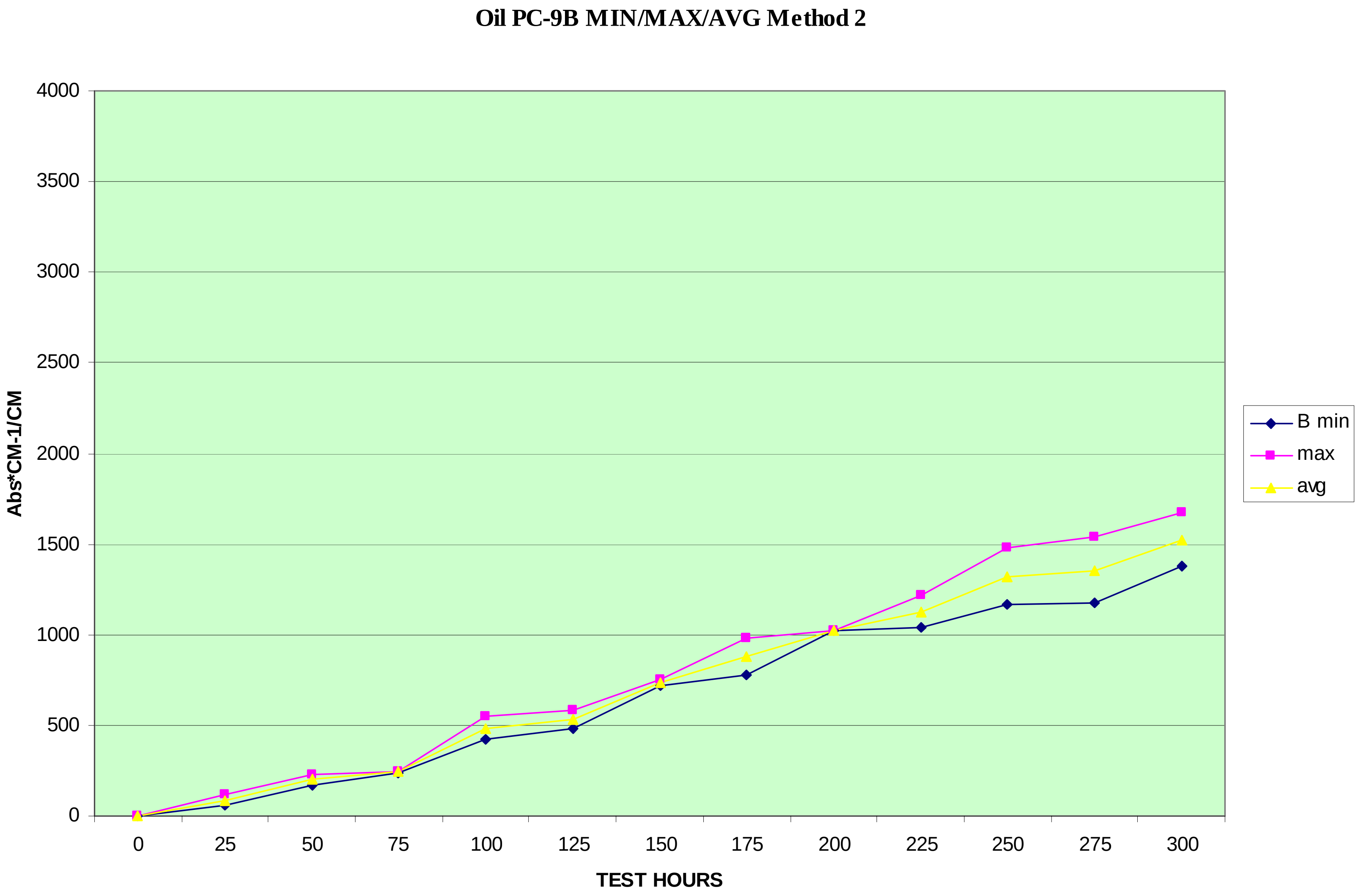
NOT AVAILABLE

PC-9A M2



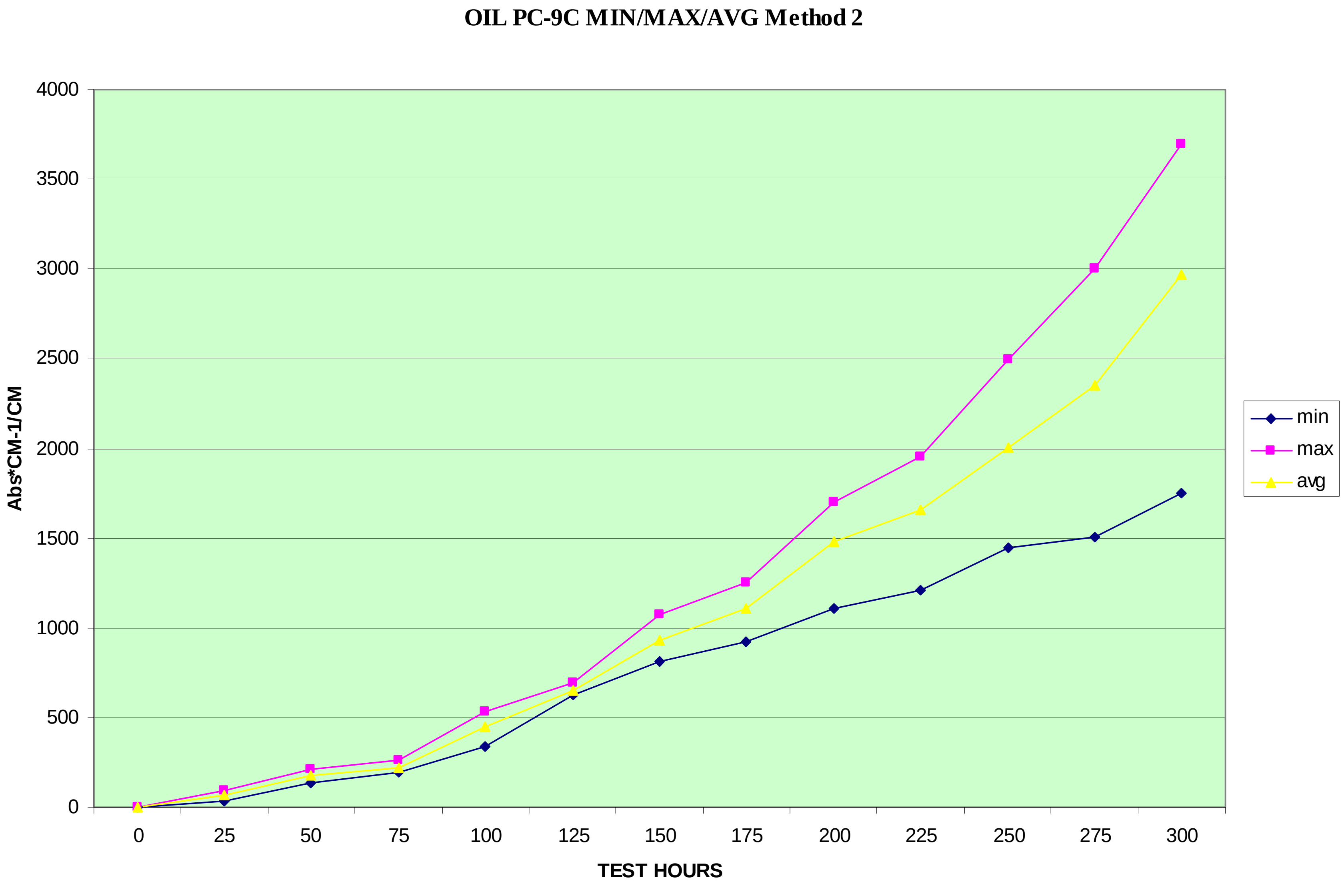
ATTACHMENT 5, 3 OF 23

PC-9B M2



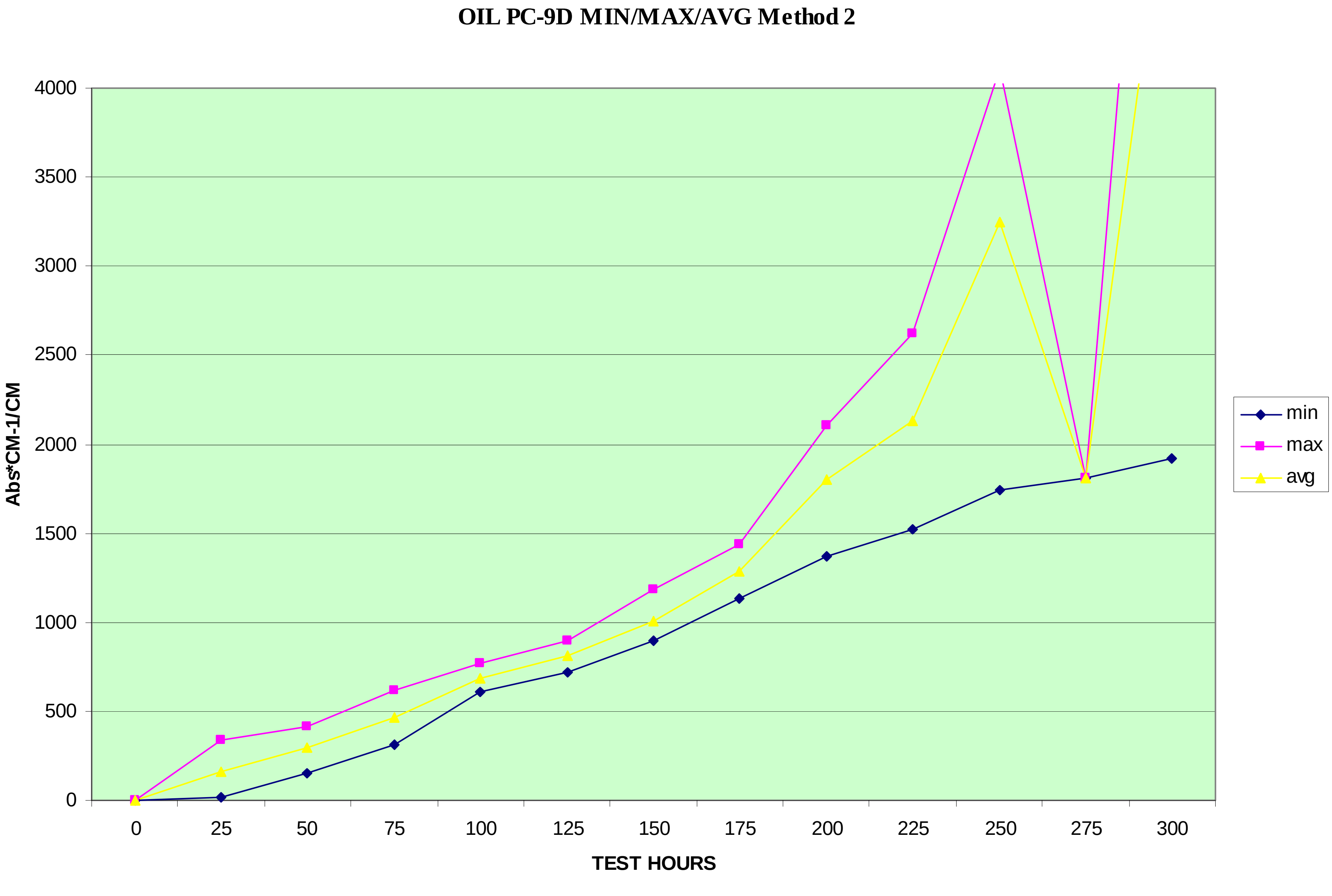
ATTACHMENT 5, 4 OF 23

PC-9C M2



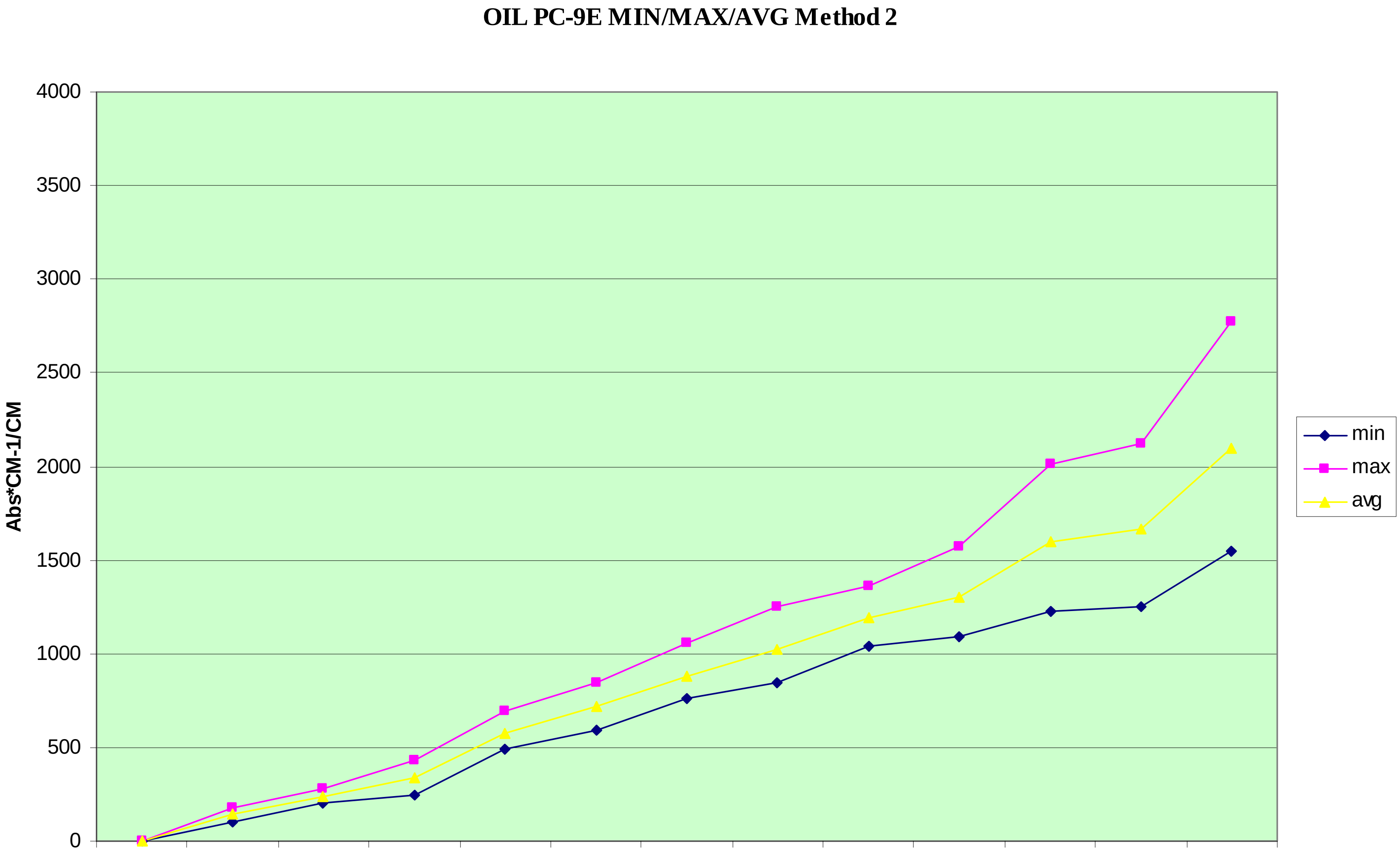
ATTACHMENT 5, 5 OF 23

PC-9D M2



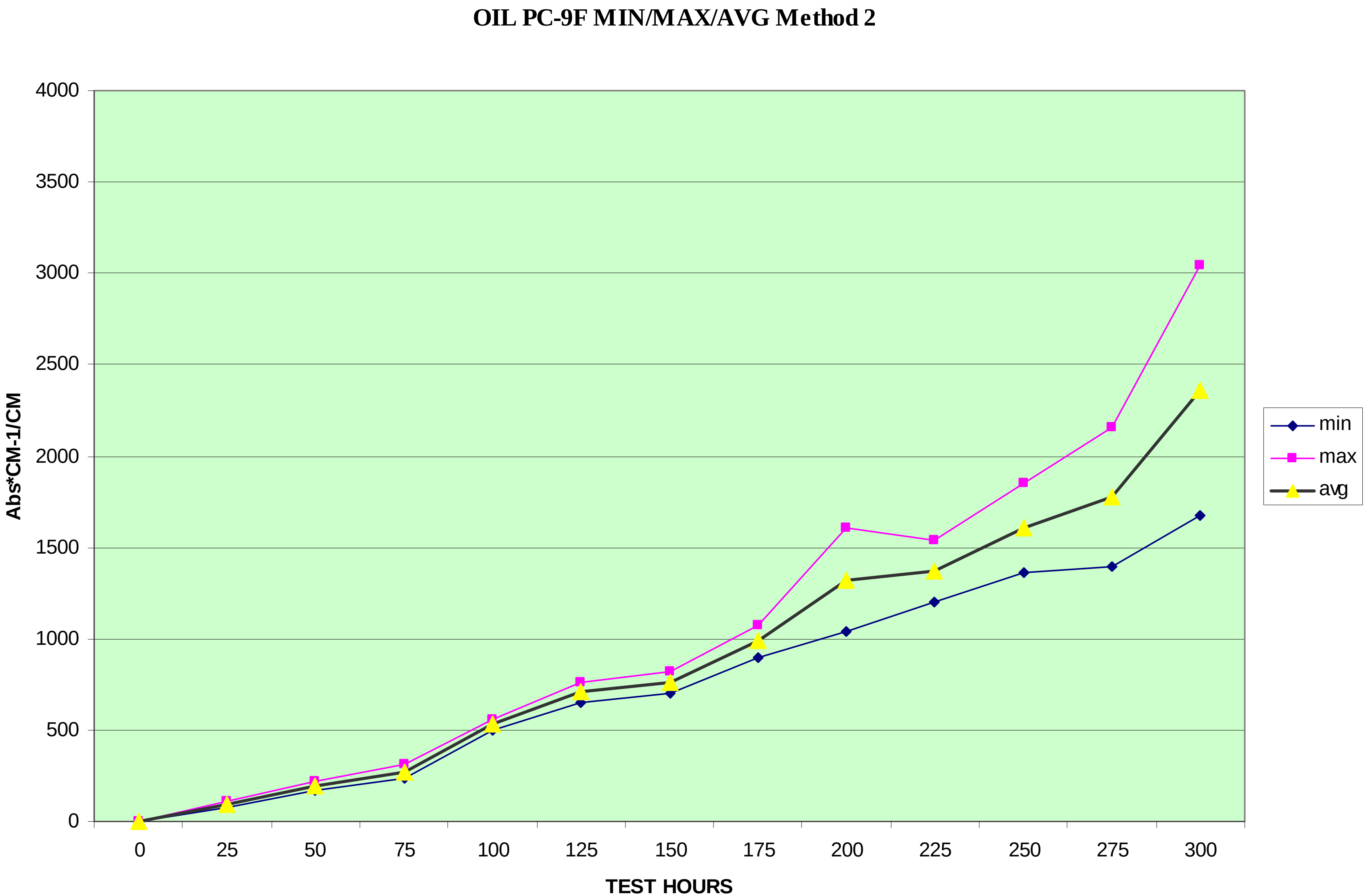
ATTACHMENT 5, 6 OF 23

PC-9E M2



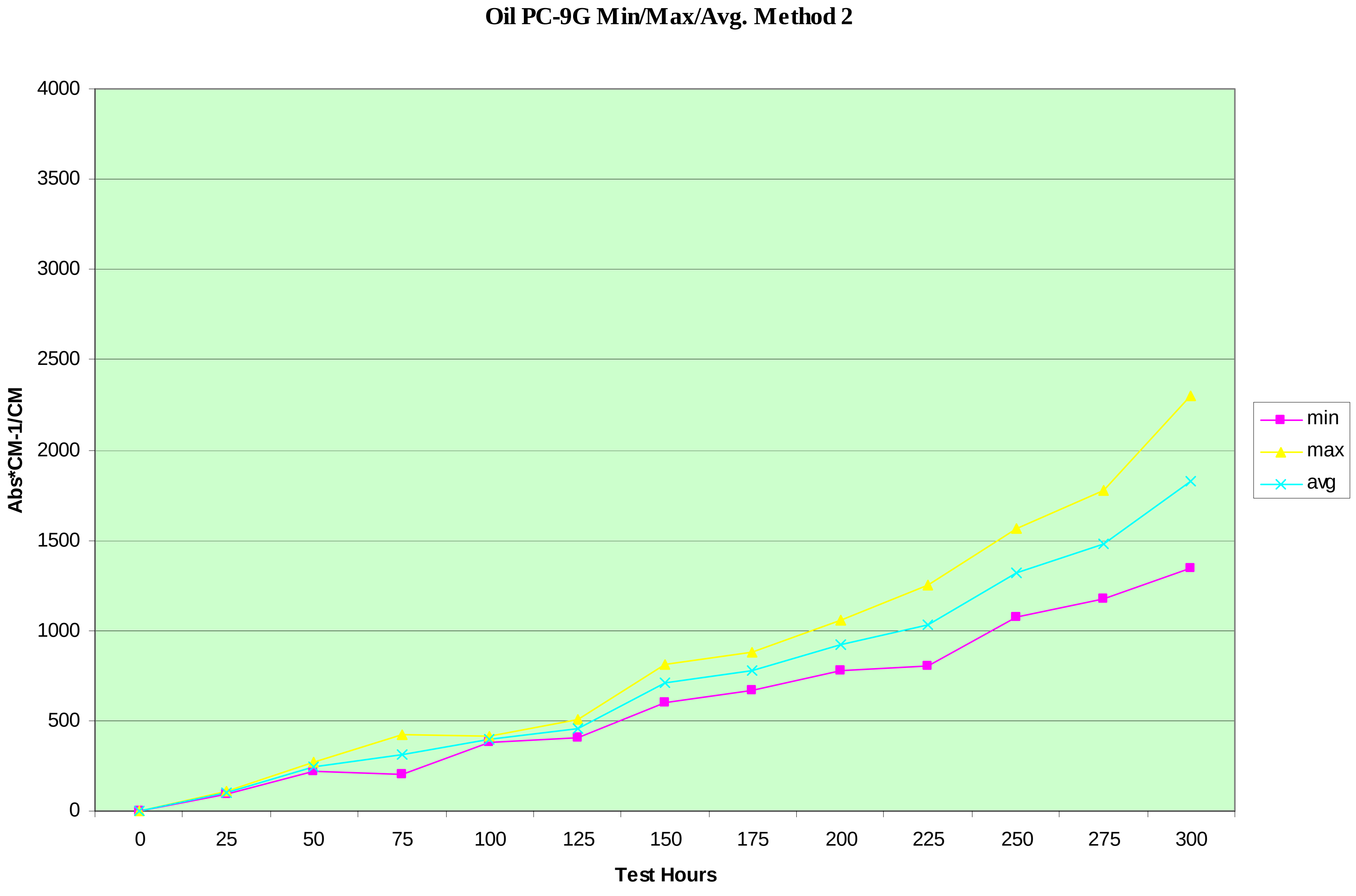
ATTACHMENT 5, 7 OF 23

PC-9F M2



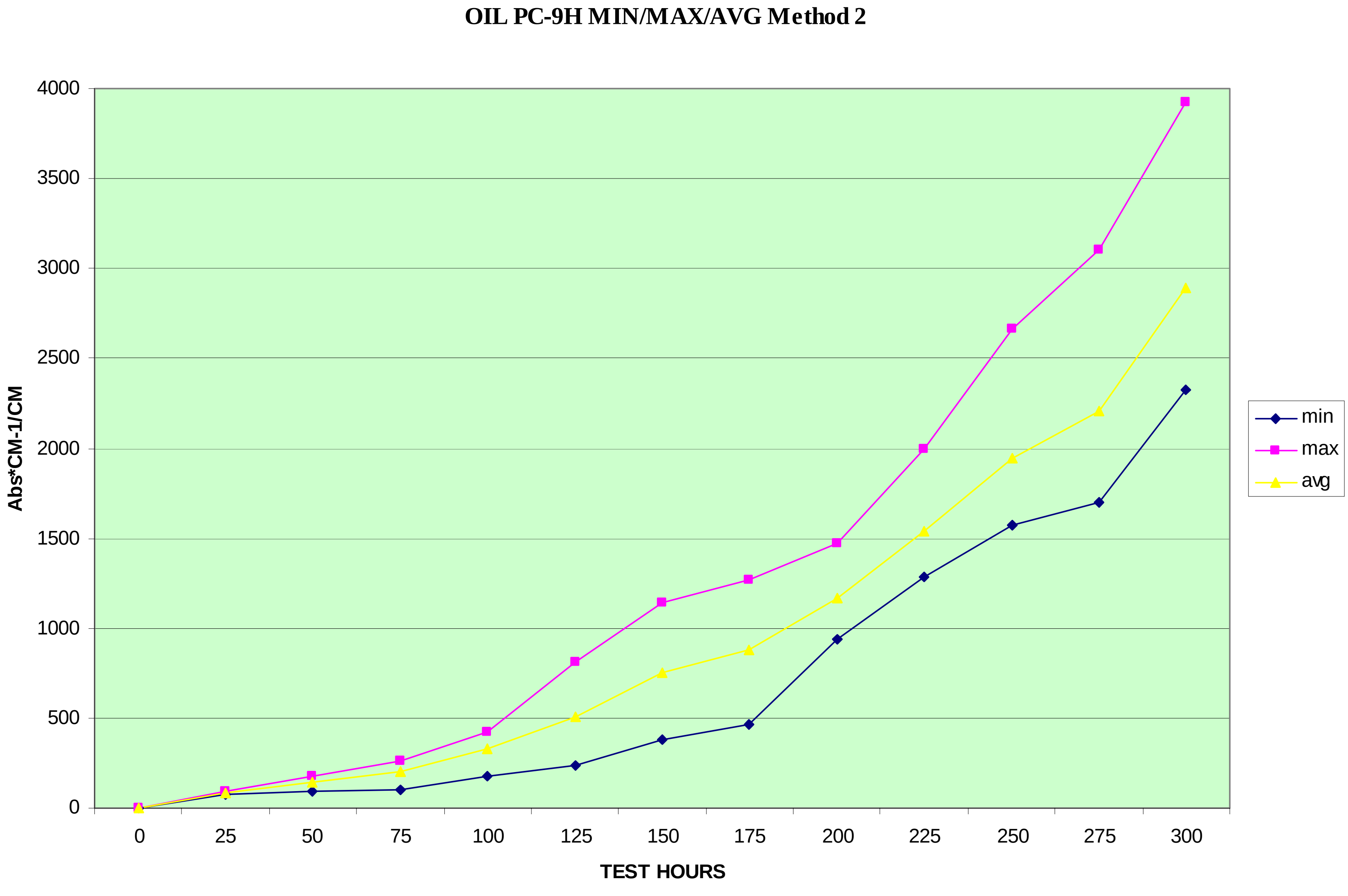
ATTACHMENT 5, 8 OF 23

PC-9G M2



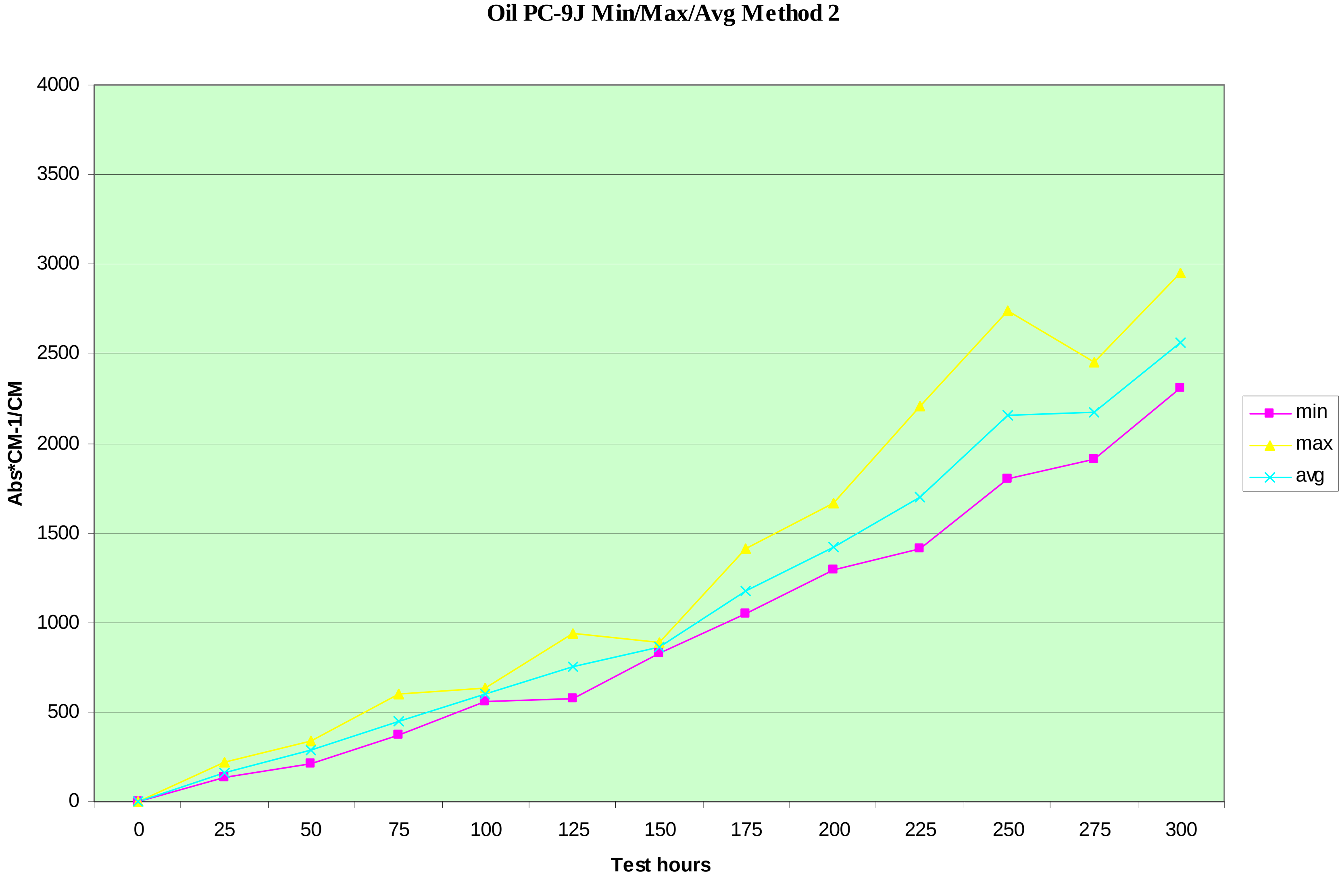
ATTACHMENT 5, 9 OF 23

PC-9H M2



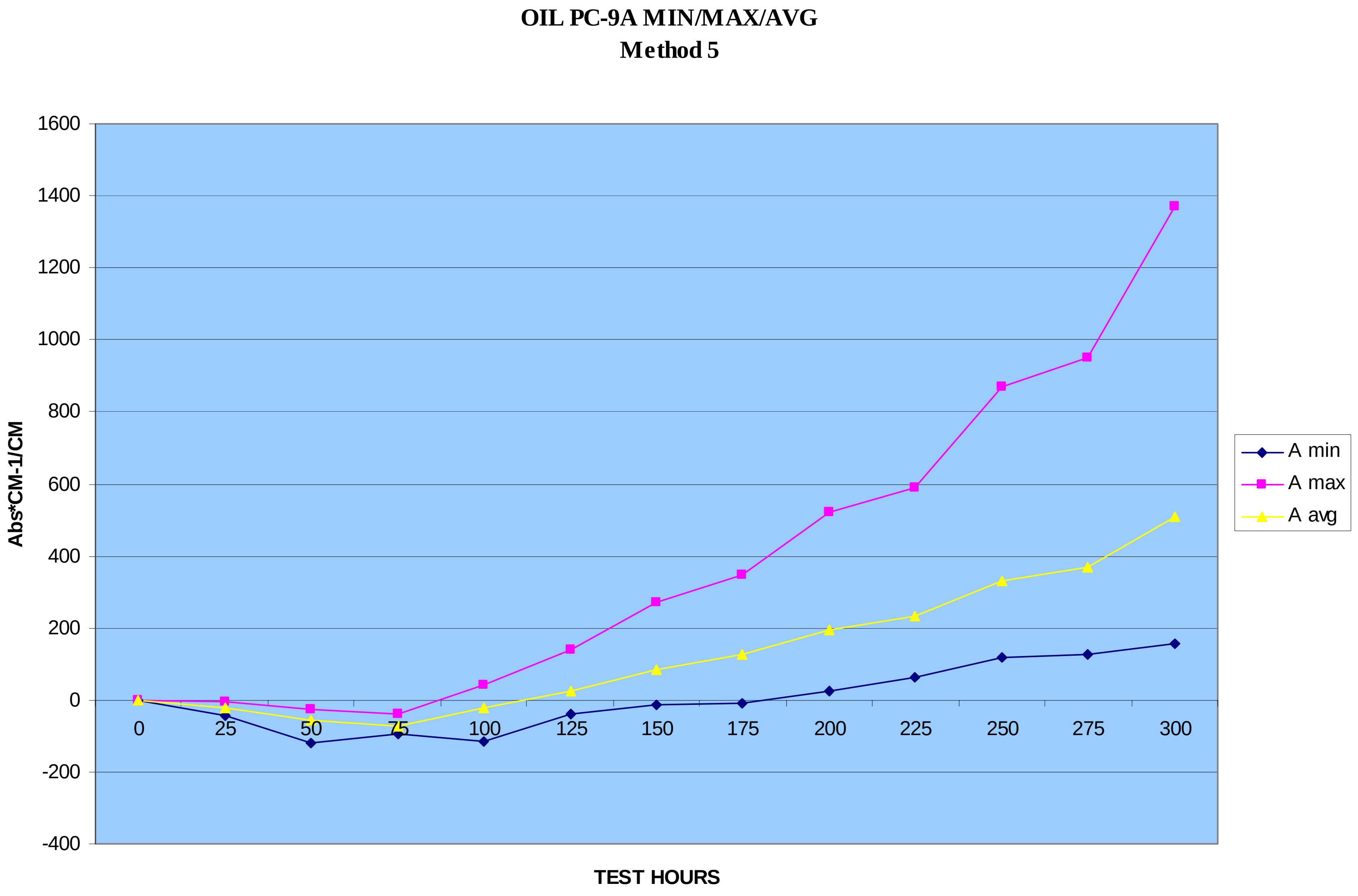
ATTACHMENT 5, 10 OF 23

PC-9J M2



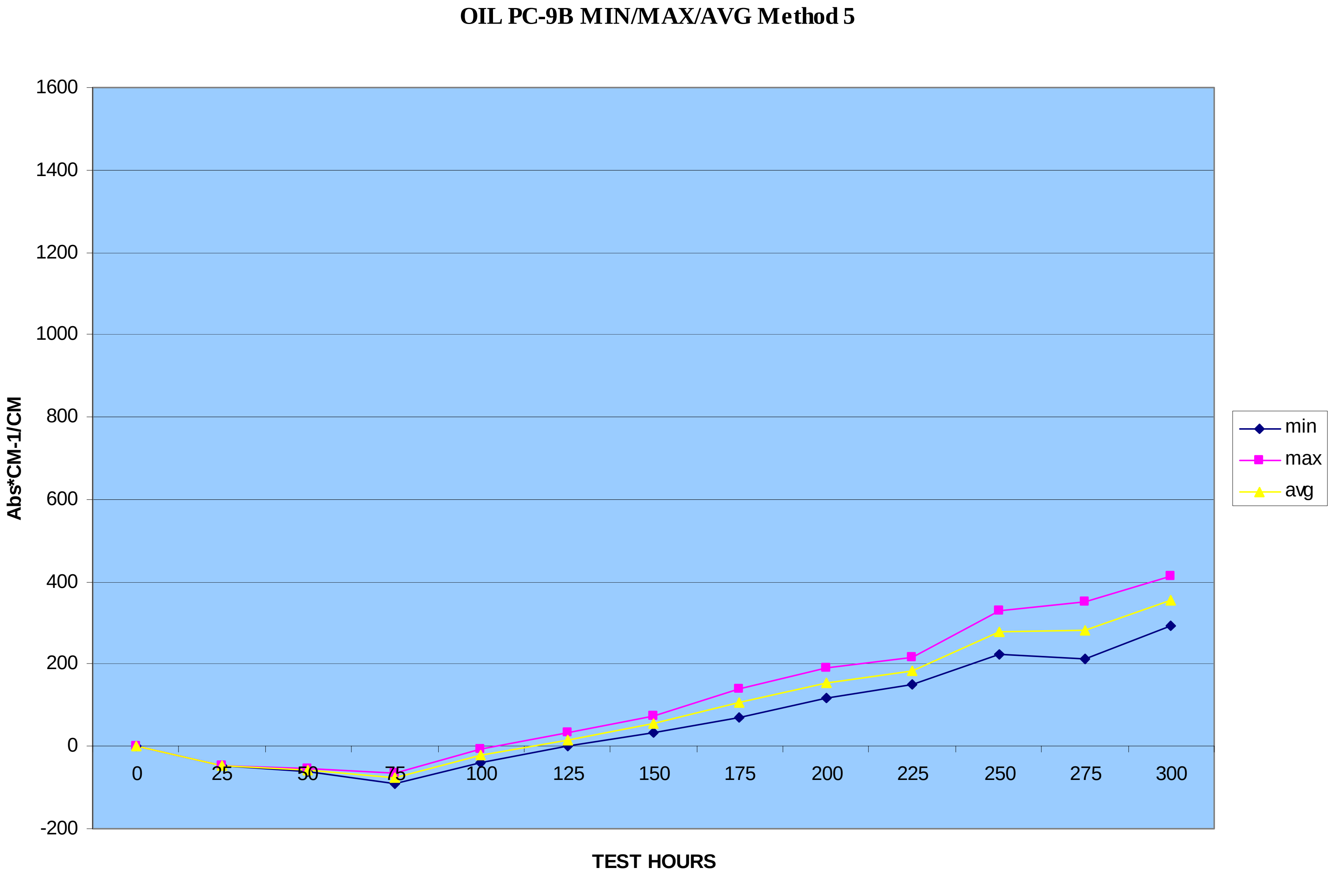
Oil PC-9J Min/Max/Avg Method 2
Abs*CM-1/CM
0
500
1000
1500
2000
2500
3000
3500
4000
0
25
50
75
100
125
150
175
200
225
250
275
300
Test hours
min
max
avg

PC-9A M5

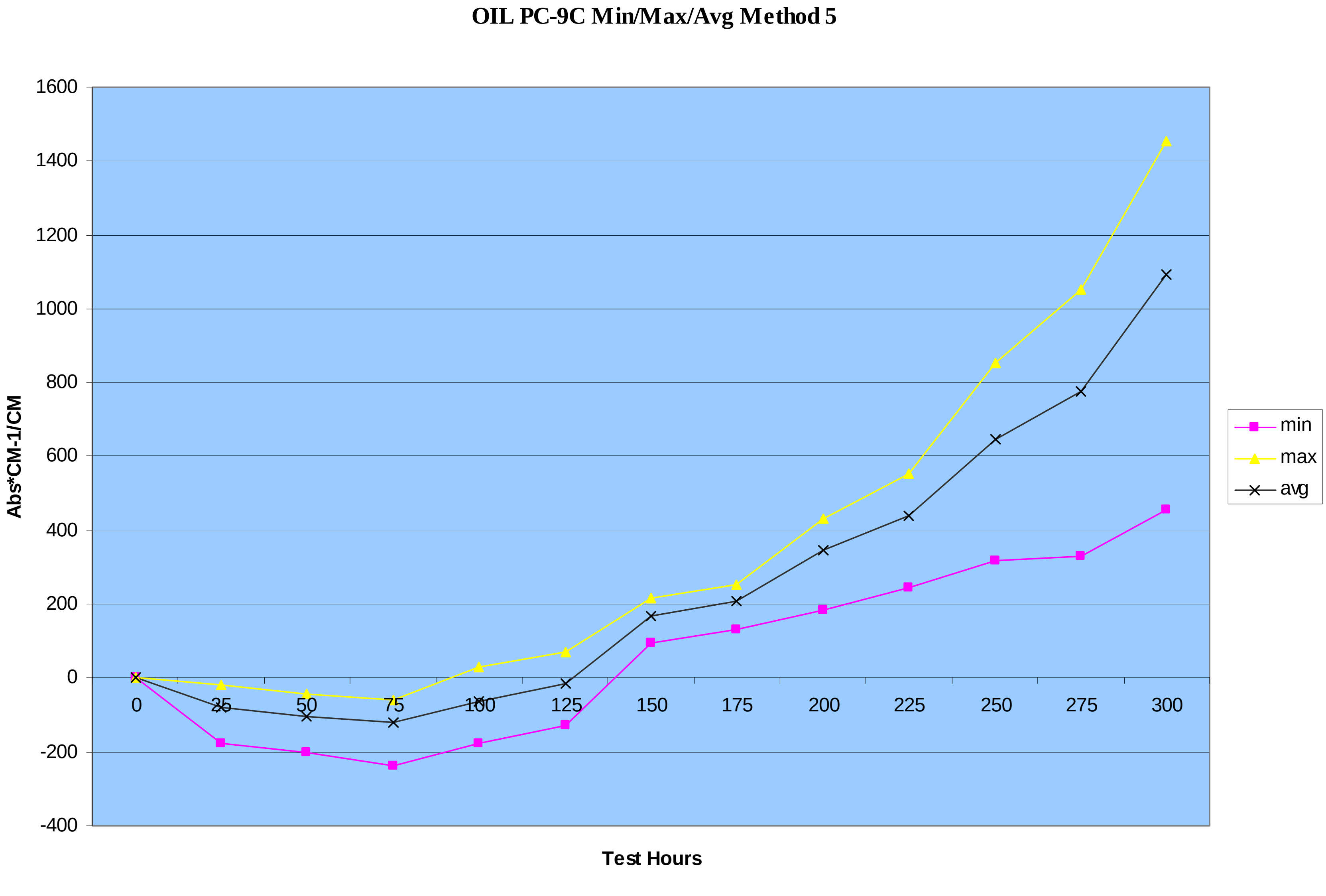


ATTACHMENT 5, 12 OF 23

PC-9B M5

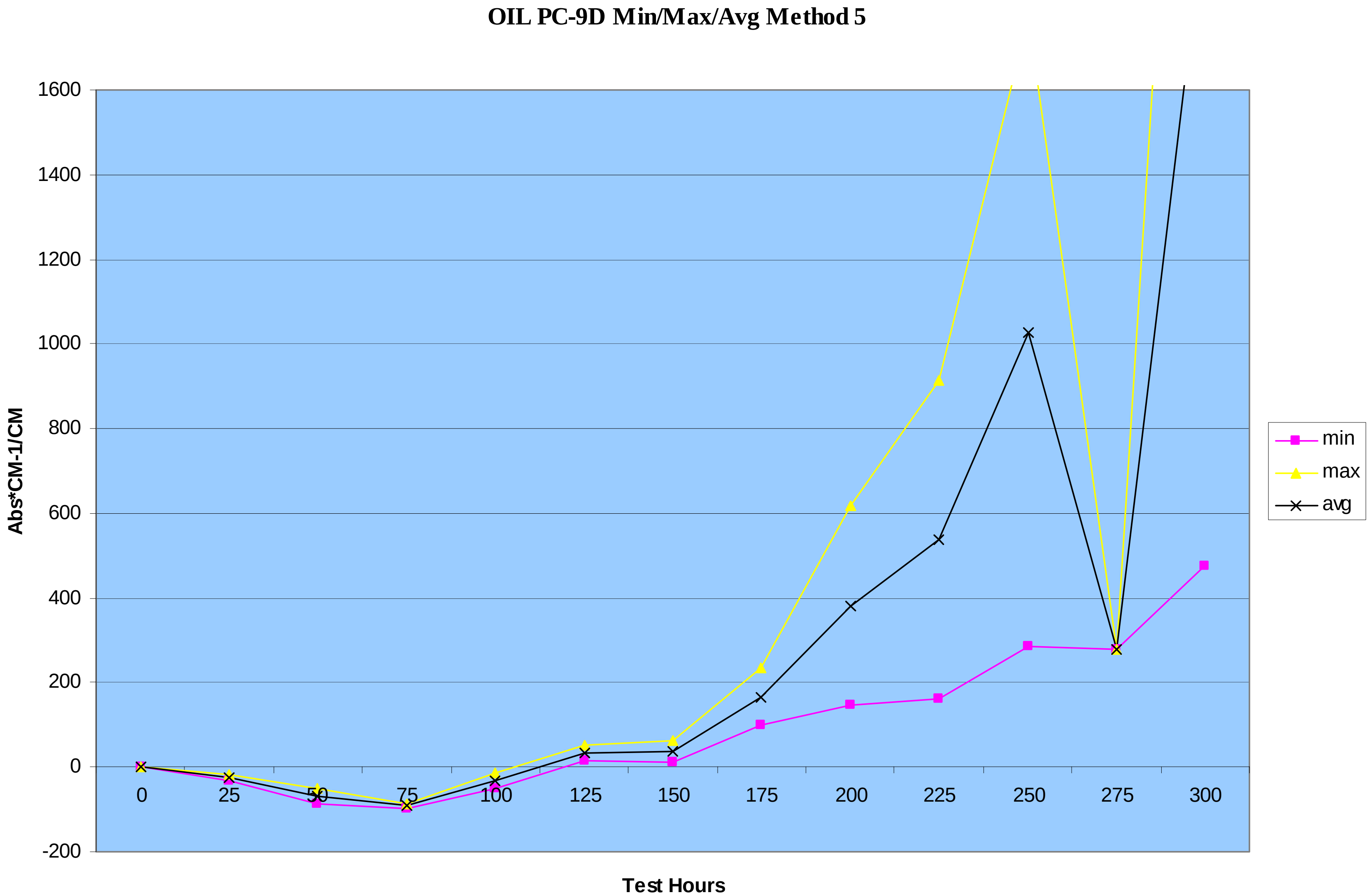

OIL PC-9B MIN/MAX/AVG Method 5
Abs*CM-1/CM
1600
1400
1200
1000
800
600
400
200
0
-200
0
25
50
75
100
125
150
175
200
225
250
275
300
TEST HOURS
min
max
avg

PC-9C M5



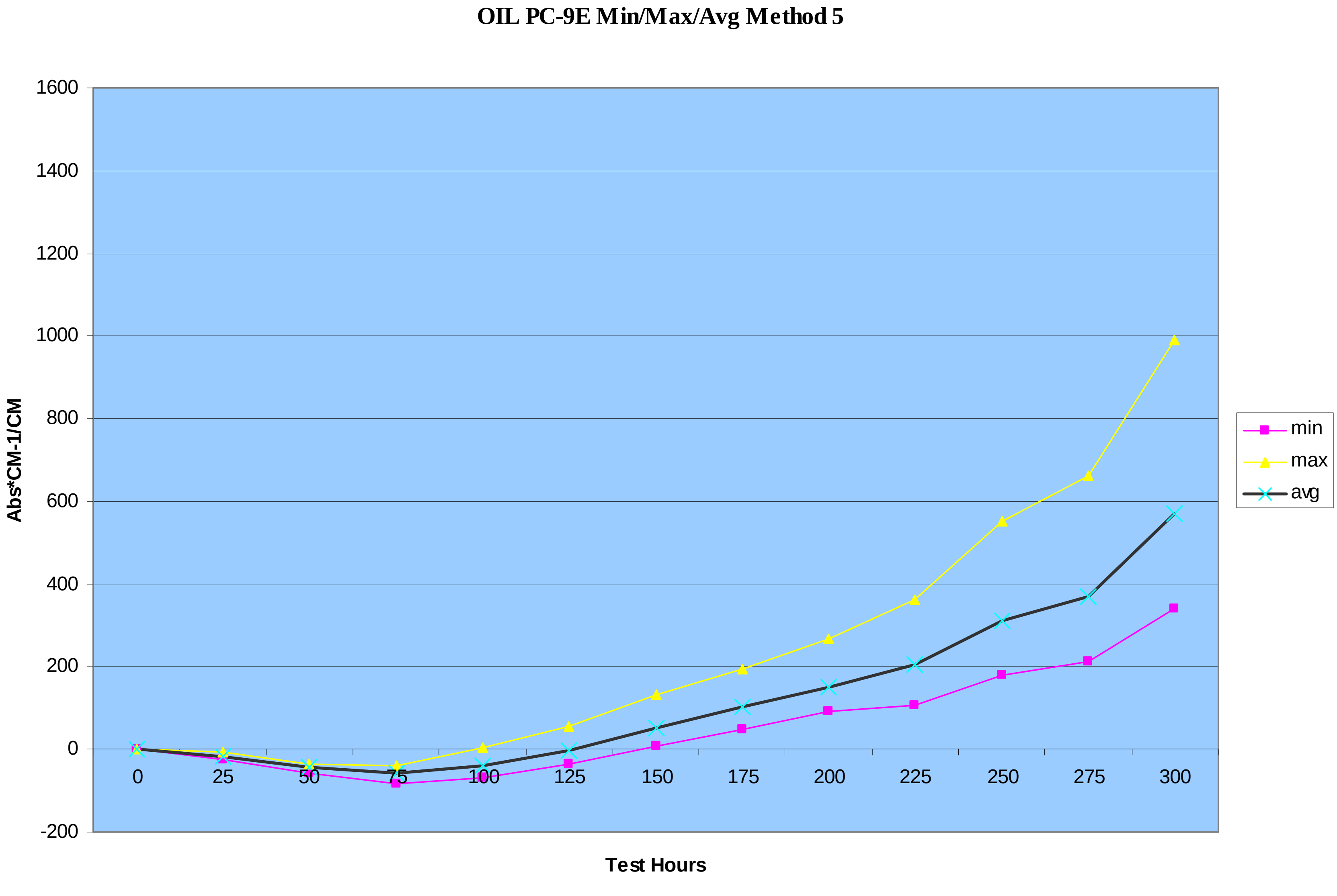
ATTACHMENT 5, 14 OF 23

PC-9D M5

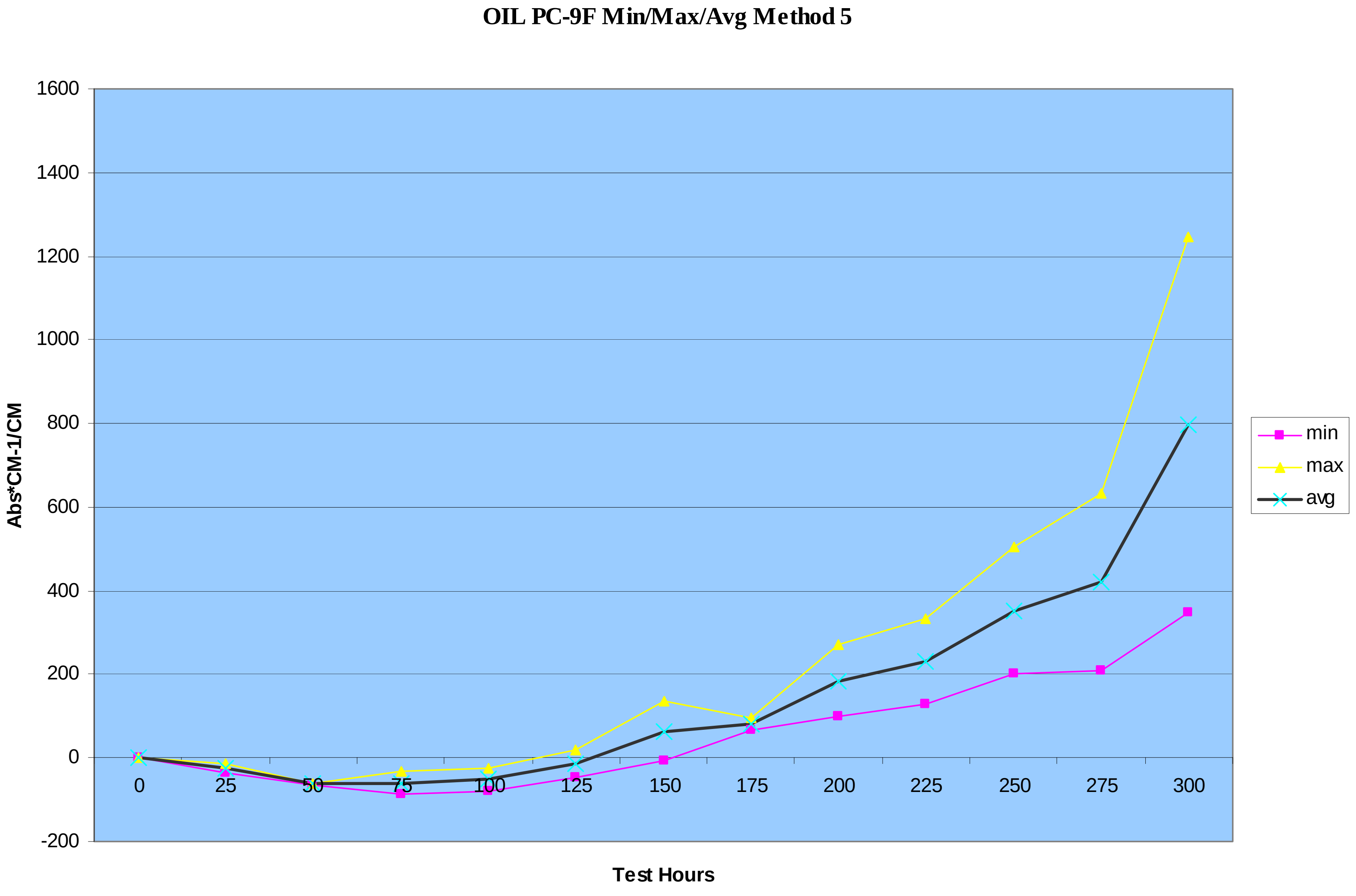


OIL PC-9D Min/Max/Avg Method 5
1600
1400
1200
1000
800
600
400
200
0
-200
Abs*CM-1/CM
0
25
50
75
100
125
150
175
200
225
250
275
300
Test Hours
min
max
avg

PC-9E M5


OIL PC-9E Min/Max/Avg Method 5
1600
1400
1200
1000
800
600
400
200
0
-200
Abs*CM-1/CM
0
25
50
75
100
125
150
175
200
225
250
275
300
Test Hours
min
max
avg

PC-9F M5



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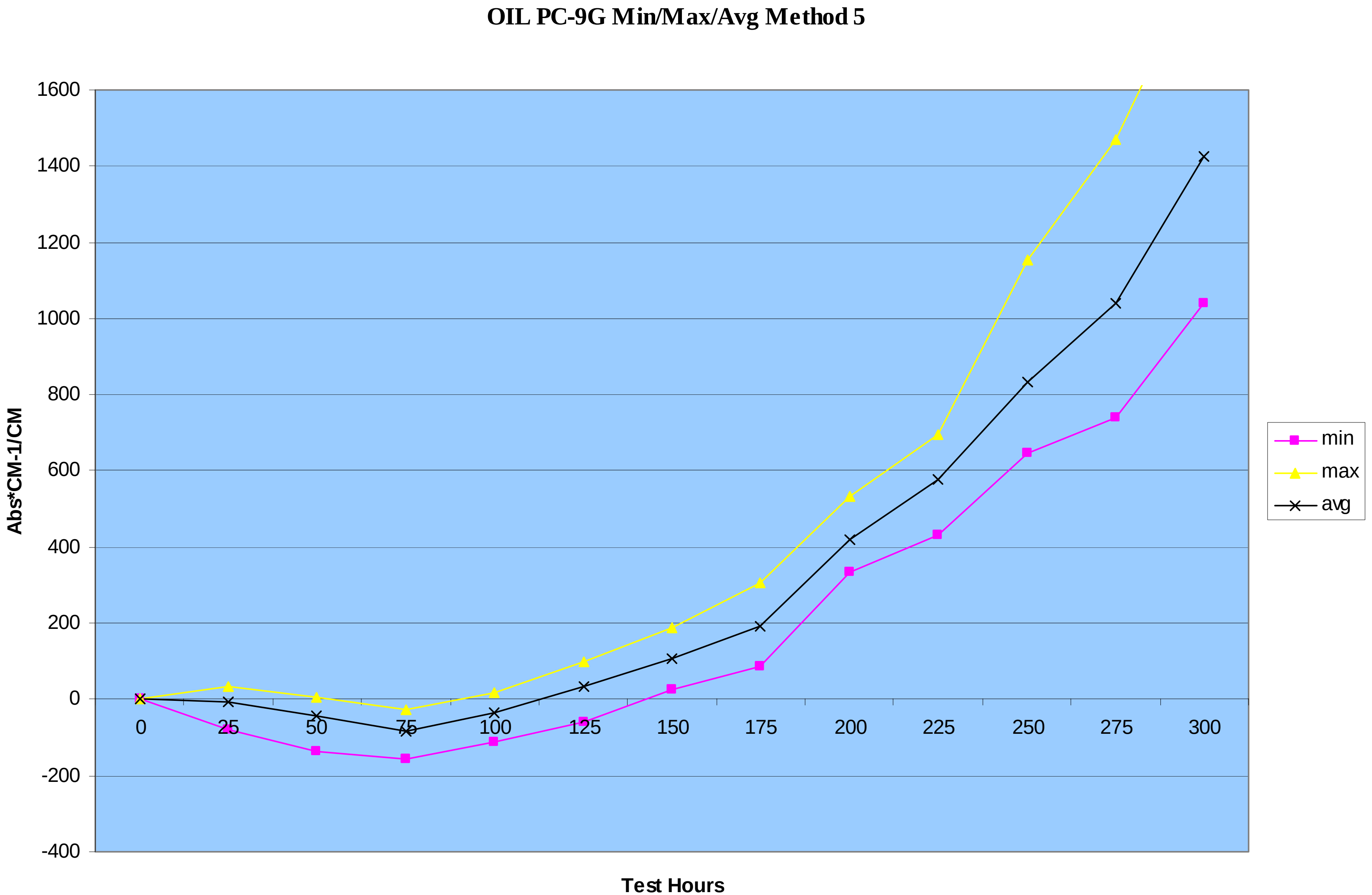
PC-9G M5



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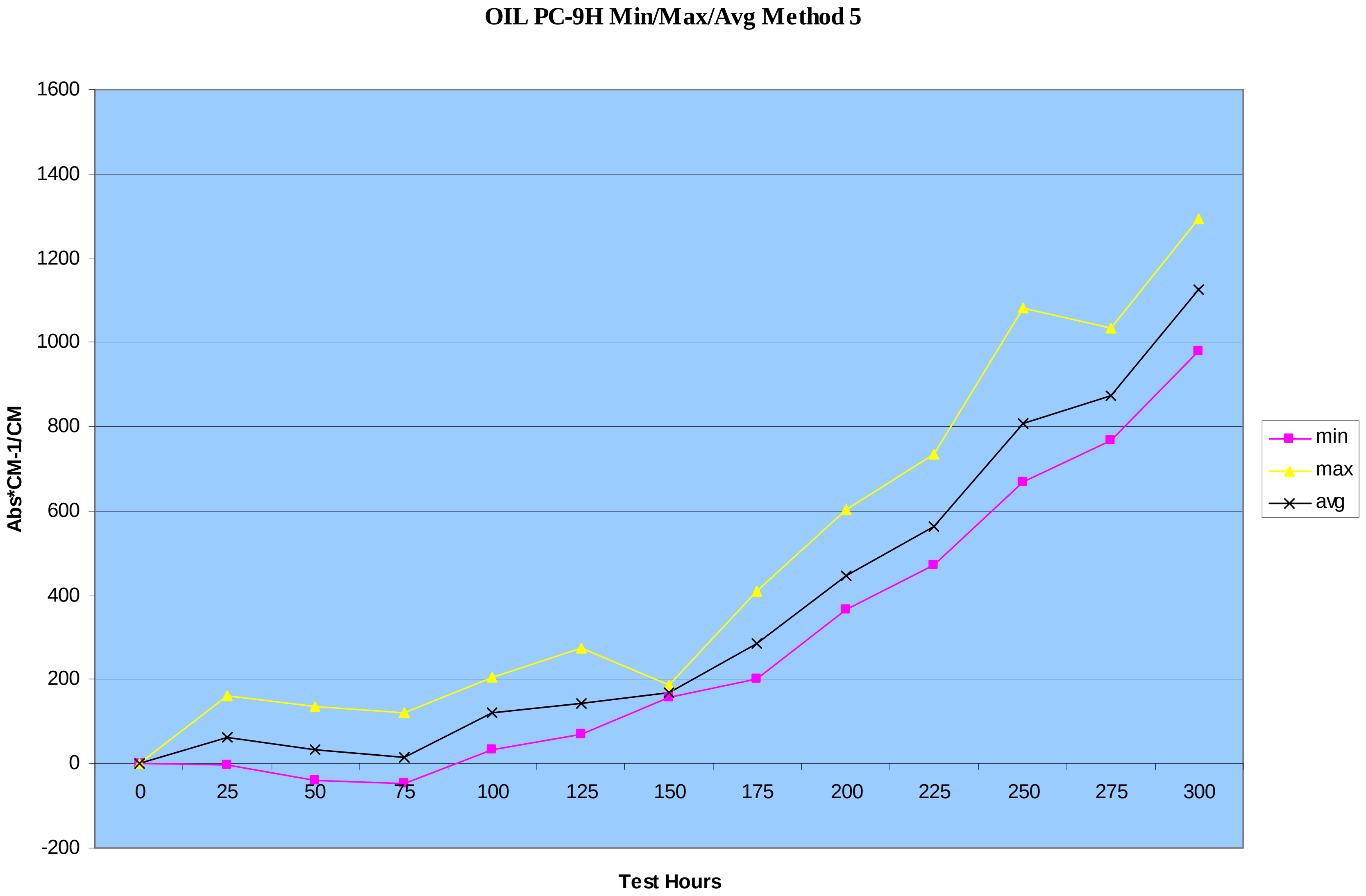
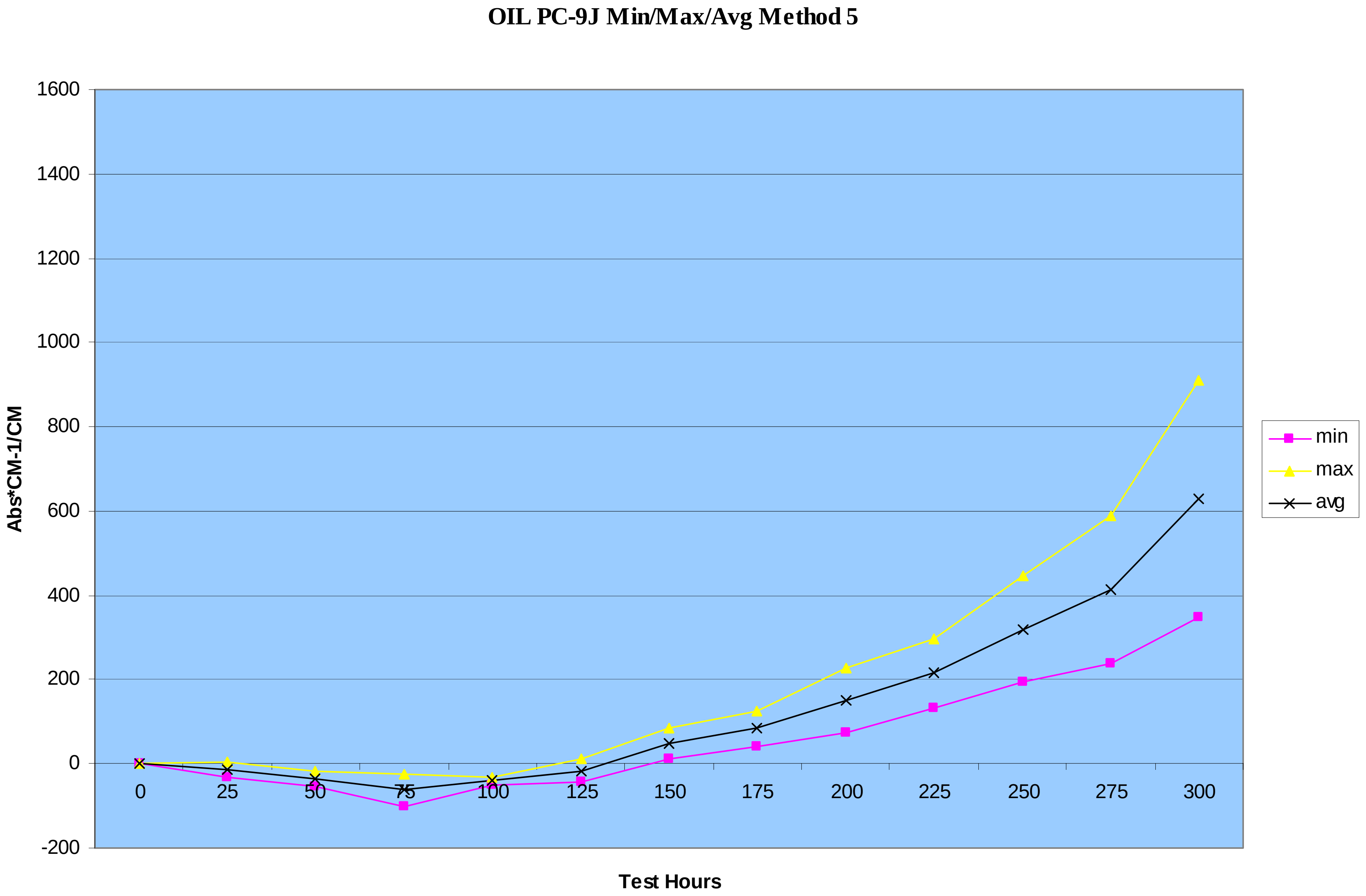
PC-9H M5



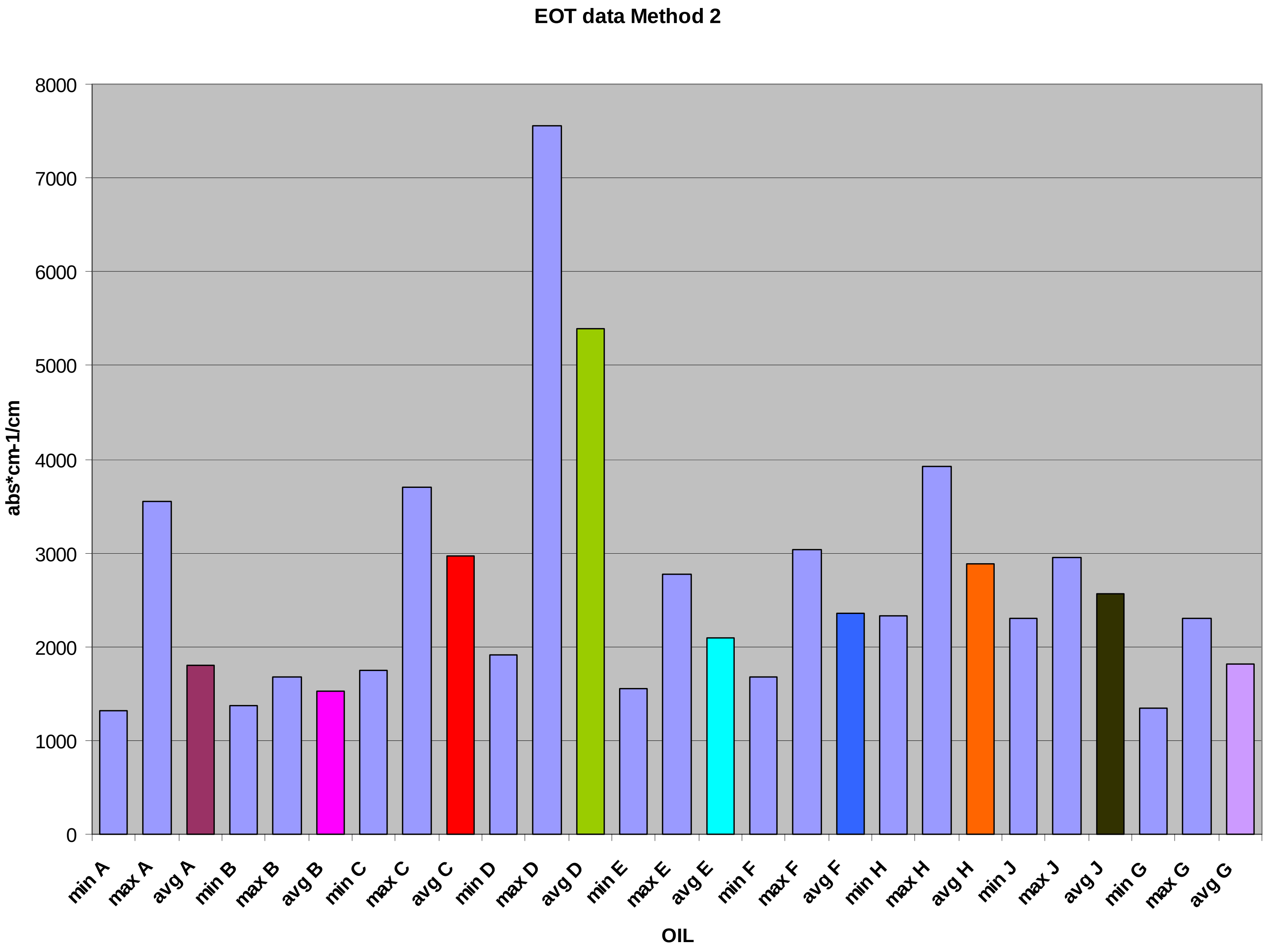
OIL PC-9H Min/Max/Avg Method 5
Abs*CM-1/CM
1600
1400
1200
1000
800
600
400
200
0
-200
0
25
50
75
100
125
150
175
200
225
250
275
300
Test Hours
min
max
avg

PC-9J M5



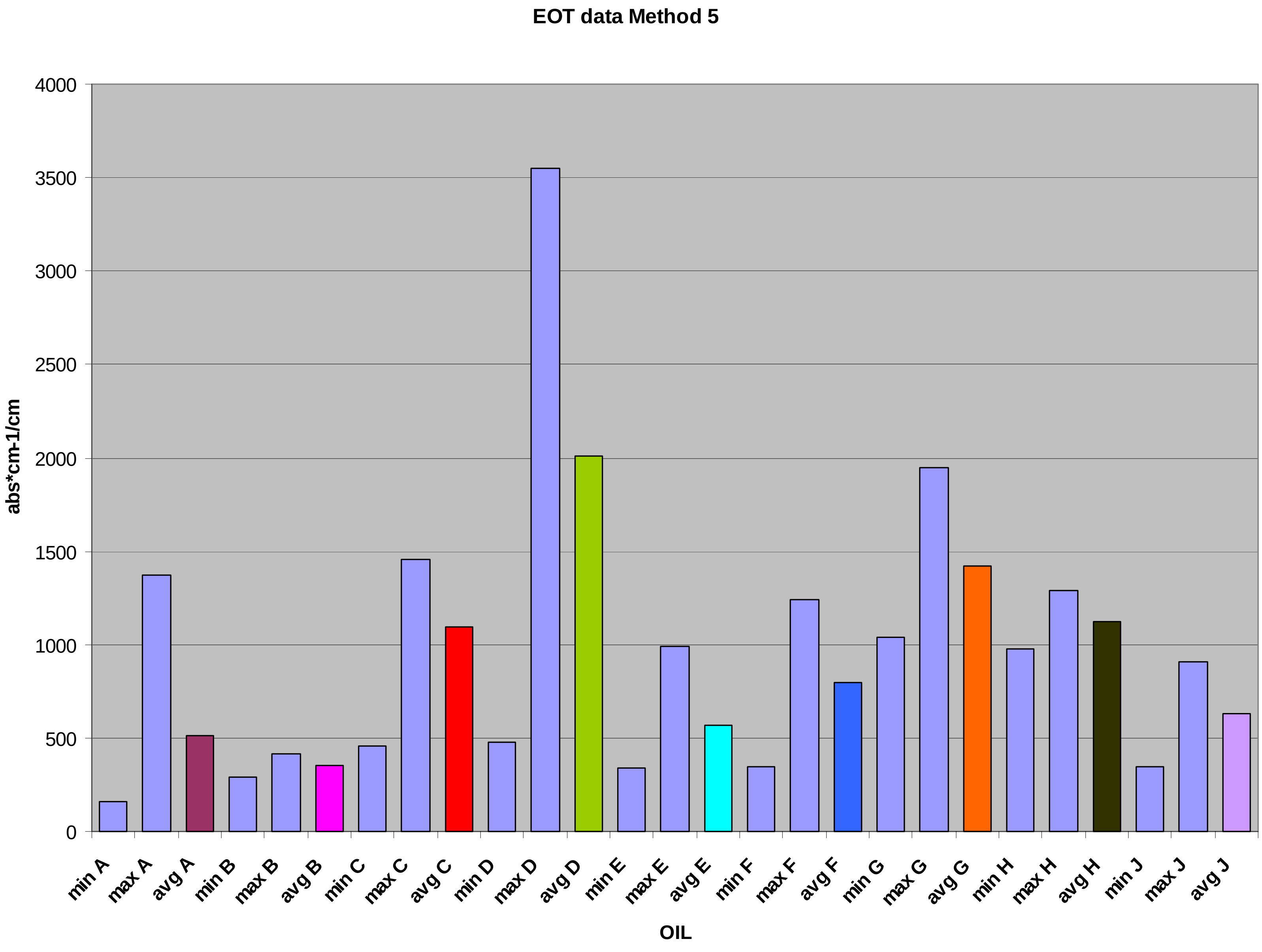
OIL PC-9J Min/Max/Avg Method 5
1600
1400
1200
1000
800
600
400
200
0
-200
Abs*CM-1/CM
0
25
50
75
100
125
150
175
200
225
250
275
300
Test Hours
min
max
avg

METHOD 2 EOT DATA

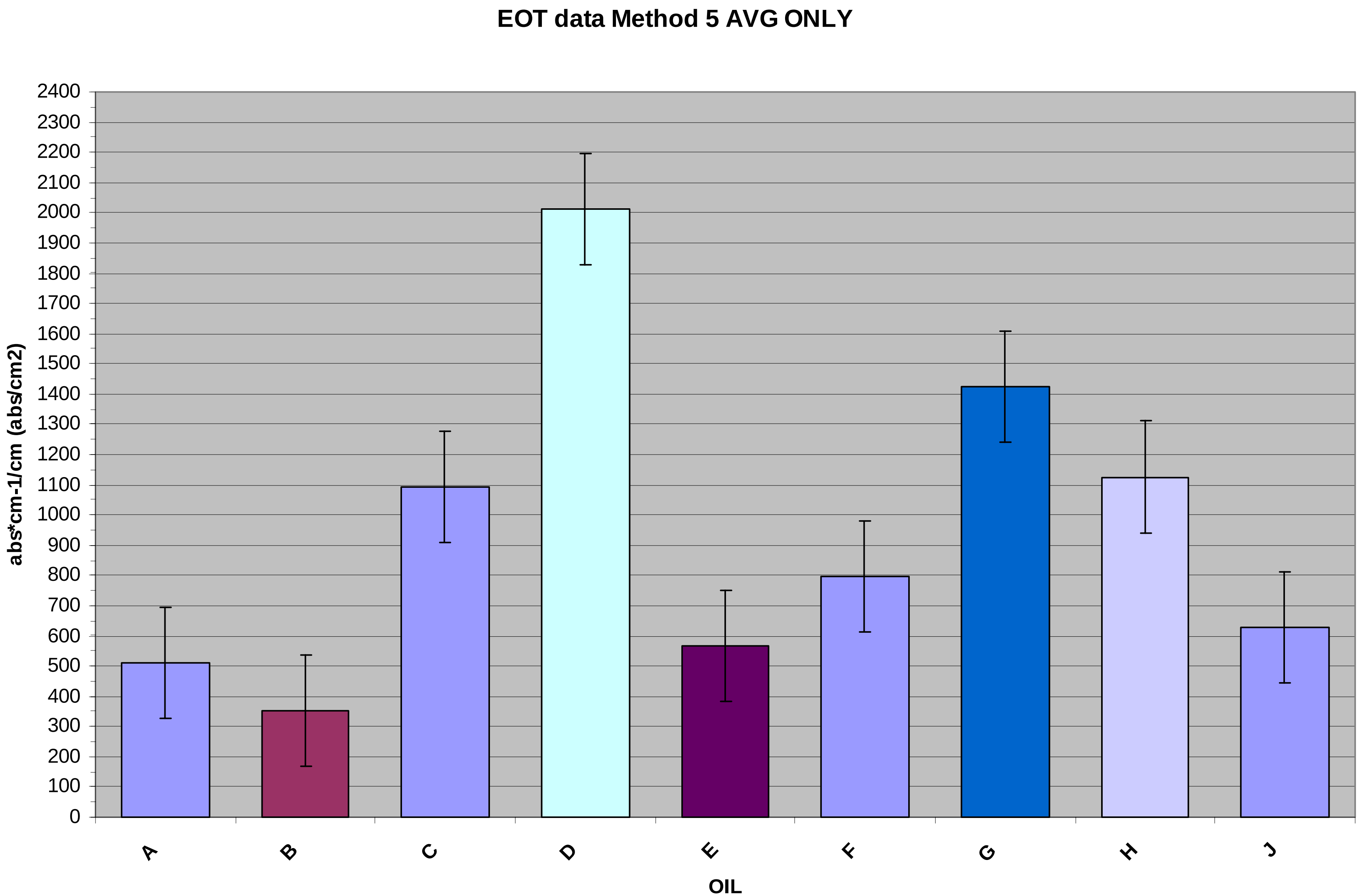


ATTACHMENT 5, 21 OF 23

METHOD 5 EOT DATA



METHOD 5 EOT AVG



Mack T10 Status

- Task Force Meeting & 2 Conference Calls Since Last Class Panel Mtg
- Issues :CO2 Control, Oxidation Data,Oil Consumption,Soot Correction
- Oxidation Data Analyzed, OC Data (Phase2) - No Value in Correcting Liner Wear or Ring Weight Loss for Soot Levels, Restricted CO2 Intake Limits

Mack T10 Status

- Agreement on Referencing Period & LTMS
- August 13 - Task Force Voted to Recommend to the Class Panel the test should be Approved for PC9

Draft Addendum to the Statistical Summary of the Mack T10 Precision/BOI Matrix Including Low Temperature Vicsometrics

Summary

- This is a preliminary analysis. A draft analysis of the MRV numbers is presented in this draft. It is not a consensus analysis.
- The MRV numbers were not significantly correlated with any potential criterion.
- Technology, Base Oil, and their interaction had significant effects.
- There were no observations with large Studentized residuals.
- Oil means and standard deviations are given for potential use in LTMS.

Data Set

- Table 1 shows the design for the matrix.
- All operationally valid data with the exception of CMIR 38815 are included.
- The T10 Task Force decided to eliminate CMIR 38815 from the analysis.
  - This was an early test in Lab B on Oil A which had high silicon and aluminum in the used oil. It also had high ring weight loss with low cylinder liner wear. The lab ran Oil A again with non-anomalous results. The matrix remains intact as planned.
- D4684 MRV @ -20º of samples at 75 hours have been added.

Table 1. Mack T10 Precision Matrix Plan

Base Oil	Technology X	Technology Y	Technology Z
Base Oil 1	PC-9A	PC-9D	PC-9G
Base Oil 2	PC-9B	PC-9E	PC-9H
Base Oil 3	PC-9C	PC-9F	PC-9J

Lab/Stand						
Lab A		Lab D	Lab G		Lab F	Lab B
1	2	3	4	5	6	7
A	A	A	A	A	A	A
G	A	G	D	A	A	D
E	E	B	H	E	H	B
C	J	F	C	J	F	J

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Table 2. Mack T10 Precision Matrix Data

from TMC 07/16/01 (MRV from Jim Wells 08/06/01)

Test	CMIR	Lab	Stand	EOT Date	Oil	Tech	Base Oil	DPBFNL	ABWLU	ATRWLFNL	CLWFNL	OILCON	M2IR300	M5IR300	MRV@-20
1	38814	F	1	20001211	A	X	1	33	257	139	36	79	2048	452	14300
2	38809	A	1	20001219	A	X	1	23	206	158	33	52	1520	348	14400
3	38811	D	1	20001224	A	X	1	12	195	139	38	52	1320	210	13600
4	38945	D	1	20010215	F	Y	3	21	222	69	27	56	1674	347	15000
5	38953	F	1	20010217	H	Z	2	73	364	150	33	61	2326	1042	9800
6	38939	A	1	20010305	C	X	3	33	243	116	25	63	1750	458	14600
7	38810	A	2	20010313	A	X	1	19	159	168	38	46	1592	334	14200
8	38947	G	1	20010318	H	Z	2	115	378	156	34	64	3923	1949	11000
9	38937	A	1	20010329	E	Y	2	18	151	118	21	53	1550	342	14800
10	38951	G	2	20010330	A	X	1	37	218	125	33	53	1741	497	14700
11	38943	D	1	20010401	B	X	2	17	182	125	31	44	1376	294	13400
12	38957	B	1	20010403	D	Y	1	25	183	204	46	54	1917	477	21000
13	38942	A	2	20010408	A	X	1	16	182	87	27	41	1368	280	14200
14	38948	G	2	20010419	J	Z	3	90	343	119	35	47	2952	1292	17000
15	38952	F	1	20010419	F	Y	3	62	321	106	26	51	3041	1244	15200
16	38949	G	1	20010420	C	X	3	77	336	133	35	66	3696	1454	10700
17	38941	A	1	20010422	G	Z	1	71	324	107	29	52	2300	910	24400
18	38938	A	2	20010504	J	Z	3	44	278	153	31	58	2418	980	11300
19	38944	D	1	20010504	G	Z	1	27	238	154	39	47	1346	348	27000
20	38956	B	1	20010509	J	Z	3	50	314	127	30	35	2308	1106	11900
21	38950	G	2	20010512	E	Y	2	52	317	109	28	55	2771	991	17200
22	38946	G	1	20010517	D	Y	1	206	344	108	33	71	7555	3551	17000
23	38940	A	2	20010528	E	Y	2	22	184	67	20	45	1639	373	14400
24	40919	B	1	20010529	B	X	2	34	234	121	24	54	1671	415	12400
25	40230	G	2	20010602	A	X	1	25	197	108	34	48	1607	200	14900
26	41135	F	1	20010611	A	X	1	28	248	128	26	60	1876	482	14800
27	41410	B	1	20010618	A	X	1	34	229	140	35	42	1557	347	13200
28	41412	G	1	20010703	A	X	1	66	295	123	39	64	3547	1372	16000

Transformations

- Box-Cox procedure was applied using all matrix data.
- Delta lead benefits from a natural logarithm transformation.
- Method 2 IR at 300 hours is best raised to a power of -0.8 for analyses.
- Method 5 IR at 300 hours likes a natural logarithm transformation.
- No data transformations are indicated for other responses analyzed.

D4684 MRV @ -20º C
Summary of Model Fit

- Model factors include Laboratory (A,B,D,F,G), Technology (X,Y,Z), Base Oil (1,2,3) and Technology by Base Oil interaction.

- Technology, Base Oil, and Technology by Base Oil interaction were significant.
  - Root MSE from the model was 1727 (15 df).
  - The R^2 for the model was 0.88.
  - Figure 1 illustrates the least squares means by oil.
  - Figure 2 summarizes least squares means for oils.
  - There were no large Studentized residuals.

Figure 1
Least Squares Means for Oils

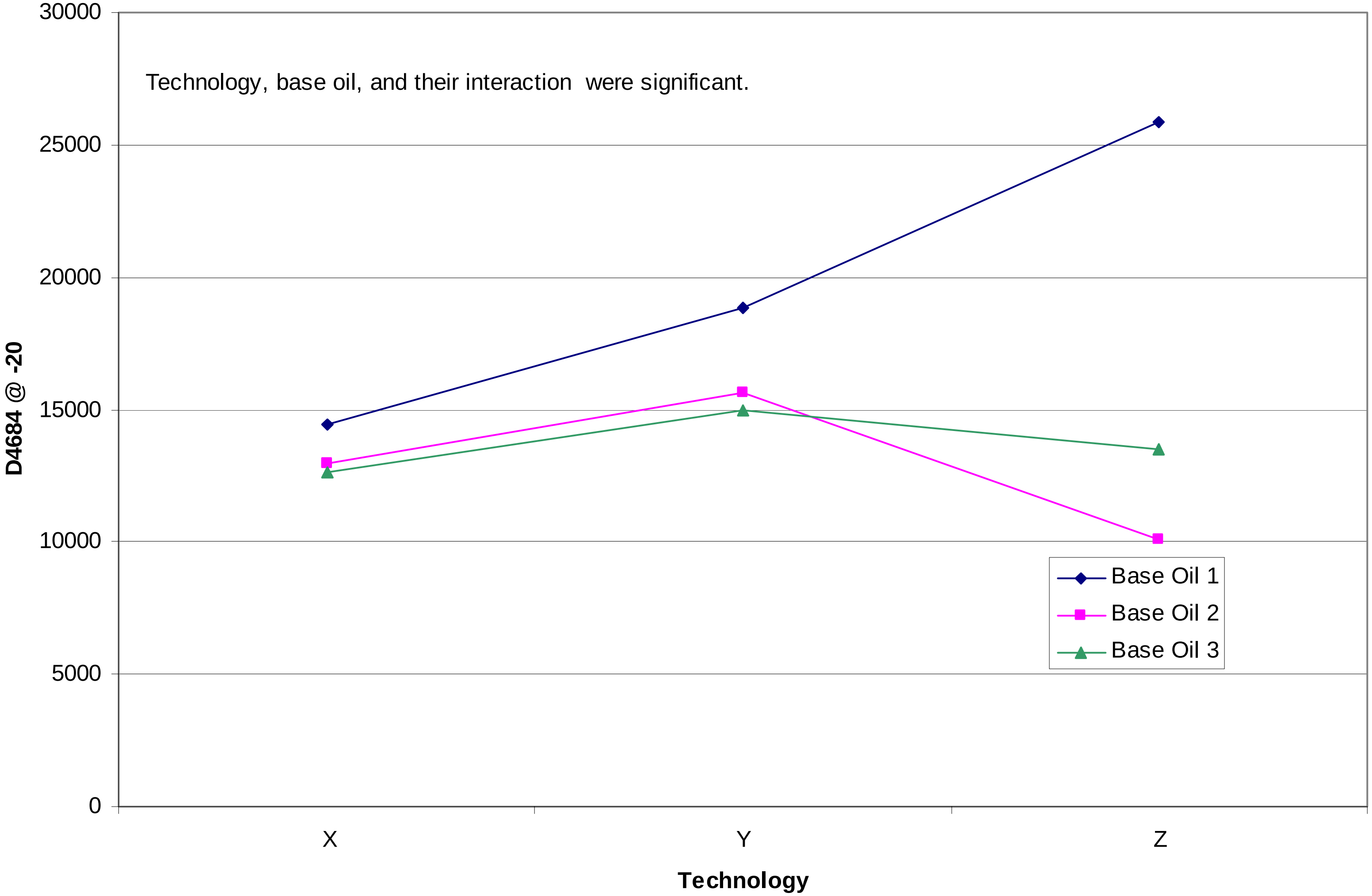

Figure 2
Oil Least Squares Means for D4684 MRV @ -20º C

Technology	Base Oil	Least Squares Mean	p-value for test of equal means (Tukey)								
			vs X1	vs x2	vs X3	vs Y1	vs Y2	vs Y3	vs Z1	vs Z2	vs Z3
X	1	14414		0.98	0.92	0.12	0.98	1.00	<.0001	0.12	1.00
X	2	12952	0.98		1.00	0.10	0.86	0.97	0.00	0.86	1.00
X	3	12624	0.92	1.00		0.07	0.63	0.95	<.0001	0.89	1.00
Y	1	18866	0.12	0.10	0.07		0.64	0.59	0.05	0.01	0.08
Y	2	15623	0.98	0.86	0.63	0.64		1.00	0.00	0.10	0.86
Y	3	14974	1.00	0.97	0.95	0.59	1.00		0.00	0.25	0.99
Z	1	25860	<.0001	0.00	<.0001	0.05	0.00	0.00		<.0001	<.0001
Z	2	10088	0.12	0.86	0.89	0.01	0.10	0.25	<.0001		0.58
Z	3	13484	1.00	1.00	1.00	0.08	0.86	0.99	<.0001	0.58	

Correlations Among the Criteria

Raw Data	ln(Delta Pb)	URBWL	TRWL	CLW	OC	t(M2IR)	ln(M5IR)	D4684at_20
ln(Delta Pb)	1.00	**0.92**	0.01	0.10	**0.44**	**-0.93**	**0.95**	-0.01
URBWL	**0.92**	1.00	0.00	0.07	**0.40**	**-0.85**	**0.89**	-0.08
TRWL	0.01	0.00	1.00	**0.72**	0.12	0.01	0.03	0.05
CLW	0.10	0.07	**0.72**	1.00	0.14	-0.10	0.07	0.25
OC	**0.44**	**0.40**	0.12	0.14	1.00	**-0.54**	**0.43**	-0.11
t(M2IR)	**-0.93**	**-0.85**	0.01	-0.10	**-0.54**	1.00	**-0.96**	0.10
ln(M5IR)	**0.95**	**0.89**	0.03	0.07	**0.43**	**-0.96**	1.00	-0.07
D4684at_20	-0.01	-0.08	0.05	0.25	-0.11	0.10	-0.07	1.00

Residuals	ln(Delta Pb)	URBWL	TRWL	CLW	OC	t(M2IR)	ln(M5IR)	D4684at_20
ln(Delta Pb)	1.00	**0.68**	-0.32	-0.22	0.10	**-0.68**	**0.78**	-0.26
URBWL	**0.68**	1.00	-0.25	-0.17	0.31	**-0.70**	**0.69**	-0.35
TRWL	-0.32	-0.25	1.00	**0.77**	0.13	-0.03	-0.02	0.27
CLW	-0.22	-0.17	**0.77**	1.00	0.08	-0.16	-0.03	0.32
OC	0.10	0.31	0.13	0.08	1.00	-0.29	0.00	-0.17
t(M2IR)	**-0.68**	**-0.70**	-0.03	-0.16	-0.29	1.00	**-0.78**	0.11
ln(M5IR)	**0.78**	**0.69**	-0.02	-0.03	0.00	**-0.78**	1.00	-0.09
D4684at_20	-0.26	-0.35	0.27	0.32	-0.17	0.11	-0.09	1.00

Oil LS Means	ln(Delta Pb)	URBWL	TRWL	CLW	OC	t(M2IR)	ln(M5IR)	D4684at_20
ln(Delta Pb)	1.00	**0.80**	0.11	0.20	-0.22	**-0.74**	**0.88**	0.45
URBWL	**0.80**	1.00	0.24	0.22	-0.14	-0.41	0.60	0.13
TRWL	0.11	0.24	1.00	**0.87**	0.56	0.19	-0.01	-0.04
CLW	0.20	0.22	**0.87**	1.00	0.47	0.00	0.09	0.26
OC	-0.22	-0.14	0.56	0.47	1.00	0.24	-0.30	-0.05
t(M2IR)	**-0.74**	-0.41	0.19	0.00	0.24	1.00	**-0.94**	-0.29
ln(M5IR)	**0.88**	0.60	-0.01	0.09	-0.30	**-0.94**	1.00	0.31
D4684at_20	0.45	0.13	-0.04	0.26	-0.05	-0.29	0.31	1.00

Oil Least Squares Means and Standard Deviations

Oil	lnDeltaPb	URBWL	TRWL	CLW	OilCon	tM2IR	lnM5IR	MRV@-20
A	3.1683	210.2	135	34.9	52.5	0.002694	5.8709	14414
B	3.6333	239.6	114	24.8	54.8	0.002407	6.3253	12952
C	3.3968	278.7	135	31.7	63.6	0.002507	6.0928	12624
D	3.7706	242.0	157	38.7	65.4	0.002067	6.6280	18866
E	3.2942	220.7	107	25.4	51.3	0.002371	6.2920	15623
F	3.8216	277.3	83	25.5	49.6	0.001978	6.6472	14974
G	4.2122	323.8	130	33.9	51.6	0.002183	6.7337	25860
H	3.7972	323.2	159	34.3	55.7	0.002466	6.4090	10088
J	4.0624	307.5	136	32.8	49.0	0.001818	7.1393	13484
Std Dev	0.2946	38.0	28	4.4	8.6	0.000223	0.3215	1727

A Study of the Low-Temperature Flow Properties of Highly Sooted, Heavy-Duty Engine Oils

Results from a New Temperature-Scanning Viscometric Technique

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Background:

- The negative impact of highly sooted, heavy duty engine oils regarding low-temperature starting and, particularly, pumpability has generated considerable interest, concern, and work.

- Older pumpability methods originally developed for fresh passenger car engine oils have been applied to sooted oil pumpability with limited success regarding analysis time, precision, and sensitivity to soot effects.

- What is obviously needed is a fast, precise test -- capable of providing all critical information regarding viscosity and soot structure.

Recent Background:

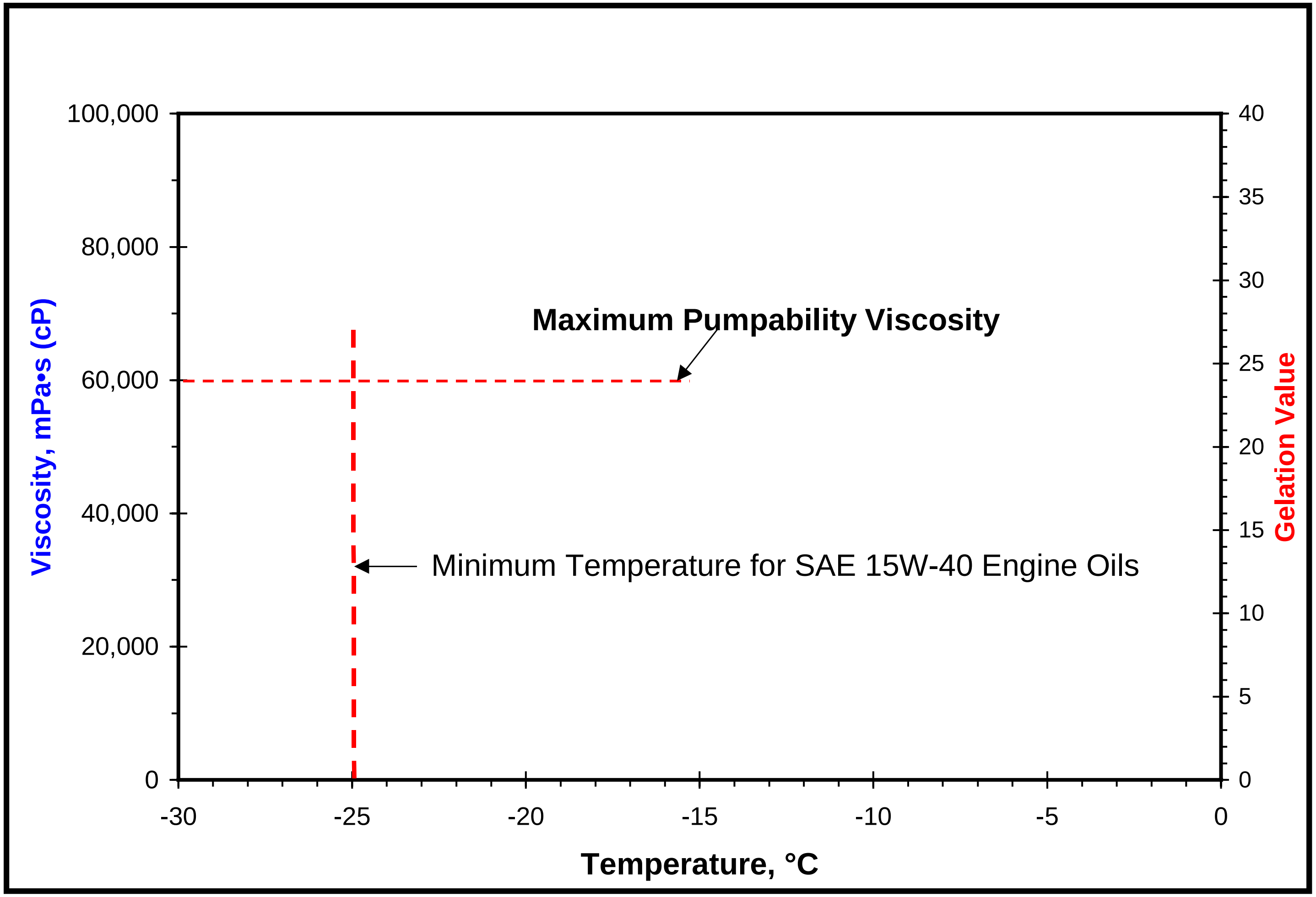
- The higher-torque temperature-scanning approach reported earlier has now been matched with a new program.
- Very recently, Chris May kindly supplied Savant with seven sooted oils from his collection.
- Savant used the oils and the new viscometers and program to apply a new method for characterizing the low temperature flow of sooted oils.
- Extensive work was completed and analyzed last week and the results are promising.

The method developed and used in the study:

- The oil is heated to 90°C for one hour in a viscometer cell.
- The cell is brought to +20°C in the bath to be used while stirring the oil with the rotor at 12 RPM continuously.
- Alternatively, the oil is brought to -5°C while stirring.
- Starting at either +20°C or -5°C, the oil is cooled at 3°C/hr. Until the bath reaches -26°C.
- The temperature scan of viscosity is completed in either 16 hours or in 7 hours, respective to the starting temperature. (All oils in this study were cooled 16 hours.)

A couple of examples to show how the data will be presented:

- A viscosity-temperature/Gelation Index graph:



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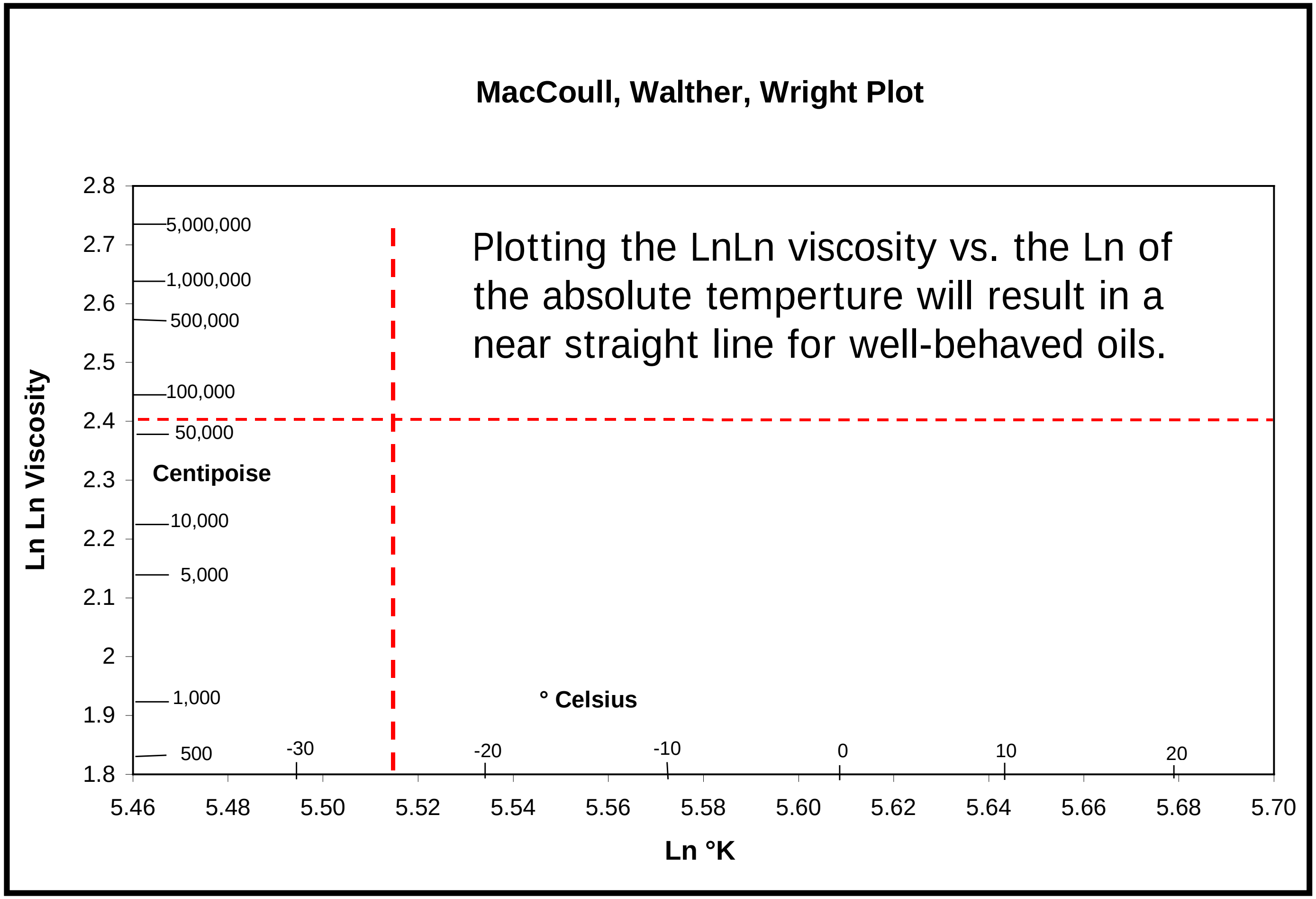
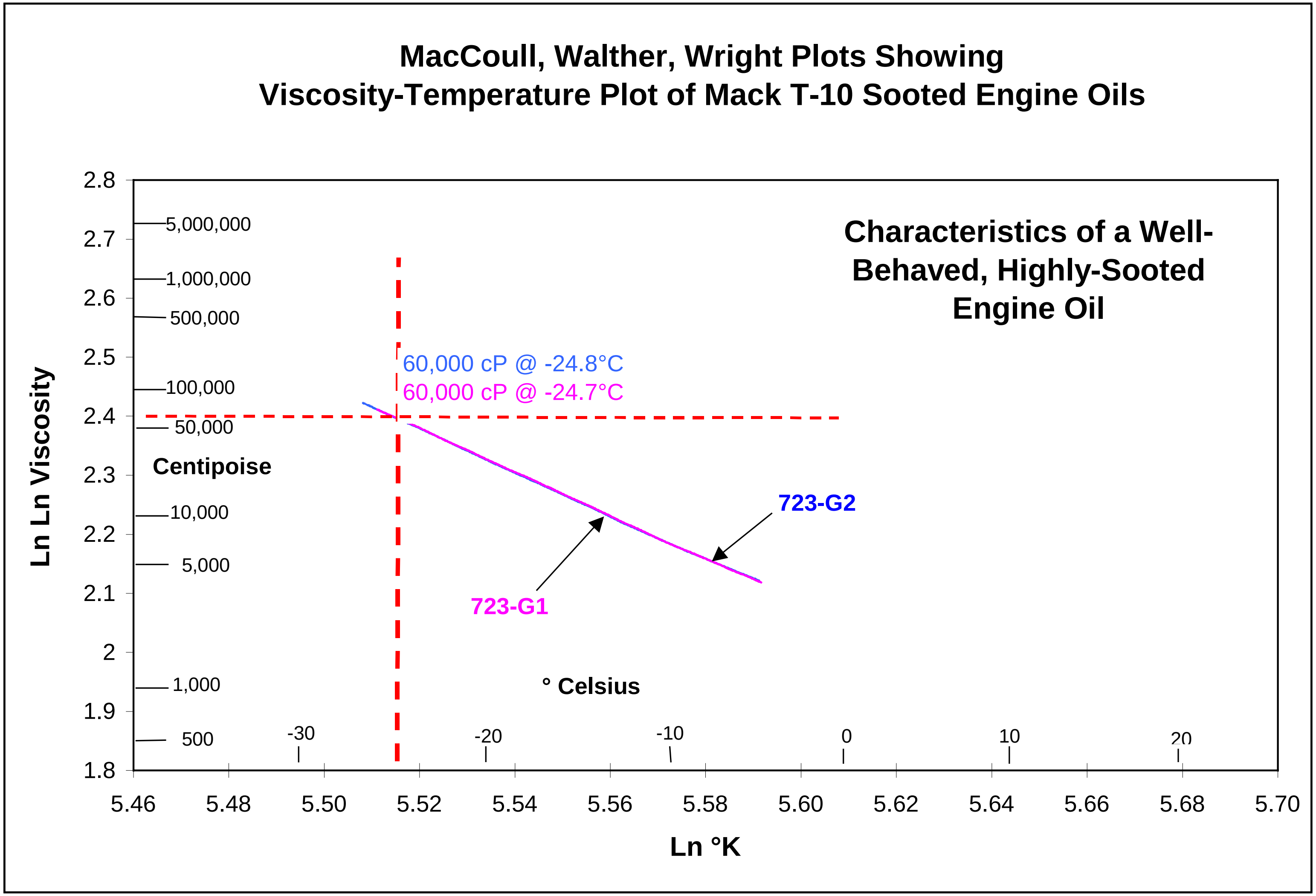
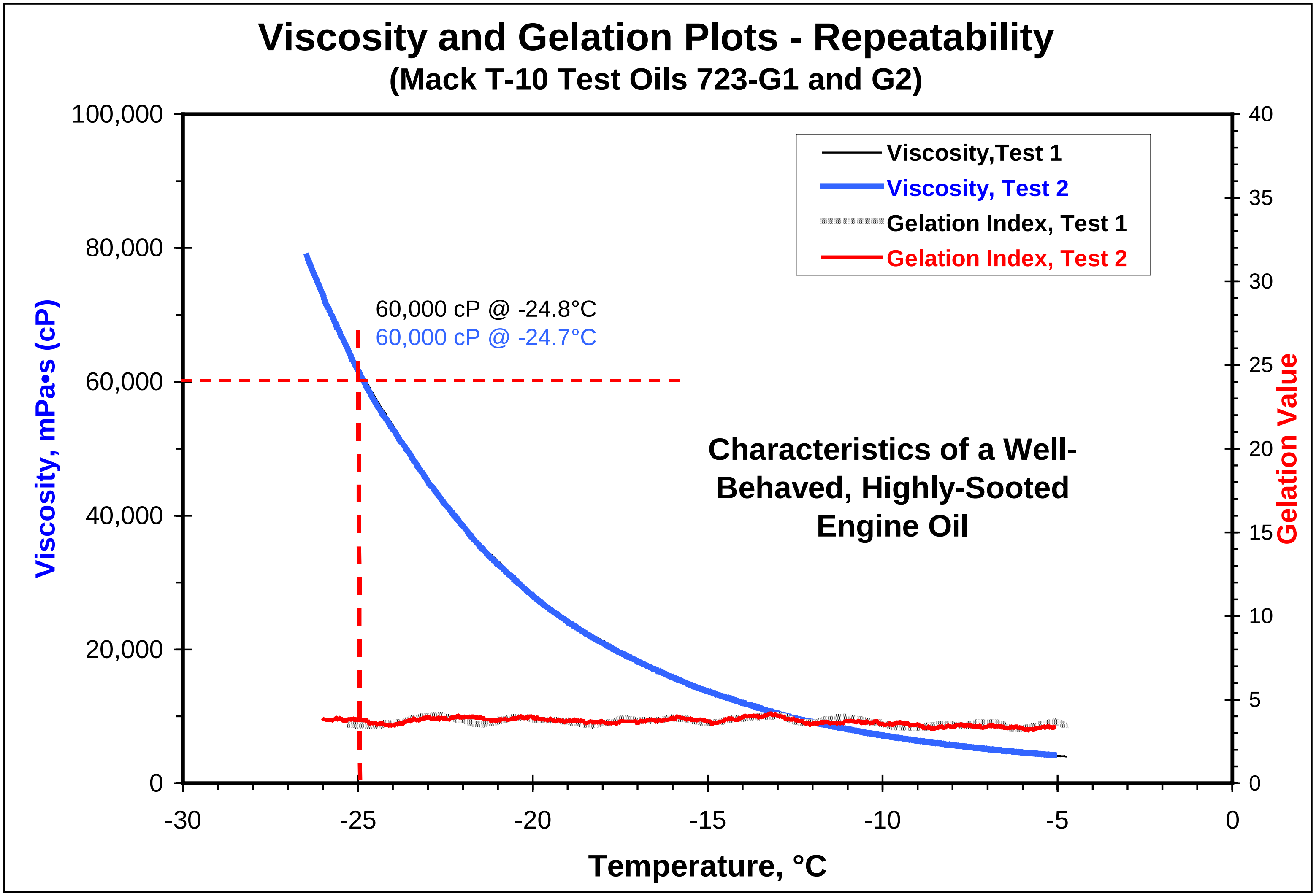
- A MacCoull, Walther, Wright graph:



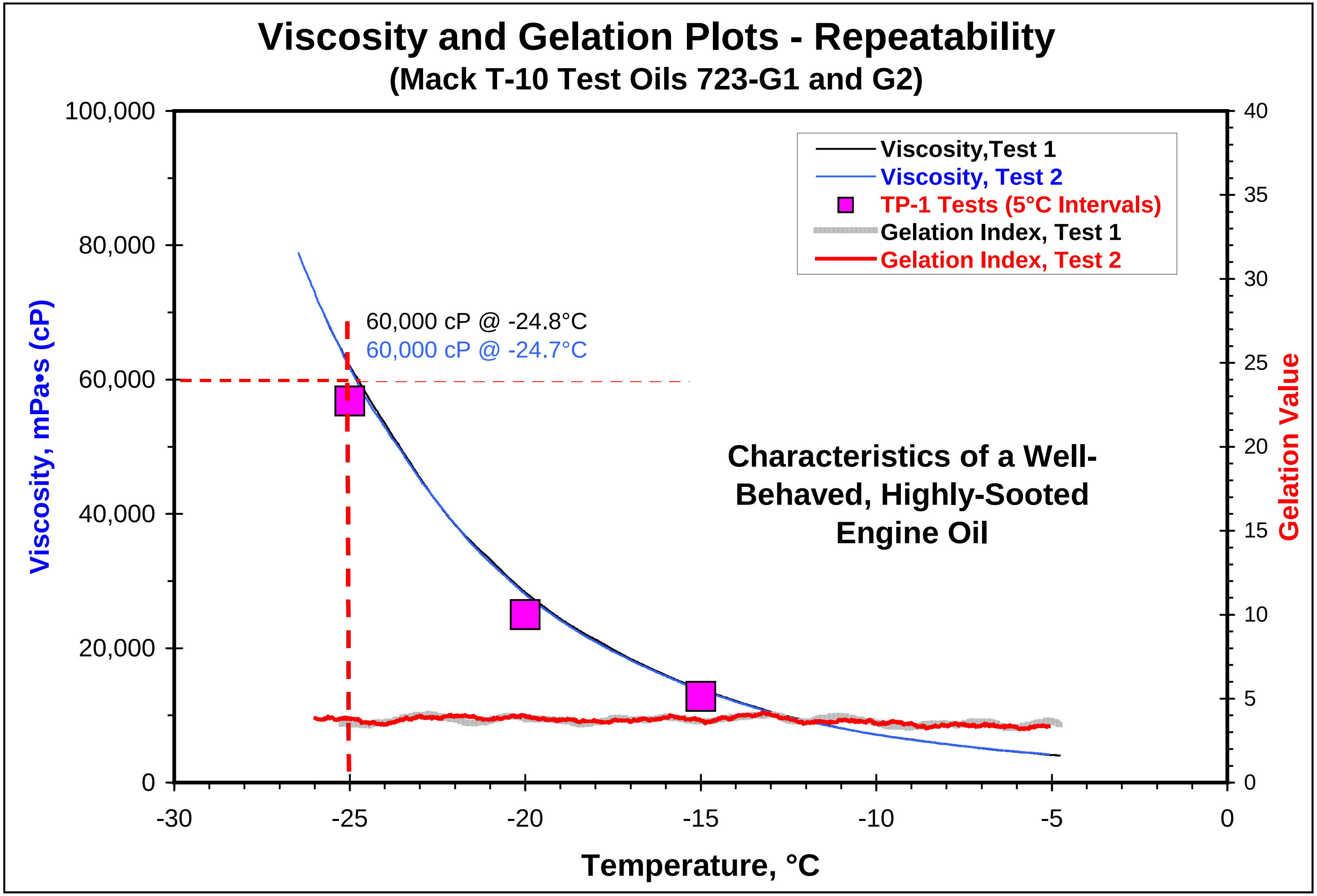
Well-behaved highly sooted Oil 723-G run in duplicate using temperature-scanning viscometry. Note the straight line of superimposed data.



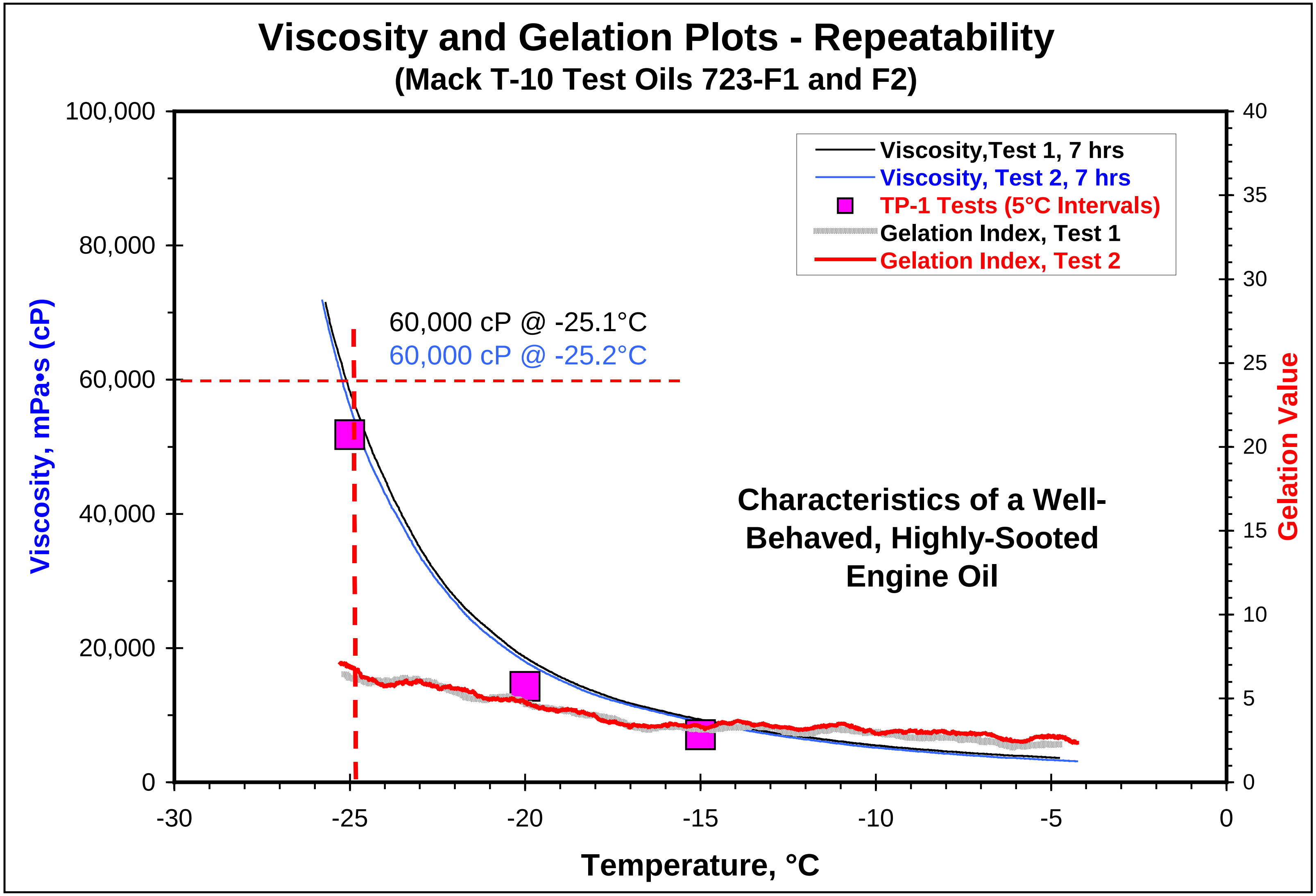
Another view of Oil 723-G run in duplicate showing the simple viscosity-temperature curve and Gelation Index. Repeatability is very good.



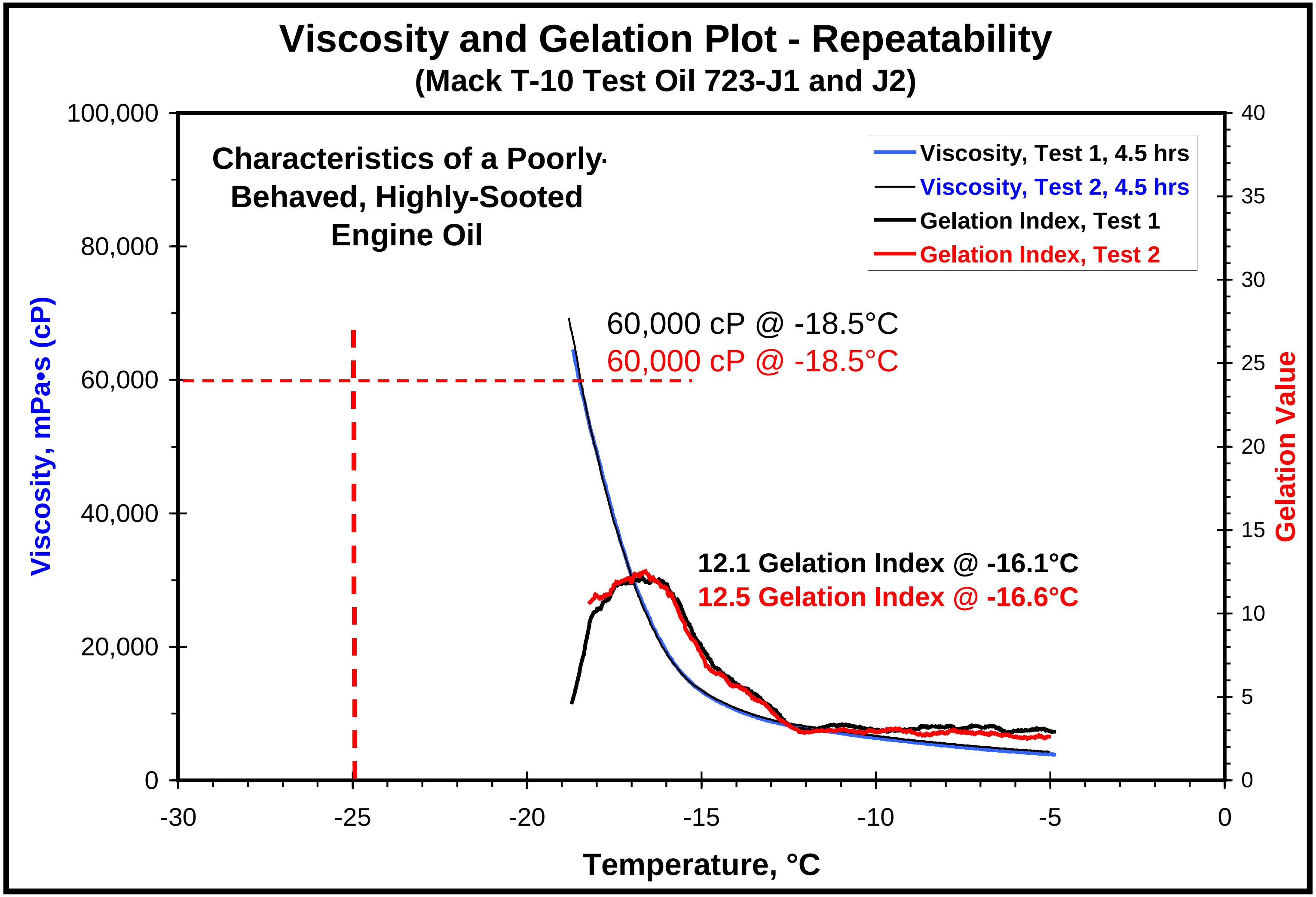
Three TP-1 values obtained at 5°C intervals are added to the information. Agreement of the two instruments is good with well-behaved oil.



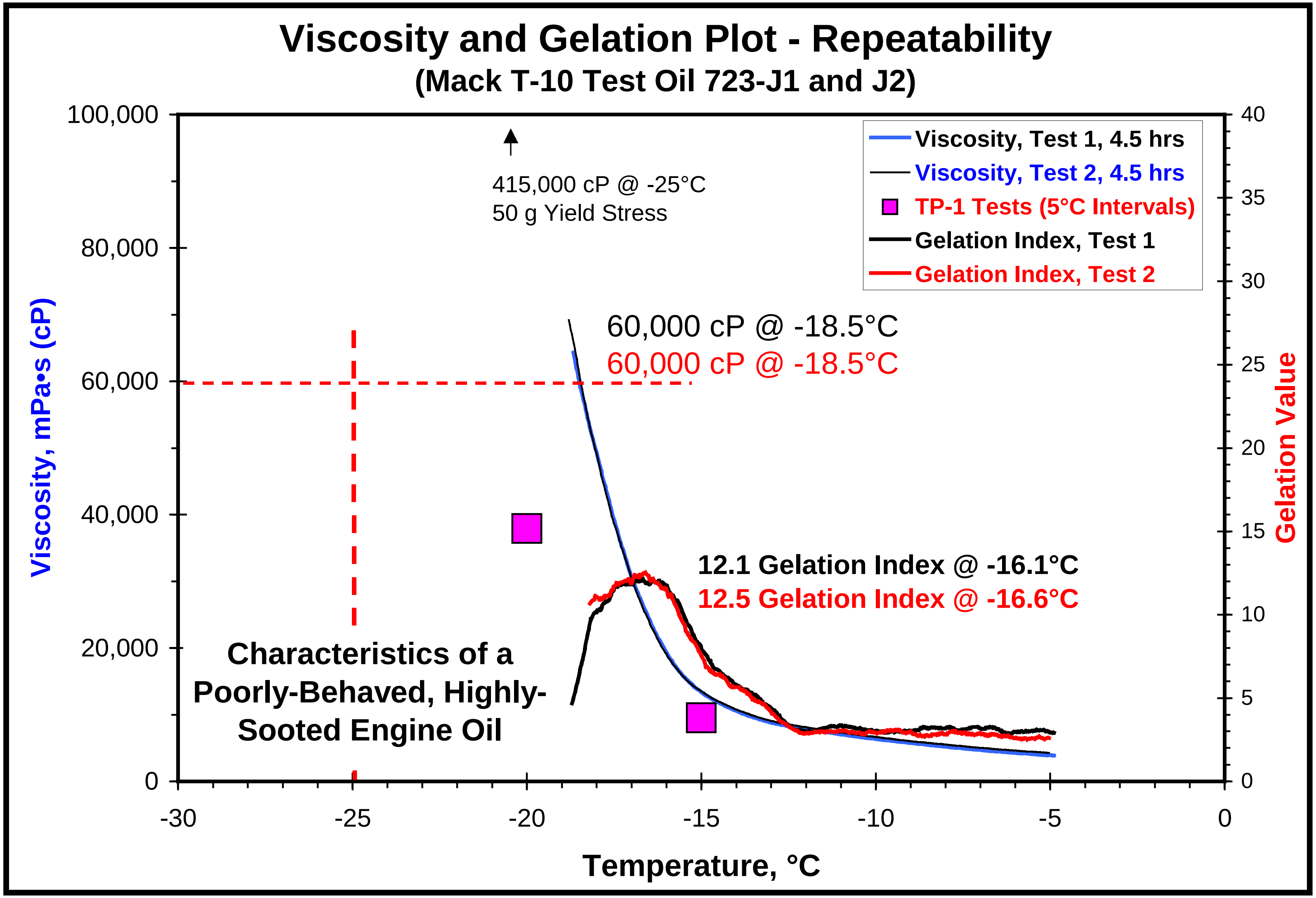
Another well-behaved oil is shown here. Again, repeatability of the temperature-scanning technique is good as is agreement between the two viscometric approaches.



With poorly behaved oils a different viscometric character is shown. Gelation Indices are shown for Oil 723-J and are closely repeatable. The duplicate samples pass 60,000 cP at -18.5°C -- well below -25°C.



Including results from the TP-1 shows that agreement between the two methods is only reasonably close at -15°C -- before gelation begins.



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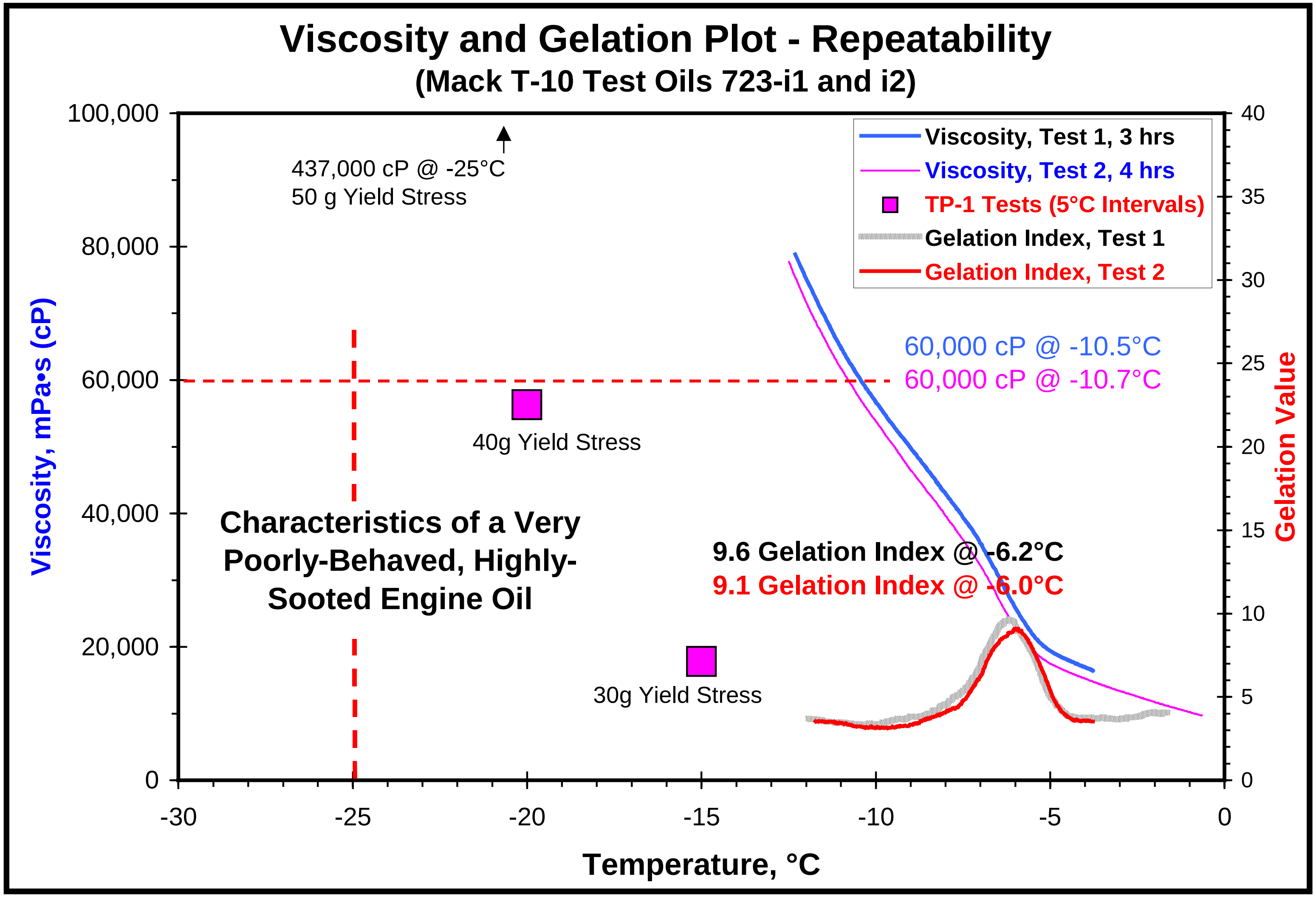
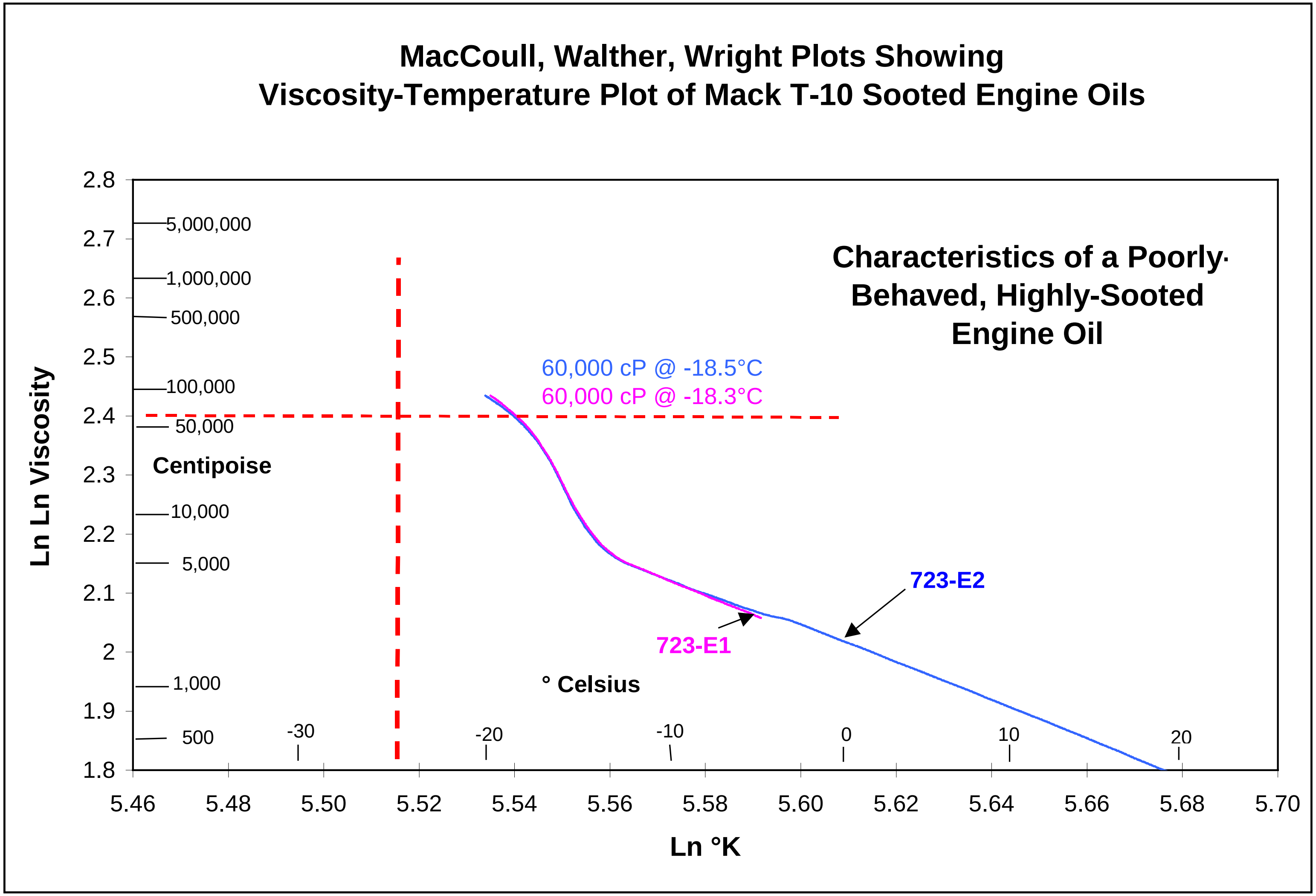
A very poorly behaved Oil 723-i passes 60,000 cP at -10.5° to -10.7°C and has a clear Gelation Index of 9.1 to 9.6 at ~-6°C. No correlation with the TP-1 data is shown with this oil. The latter method shows Yield Stresses at all temperatures.



Recording the data continuously from +20°C to -25°C shows that further data can be collected if desired. In the case of Oil 723-E, the oil has a well behaved appearance from +20° to -12°C at which point the oil deteriorates into poor flow behavior.



Summarizing the data from the seven Mack T-10 highly sooted oils, the information in Table 1 is helpful. The Average Differences shows that the repeatability of the broader range scanning viscometry is good.

Table 1 - Analysis of Seven Mack T-10 Highly-Sooted Engine Oils at Low Temperatures

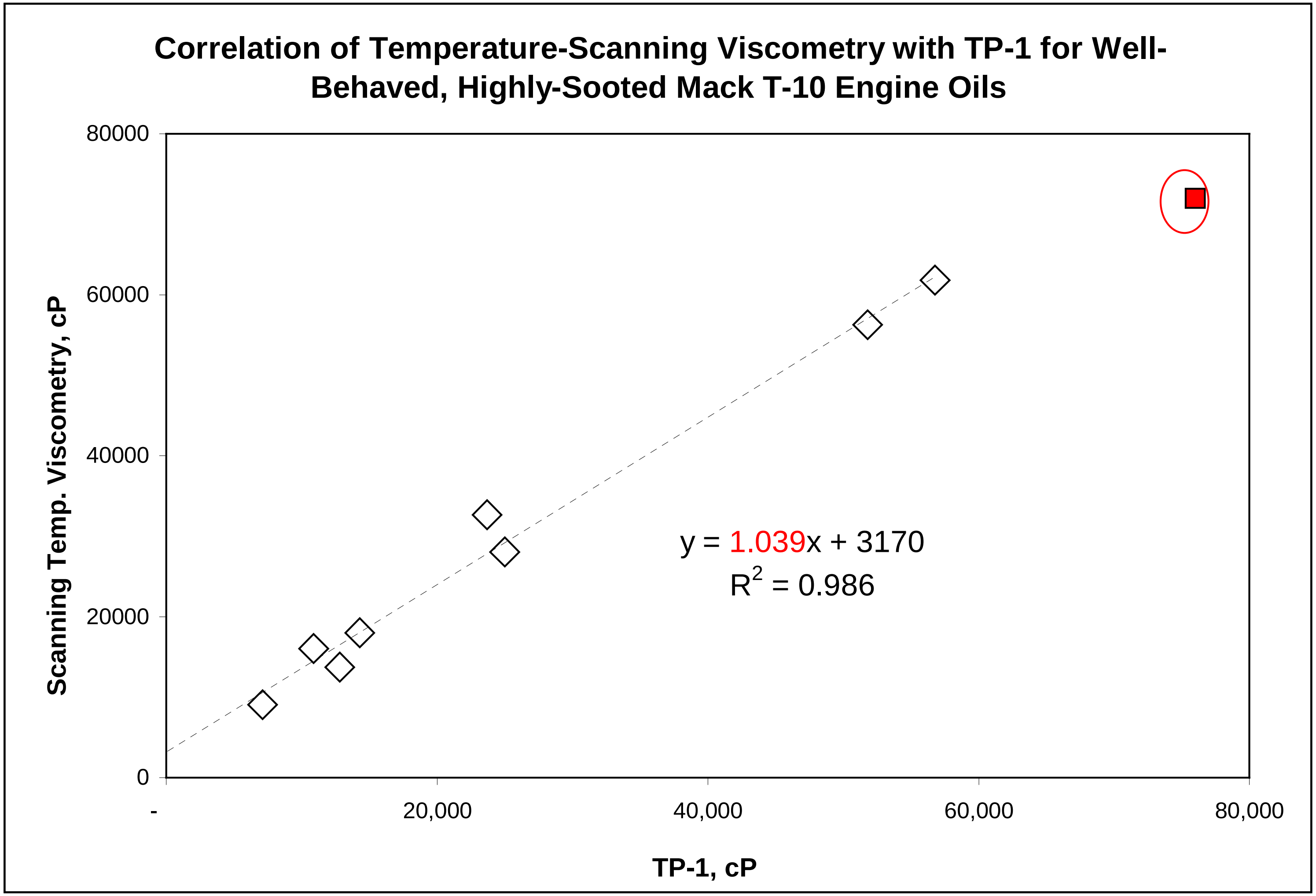
Oil ID	Temperature at 60,000 cP		Well-Behaved?	Gelation Index		Gelation Index Temperature		TP-1 Viscosity, cP		
	Test 1	Test 2						-15°C	-20°C	-25°C
723-D	-17.9°C	-18.1°C	No	15.1	15.7	-16.6°C	-16.6°C	8,040	26,500	165,000
723-E	-18.3°C	-18.5°C	No	16.2	17.1	-16.2°C	-17.1°C	6,940	25,200	562,000
723-F	-25.2°C	-25.1°C	Yes					7,100	14,300	51,800
723-G	-24.7°C	-24.8°C	Yes					12,800	25,000	56,800
723-H		-23.2°C	Yes					10,900	23,700	76,000
723-I	-10.5°C	-10.7°C	No	9.6	9.1	-6.2°C	-6.0°C	17,800	56,300	437,000
723-J	-18.5°C	-18.5°C	No	12.1	12.5	-16.4°C	-16.6°C	9,520	37,900	415,000
Average Difference	1.3°C			0.6		0.3°C				

Repeatability of the temperature-scanning viscosities taken at -15°, -20°, and -25°C is shown in Table 2. In general, the repeatability is good.

Table 2 - Repeatability of Viscosities at Three Temperatures

Oil ID	-15°C		-20°C		-25°C	
	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2
723-D	12700	12700				
723-E	10700	10700				
723-F	9400	9100	18600	18000	58100	56300
723-G	13900	13700	28200	28100	62000	61800
723-J	13400	13500				

Agreement between the Temperature Scanning Technique and the TP-1 method has been indicated to be fairly good. The following plot of the data collected in this study shows good correlation for viscosities lower than 70,000 cP with a slope of 1.039 and an R^2 value of 0.986.



Conclusions:

The new method is

- Fast
  - 7 hours or 16 hours depending on the temperature range desired.

- Precise
  - Closely replicates viscosities, 60,000 cP intercepts, Gelation Indexes, and total flow curves.

- Informative
  - Shows entire flow curve and reasons for poor oil behavior.

- Correlates with TP-1
  - Correlates quantitatively with TP-1 values on well-behaved sooted oils.
  - Correlates qualitatively on failure of poorly behaved oils.

Thanks for your time and attention

Ted Selby

Mack T10
Proposed PC 9 Limits

• Liner Wear (um)	30
• Top Ring Weight Loss (mg)	140
• EOT Lead (Delta ppm)	30
250-300 Lead(Delta)	10
• Avg Oil Consumption Phase 2	60 gr/hr
• EOT Oxidation	
Method 5	750
	Absorbance per cent /sq

ATTACHMENT 9

Comparison of Test Conditions

- Mack T-9 Ring and Liner Wear Test - 500 hr., 1.75 % soot @ 75 hr.

	Fuel Flow, #/h	Speed, rpm	HP	Torque, #ft	BMEP, psi
Stage 1	139	1800	352	1027	213
Stage 2	121	1250	381	1600	331

- Mack T-10 Ring and Liner Wear Test - 300 hr., 4.8 % soot @ 75 hr.

Stage 1	130.5	1800	345	1007	209
Stage 2	140	1200	434	1900	394

- Cummins M11- EGR Test - 300 hr., 4.6 % average soot.

Soot Con.	127.6	1800	329	960	216
Wear Con.	141.7	1600	434	1425	320

T-10 Liner Wear

- Statistical analysis of the T-10 matrix data shows no impact of technology, even with the designed-in D.I. uptreats and downtreats.
  - Suggests parameter is not responsive to formulation variables.
  - Only response is to test conditions and statistical variability.
- T-10 loads to significantly higher soot @ 75 hr with higher BMEP, but test is shorter.
  - Model one: 25.4 microns * 4.8% / 1.75% * 225 h / 425 h = 36.9 microns as the one test pass / fail target.
- Oil E is a “good” oil, therefore it should pass at the two sigma level.
  - Model two: oil E averages 25 microns liner wear, using the sigma for the full data set equal to 5, mean plus 2 sigma = 35 microns as the one test pass / fail target.
- Infineum suggests the slightly more conservative 35 micron target.

T-10 Ring Weight Loss

- Like liner wear, the statistical analysis of the T-10 matrix data shows no impact of technology.
  - Following the same logic as liner wear, we present two models.

- Model one: 120 mg * 4.8 % soot / 1.75 % soot * 225 h / 425 h = 174 mg as the one test pass / fail target.

- Model two: oil E averages 114 mg top ring weight loss, and the sigma for the full data set is 27, mean plus 2 sigma = 168 mg as the one test pass / fail target.

- Infineum suggests a limit of 170 mg max.

T-10 Lead / URBWL / Oxidation

- Analysis of the T-10 Matrix data shows a significant degree of correlation among delta lead, upper rod bearing weight loss and oxidation. The measurement of any one parameter defines the others.
- Matrix data show that technology is significant.
- Historically, control of delta lead in the T-9 has been the true heavy duty category oxidation test.
  - TMC 1005 average performance near the 3 test pass fail limit correlates to 15 to 20 ppm of lead in 50 K mile drains.
  - Related technology at same site, which averaged 25 to 35 ppm of lead in 50 K drains, yielded 1,000,000 mile bearings with no copper exposed.
- Although shorter, the T-10 operates at higher temperature and greater NOx exposure for the oil than the T-9. (continued)

T-10 Lead / URBWL / Oxidation (continued)

- TMC 1005 lead control "breaks" at about 225 hr in the T-10, but the final lead level is artificially low due to high oil consumption.
- Oil A is the featured oil in this test.
  - Model one: oil A averages 24 ppm, log transform = 1.38, and the root MSE of the data is 0.29. 1.38 + 0.29 = 1.67, anti-log = 46.8 ppm.
- Oil E is a "good" oil and therefore should pass most of the time.
  - Model two: oil E averages 27 ppm, log transform = 1.43, and the root MSE of the data is 0.29. 1.43 + 0.29 = 1.72, anti-log = 52.5 ppm.
- Infineum suggests that delta lead should be the measured parameter for oxidation and bearing weight loss, and the pass / fail target should be 50 ppm max.

Cummins M11EGR
Precision/BOI Matrix Analysis

08/02/01

Experimental design

Lab A		Lab B	Lab D	Lab G	
S1	S2	S1	S1	S1	S2
B	A	B[a]	C[a]	A	C[b]
E	E	D	D	E	E
E	E	E	E	E	E
F	J	J	H	F	G
G				H	

[a] Replaced oil filter due to low oil gallery pressure

[b] CMIR 38958.Terminated at 228 hrs. due to low oil gallery pressure (only included in OFDP analysis)

		Base stock		
		1	**2**	**3**
Technology	**X**	A	B	C
	Y	D	E	F
	Z	G	H	J
		Group II	Group II	Group I

Significant Effects

- Lab
  - Crosshead Wear
  - Average Engine Sludge
  - Adjusting Screw Weight Loss
  - Rod Bearing Weight Loss
  - Average Wear Step
- Base oil
  - Crosshead Wear
- Technology
  - Rod Bearing Weight Loss
  - Average Wear Step
- Base oil/Technology
  - Oil Filter Differential Pressure
  - Average Engine Sludge

Crosshead Wear

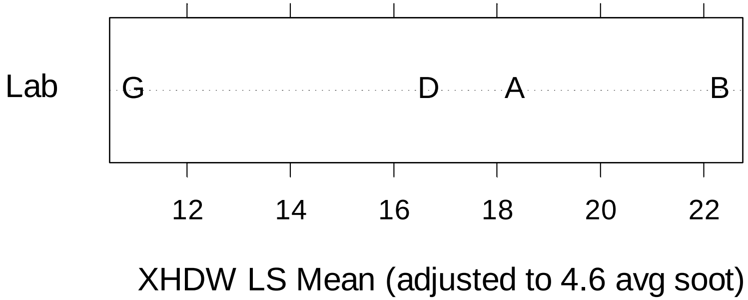
- Crosshead wear is transformed and adjusted to 4.6 average soot.

$$XHDW_{adj} = 10^{\log(XHDW) - 0.2575(avSoot - 4.6)}$$

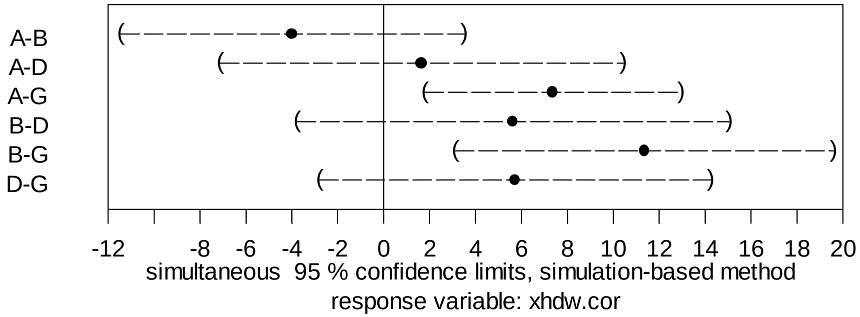
- Lab and base oil are significant
  - Lab G has lower wear than labs A and B
  - base oil 1 has lower wear that base oil 3
- RMSE = 3.7 (adj mg)
- $R^2 = 0.74$
- No highly influential observations

Crosshead Wear
(lab effect)

- Lab effect is due to Lab G having lower wear than Labs A and B



Confidence intervals for lab differences

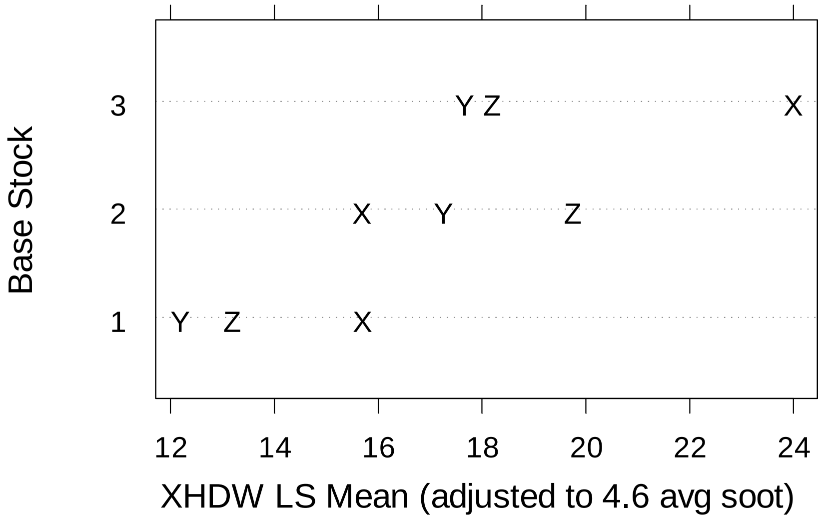


Lab LS Means

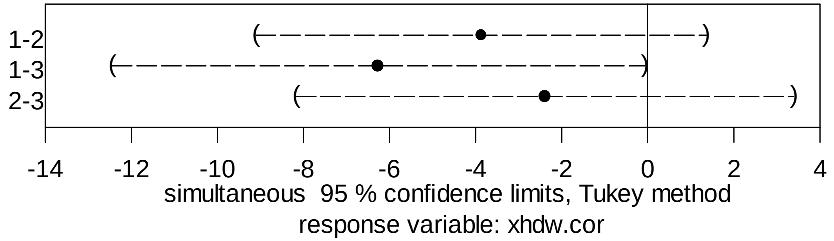
Lab	A	B	D	G
LS Mean	18.3	22.3	16.7	11.0

Crosshead Wear
(base oil effect)

- Base oil effect is due to lower wear in base oil 1 than in base oil 3



Confidence intervals for base oil differences

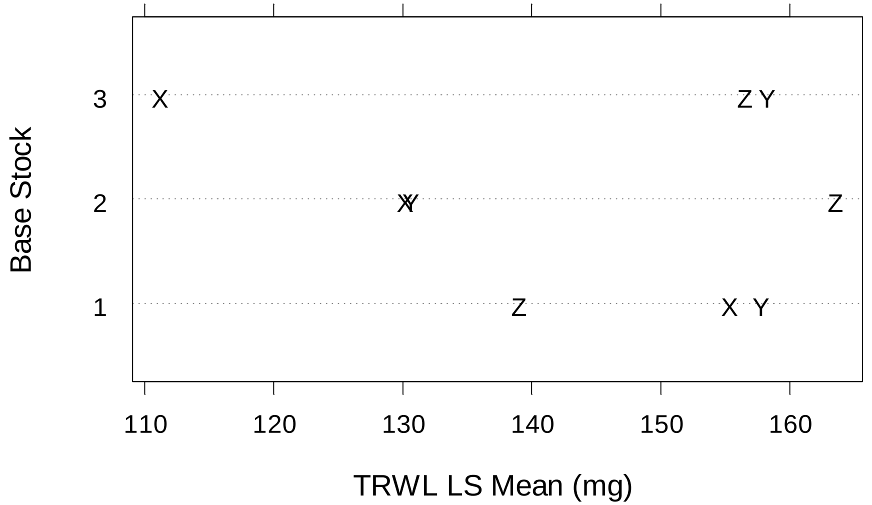


Oil LS Means

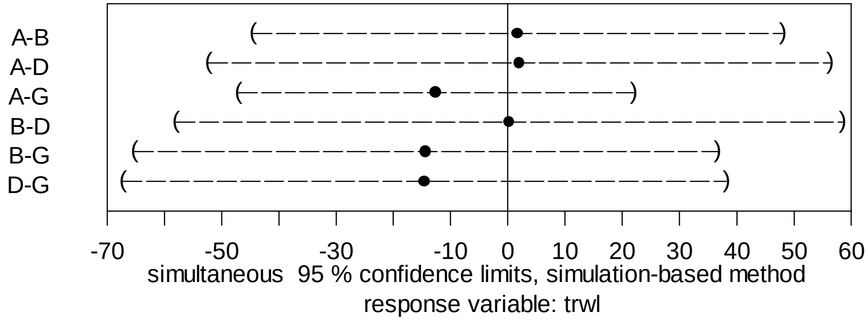
BS \ Tech	X	Y	Z
1	15.7	12.2	13.2
2	15.7	17.3	19.7
3	24.0	17.7	18.2

Top Ring Weight Loss

- No significant effects
- No transform necessary
- RMSE = 22.9
- $R^2 = 0.49$
- No highly influential observations



Confidence intervals for lab differences

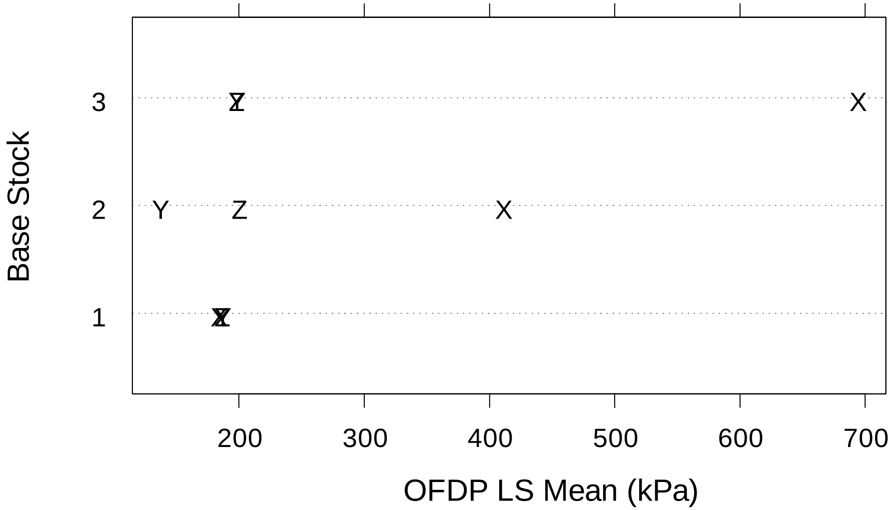


Oil LS Means

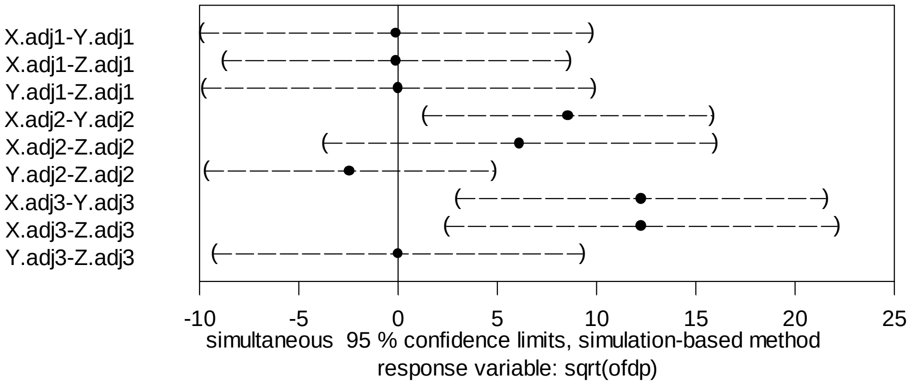
BS \ Tech	X	Y	Z
1	156.3	157.9	140.1
2	131.5	131.7	162.8
3	111.3	161.5	158.2

Oil Filter Differential Pressure
(including extreme values)

- Significant base oil/technology interaction
- Square root transformation
- RMSE = 2.7 (sqrt kPa)
- $R^2 = 0.81$



Confidence intervals for technology differences



Oil LS Means

BS \ Tech	X	Y	Z
1	184.1	186.9	186.7
2	411.2	137.3	200.2
3	694.2	198.3	198.1

08/02/01

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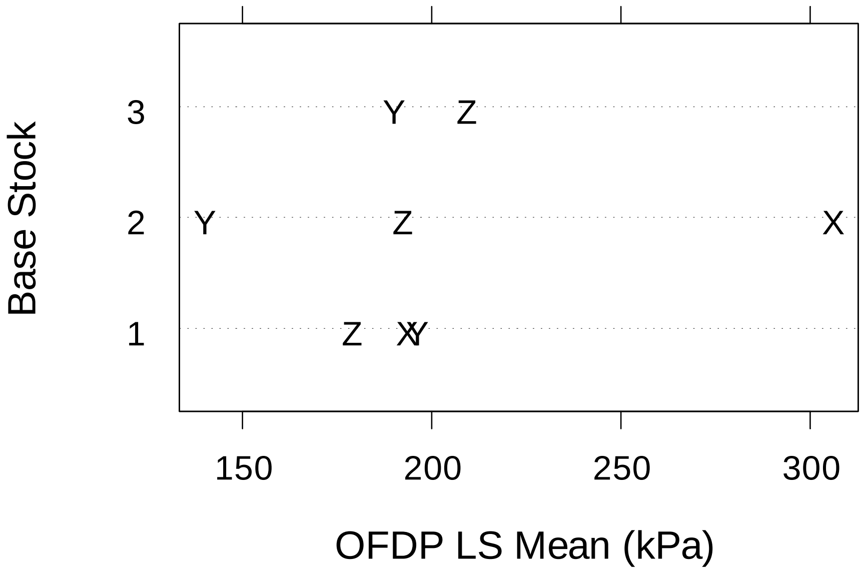
Oil Filter Differential Pressure
(excluding extreme values)

- This excludes
  - CMIR 38972 (oil B, lab B)
  - CMIR 38965 (oil C, lab D)
  - CMIR 38958 (oil C, lab G)
- Collectively these observations are highly influential
- Nothing significant
- No transformation necessary
- RMSE = 67
- $R^2 = 0.46$

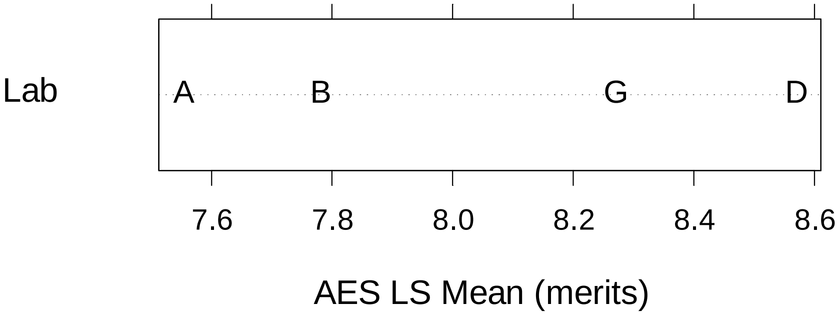


Oil LS Means

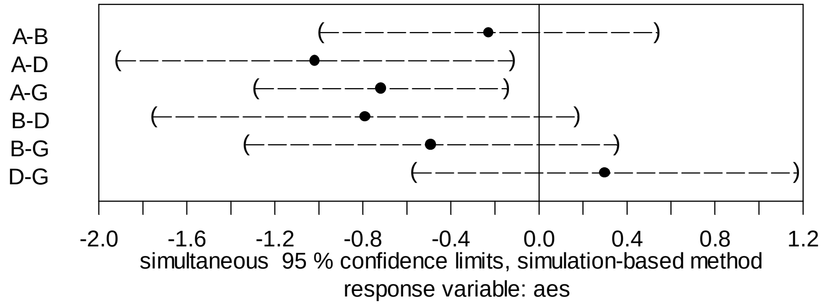
BS \ Tech	X	Y	Z
1	193.4	196.1	178.9
2	306.0	139.9	192.3
3	NA	189.9	209.2

Average Engine Sludge

- Significant lab differences and technology/base stock interaction
  - Lab effect is due to Lab A having lower sludge than Labs D and G
  - Interaction is due to low sludge rating for technologies Y and Z in base oil 1
- No transformation necessary
- RMSE = 0.38
- $R^2 = 0.82$
- No highly influential observations



Confidence intervals for lab differences

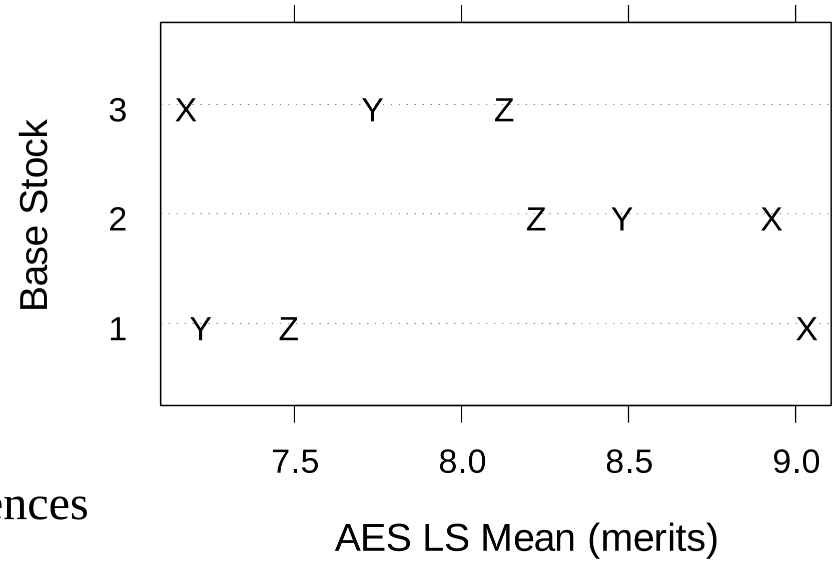


Lab LS Means

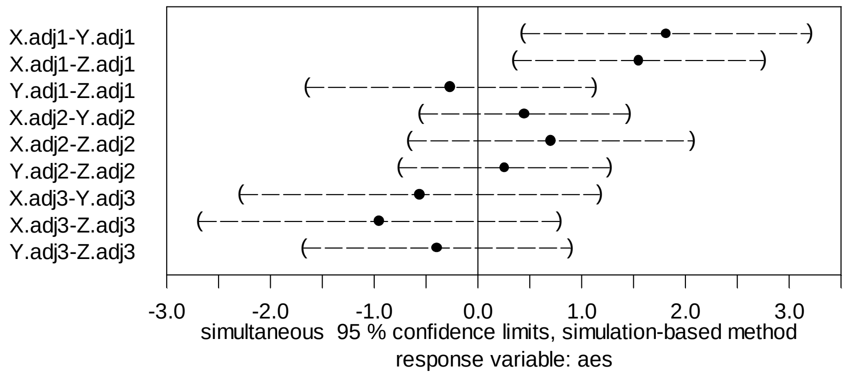
Lab	A	B	D	G
LS Mean	7.6	7.8	8.6	8.3

Average Engine Sludge
(technology/base oil interaction)

- Low sludge rating for technologies Y and Z in base oil 1



Confidence intervals for technology differences



Oil LS Means

BS \ Tech	X	Y	Z
1	9.0	7.2	7.5
2	8.9	8.5	8.2
3	7.2	7.7	8.1

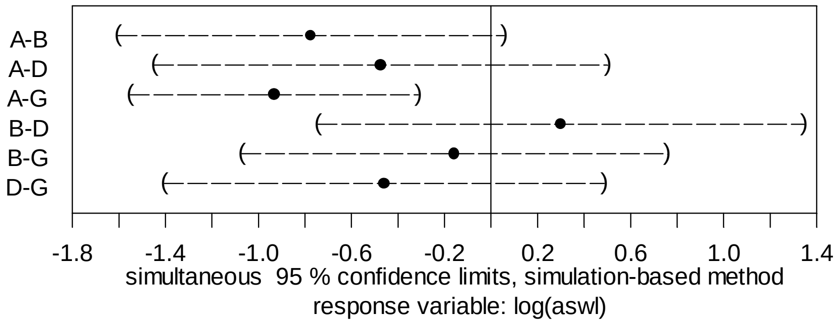
08/02/01

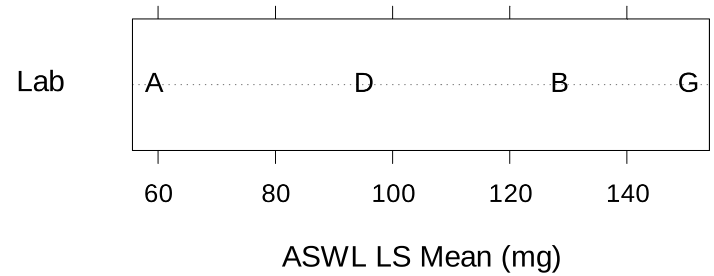
Adjusting Screw Weight Loss

- Lab is significant, with Lab A having lower wear than labs B and G
- Base oil is close to significant

- Ln transformation
- RMSE = 0.41 (ln mg)
- R^2 = 0.74

Confidence intervals for lab differences





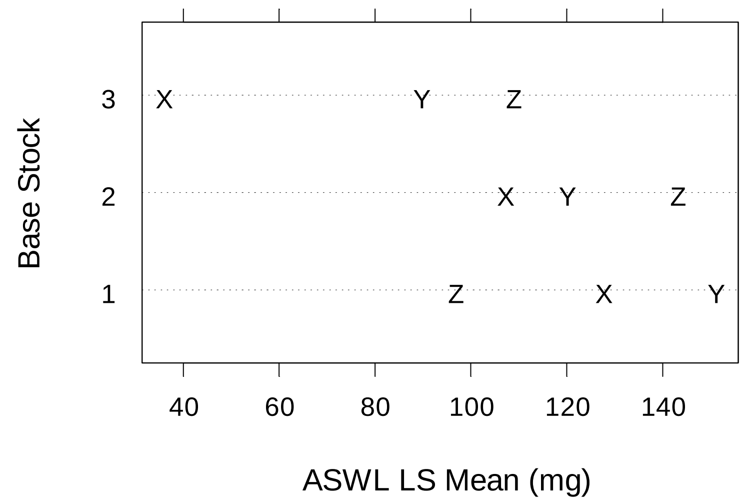
Lab LS Means

Lab	A	B	D	G
LS Mean	59.3	128.5	95.1	150.4

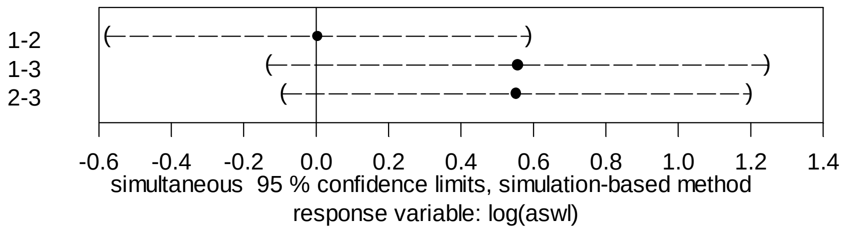
08/02/01

Adjusting Screw Weight Loss
(base oil)

- While not statistically significant, base oil 3 appears to have slightly lower wear than base oils 2 and 3



Confidence intervals for base oil differences

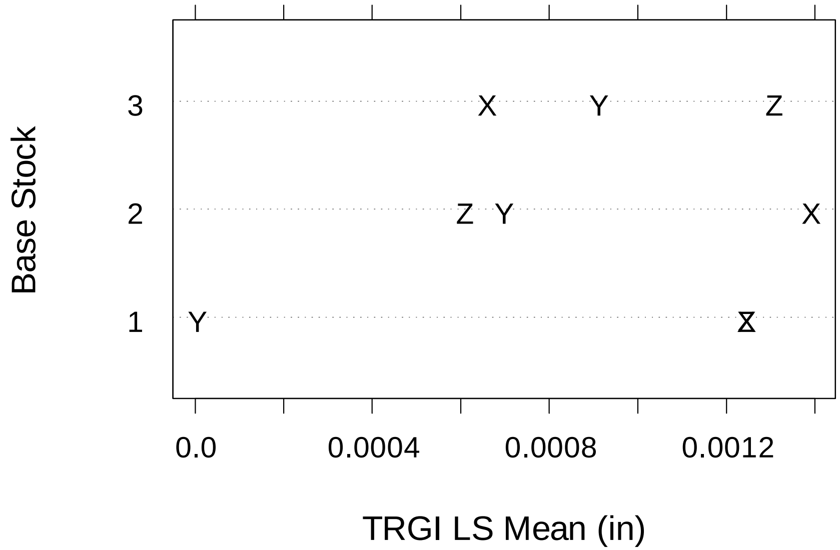


Oil LS Means

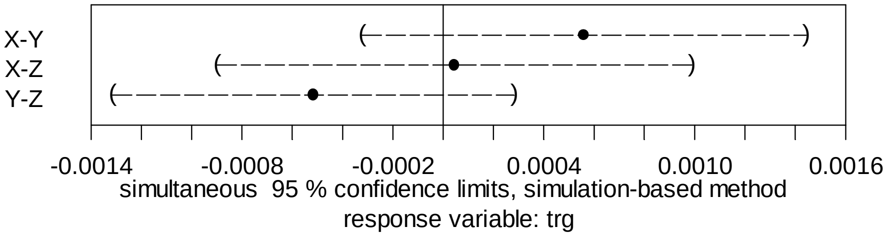
BS \ Tech	X	Y	Z
1	127.7	151.2	96.8
2	107.2	120.1	143.2
3	36.0	89.7	109.0

Top Ring Gap Increase

- Nothing is significant
- Does not correlate with TRWL
- No transformation necessary
- RMSE = 0.00056
- $R^2 = 0.43$



Confidence intervals for technology differences



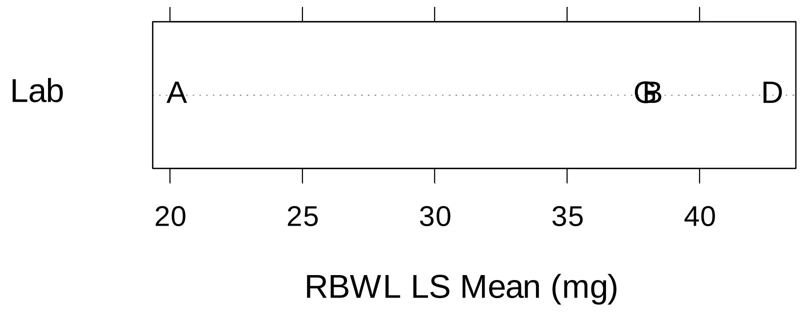
Oil LS Means

BS \ Tech	X	Y	Z
1	0.0013	0.0000	0.0013
2	0.0014	0.0007	0.0007
3	0.0006	0.0009	0.0013

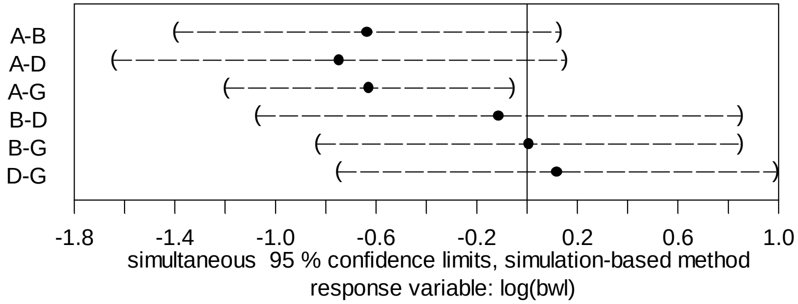
Rod Bearing Weight Loss

- Lab and technology are significant
  - Lab A is has lower weight loss than labs B, D, and G
  - Technology X has higher weight loss than Technologies Y and Z

- Ln transformation
- RMSE = 0.38 (ln mg)
- R^2 = 0.73



Confidence intervals for lab differences



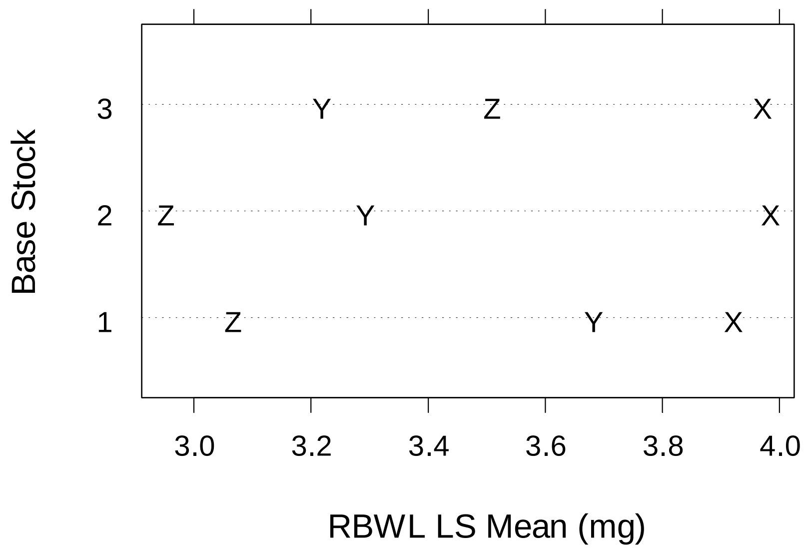
Lab LS Means

Lab	A	B	D	G
LS Mean	20.2	38.2	42.7	37.9

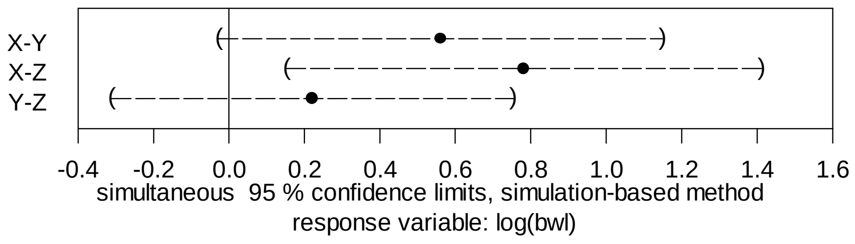
Rod Bearing Weight Loss

(technology effect)

- Technology effect is due to technology X having higher weight loss than technologies Y and Z



Confidence intervals for technology differences

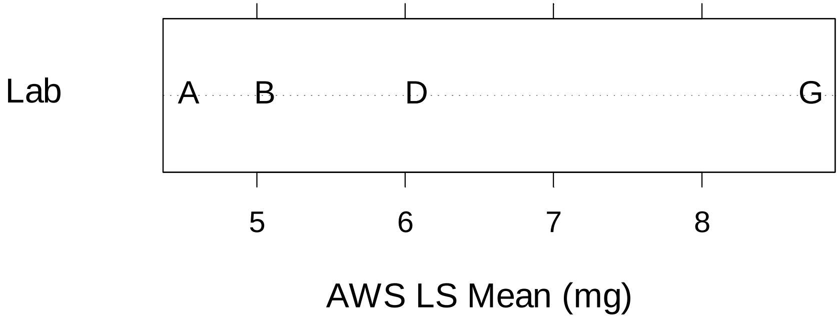


Oil LS Means

BS \ Tech	X	Y	Z
1	50.4	39.7	21.5
2	53.7	26.9	19.1
3	53.0	25.0	33.4

Average Wear Step

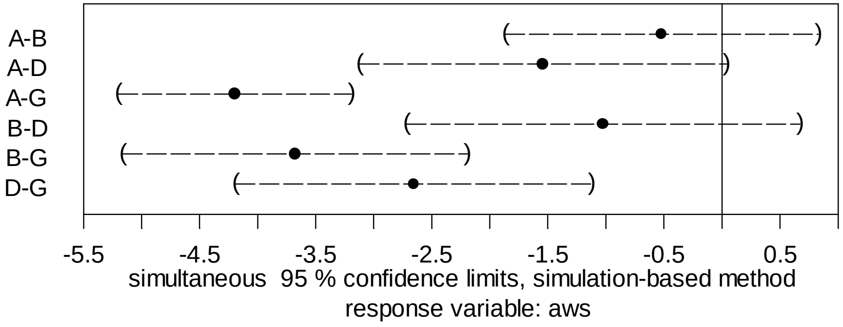
- Lab is highly significant
  - Labs G has much higher than Labs A, B, and D
- No transformation
- RMSE = 0.67
- $R^2 = 0.94$



Lab LS Means

Lab	A	B	D	G
LS Mean	4.5	5.1	6.1	8.7

Confidence intervals for lab differences



Oil LS Means

BS \ Tech	X	Y	Z
1	5.3	6.2	6.4
2	5.9	5.9	7.0
3	5.5	6.4	6.2

Parameter Correlations

Residuals

	TRWL	OFDP	AES	ASWL	TRGI	RBWL	AWS
XHDW	0.19	0.27	-0.03	-0.01	-0.27	0.08	-0.15
TRWL		0.13	-0.35	0.20	0.03	-0.01	-0.07
OFDP			0.12	-0.21	-0.69	-0.11	0.08
AES				-0.22	-0.45	0.12	-0.13
ASWL					0.35	0.55	-0.21
TRGI						0.17	-0.10
RBWL							-0.62

Raw data

	TRWL	OFDP	AES	ASWL	TRGI	RBWL	AWS
XHDW	-0.05	0.60	-0.18	0.00	0.09	0.26	-0.43
TRWL		-0.22	-0.10	0.22	0.04	-0.09	0.31
OFDP			-0.08	-0.26	0.08	0.45	-0.26
AES				0.31	0.01	0.23	0.33
ASWL					0.26	0.53	0.49
TRGI						0.35	-0.03
RBWL							0.05

Oil LS Means

	TRWL	OFDP	AES	ASWL	TRGI	RBWL	AWS
XHDW	-0.44	0.62	-0.10	-0.70	-0.01	0.10	-0.12
TRWL		-0.75	0.16	0.77	-0.08	-0.44	0.54
OFDP			-0.24	-0.83	0.04	0.61	-0.41
AES				0.45	0.57	0.19	-0.25
ASWL					-0.08	-0.34	0.41
TRGI						0.11	-0.24
RBWL							-0.83

Oil LS means and standard deviations

Oil	adjXHDW	TRWL	sqrt(OFDP)	AES	ln(ASWL)	TRGI	ln(RBWL)	AWS
A	15.7	156.3	13.5673	9.0	4.8499	0.0012	3.9209	5.3
B	15.7	131.5	20.2788	8.9	4.6749	0.0014	3.9836	5.9
C	24.0	111.3	26.3477	7.2	3.5832	0.0007	3.9706	5.5
D	12.2	157.9	13.6704	7.2	5.0184	0.0000	3.6820	6.2
E	17.3	131.7	11.7164	8.5	4.7883	0.0007	3.2919	5.9
F	17.7	161.5	14.0805	7.7	4.4964	0.0009	3.2178	6.4
G	13.2	140.1	13.6620	7.5	4.5729	0.0012	3.0668	6.4
H	19.7	162.8	14.1506	8.2	4.9642	0.0006	2.9523	7.0
J	18.2	158.2	14.0751	8.1	4.6913	0.0013	3.5089	6.2
std dev	3.7	22.9	2.7	0.38	0.4100	0.00056	0.3804	0.67

Data set

	CMIR	oil	base	tech	lab	xhdw	trwl	ofdp	aes	aswl	trgi	rbwl	aws
1	38932	E	2	Y	A	23.609126	172.0	127	7.4	108.4	0.0010000000	16.2	4.2
2	38967	B	2	X	A	18.860696	125.0	308	8.8	43.7	0.0010000000	30.1	3.9
3	38969	G	1	Z	A	12.024254	124.5	175	7.3	68.2	0.0010000000	18.6	4.7
4	38935	E	2	Y	A	17.497106	128.9	97	8.1	85.0	0.0001666667	22.3	4.1
5	38970	F	3	Y	A	20.770668	134.2	186	7.0	42.7	0.0010000000	17.6	4.3
6	38933	E	2	Y	A	11.403427	115.5	66	8.0	51.2	0.0011666667	7.6	5.3
7	38966	J	3	Z	A	20.313626	170.5	265	7.7	71.8	0.0010000000	23.8	4.5
8	38934	E	2	Y	A	16.018042	139.1	143	7.6	82.1	0.0000000000	17.1	4.5
9	38968	A	1	X	A	20.292868	144.5	288	8.9	56.6	0.0001666667	25.0	4.4
10	38936	E	2	Y	B	23.283084	147.2	246	8.7	116.6	0.0005000000	36.2	3.8
11	38971	D	1	Y	B	19.409366	144.7	191	6.9	196.6	0.0003333333	42.0	5.7
12	40920	J	3	Z	B	22.573732	139.7	179	7.8	120.7	0.0015000000	32.4	5.3
13	38972	B	2	X	B	19.005164	131.8	601	8.3	191.9	0.0016666667	66.2	5.3
14	38931	E	2	Y	D	15.914587	112.8	118	9.1	98.9	0.0011666667	37.2	6.4
15	38963	D	1	Y	D	9.810164	162.9	224	7.8	136.1	0.0000000000	54.8	5.7
16	38965	C	3	X	D	23.597374	107.1	606	7.7	33.5	0.0008333333	67.7	5.5
17	38964	H	2	Z	D	22.282757	164.0	184	8.6	155.8	0.0008333333	20.9	7.0
18	38927	E	2	Y	G	11.739236	104.1	178	9.0	160.5	0.0000000000	26.2	8.2
19	38962	F	3	Y	G	9.698728	196.9	171	8.2	160.9	0.0005000000	24.3	9.6
20	38930	E	2	Y	G	11.478874	148.2	190	8.4	96.6	0.0003333333	21.9	9.1
21	38960	H	2	Z	G	10.702293	167.7	175	8.6	180.4	0.0006666667	25.4	9.6
22	38959	A	1	X	G	6.245662	176.2	76	8.9	246.2	0.0020000000	69.8	7.3
23	38928	E	2	Y	G	14.913275	143.7	111	8.9	139.0	0.0003333333	28.1	9.0
24	38929	E	2	Y	G	12.098821	129.5	55	8.8	404.0	0.0013333333	62.6	8.0
25	38958	C	3	X	G	NA	NA	706	NA	NA	NA	NA	NA
26	38961	G	1	Z	G	9.496053	163.8	160	7.4	117.4	0.0011666667	17.0	9.1

M11 EGR Test Matrix Status

Presentation to
HDEOCP
August 16, 2001
David M Stehouwer

ATTACHMENT 12, 1 OF 5

M-11 EGR Test Status

- M11 EGR Task Force Meeting on August 9, 2001
- Task Force Recommends test to HDEOCP
- LTMS Data accepted
- Existing calibrated stands to be re-referenced in 90 days
- Post matrix stands have 6 month reference period
- Experienced labs defined as labs with 4 or more reference test completed
- Experienced labs are allowed one test reference on new stands based on reduced “k” values

M-11 EGR Test Status

- E178 will be used for crosshead outlier screening criteria (intake/exhaust)
- Labs to standardize blowby handling
  - ✓ Decrease lab differences in sludge ratings
- Tighter limits on intake CO2 for stages A and B
  - ✓ Reduce crosshead variability
  - ✓ Improve overall test precision

M-11 EGR Test Status

Proposed Limits

- ✓CWL 20 mg
- ✓TWL 175 mg (no ring gap correlation)
- ✓OFDP 275 kPa @ 250 hrs
- ✓ASR 8.0
- ✓BWL, IAS: Report Value

David M Stehouwer, Cummins Inc.

M11 EGR Action Item

- Task force has recommended acceptance of M11 EGR Test
- Therefore:
- Motion: HDEOCP accepts the M11 EGR test for PC-9

David M Stehouwer, Cummins Inc.

M11-EGR Ring Wear

- The M11-EGR test operates at about 20 % lower peak BMEP than the Mack T-10 test. Average soot is similar to the T-10.
- The wear portion of the M-11 test is 33 % shorter than the Mack T-10.
  – Lower ring loading (BMEP) combined with shorter time directionally reduces test severity.
- Cummins have indicated that ring face wear, as predicted by ring gap increase (RGI), is of greater concern than ring flank wear.
- Most of the top ring gap increase measurements from the M11-EGR matrix tests show 0.000 to 0.001 ring gap increase.
  – Correlates to 0.00032 wear on the ring face, or about 23 mg. RWL.
- The M11-EGR matrix data show no correlation between RWL & RGI.
- Infineum suggests the elimination of ring wear as a pass / fail target for the M11-EGR and using the T-10 to measure ring wear for PC-9.

M11-EGR Sludge

- M11-EGR matrix data shows a significant lab effect for sludge, with oil E giving results from 7.4 to 9.1.
  - No explanation for this lab bias has been determined.
- Oil Filter delta P appears to be a more sensitive measure of an oil's soot-handling ability.
- Oil E, the featured oil for the test, is a "good" oil and it should pass most of the time.
  - Oil E average sludge is 8.4, and the sigma = 0.60.
    8.4 minus 2 sigma = 7.2.
- Infineum suggests a target of 7.5 merits, minimum as the pass / fail target for M11-EGR sludge.

Cat 1R Matrix Status, 8/15

- 17 of 18 tests complete
  - 12 evaluated and posted on TMC website
  - 5 awaiting review
  - 1 running
- One test aborted due to operational problems

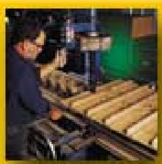
ATTACHMENT 14, 1 OF 3




CATERPILLAR®

Cat 1R Matrix Status, 8/15

- Three tests run at different flow rate
  - 63 L/min vs. 75L/min
- Task Force conference call on 8/2
- Decided that the flow rate did not affect the results
  - Tests deemed valid



CATERPILLAR®

Cat 1R Matrix Status, 8/15

- Task force is scheduled to meet in San Antonio August 21 and 22

- Review of conclusions at the September HDEOCP meeting

- Expected EOT ~ end of August




CATERPILLAR®

ATTACHMENT 14, 3 OF 3

DRAFT of the Preliminary Draft Statistical Summary of the Caterpillar 1R Precision Matrix

Preliminary Draft 08/15/2001

PRS

ATTACHMENT 15, 1 OF 9

Caterpillar 1R Matrix Summary

- The 1R matrix is not yet complete. This is a draft analysis of 12 of the 18 matrix runs. The statistician work group has not reviewed the presentation.
- Only WD, TGC, TLC, OC, ETOC analyzed to date.
- Three oils (A, D, M) are in the matrix. There is some evidence of discrimination in Oil Consumption. Note that there is only 1 run on D to date with only 2 planned.
- There is no evidence of Lab or Stand effects to date.
- No transformations are necessary and no outliers seen to date.
- There are positive correlations among the parameters especially WD/TGC and OC/ETOC.

Caterpillar 1R Matrix Status

Lab 1			Lab 2	Lab 3			Lab 4	Lab 5
Stand 1	Stand 2	Stand 8	Stand 3	Stand 4	Stand 5	Stand 9	Stand 6	Stand 7
A	M	A	M	A	M	A	M	A
M	D	M	A	M	D	M	A	M

The 1R Task Force concluded that the 3 tests at a coolant flow of 63 L/m are no different from the ones run at 70 L/m.

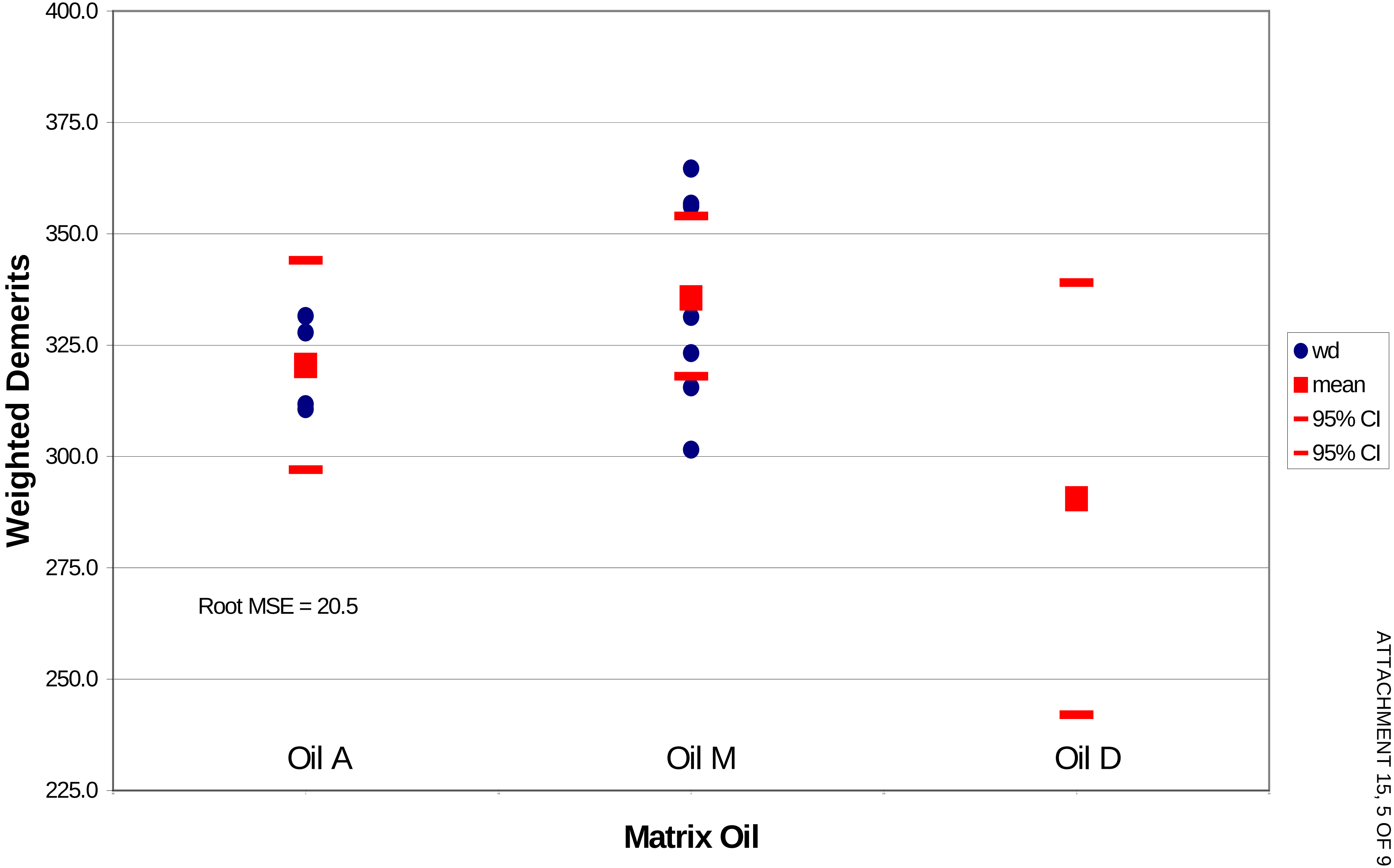
ATTACHMENT 15, 3 OF 9

Caterpillar 1R Correlations

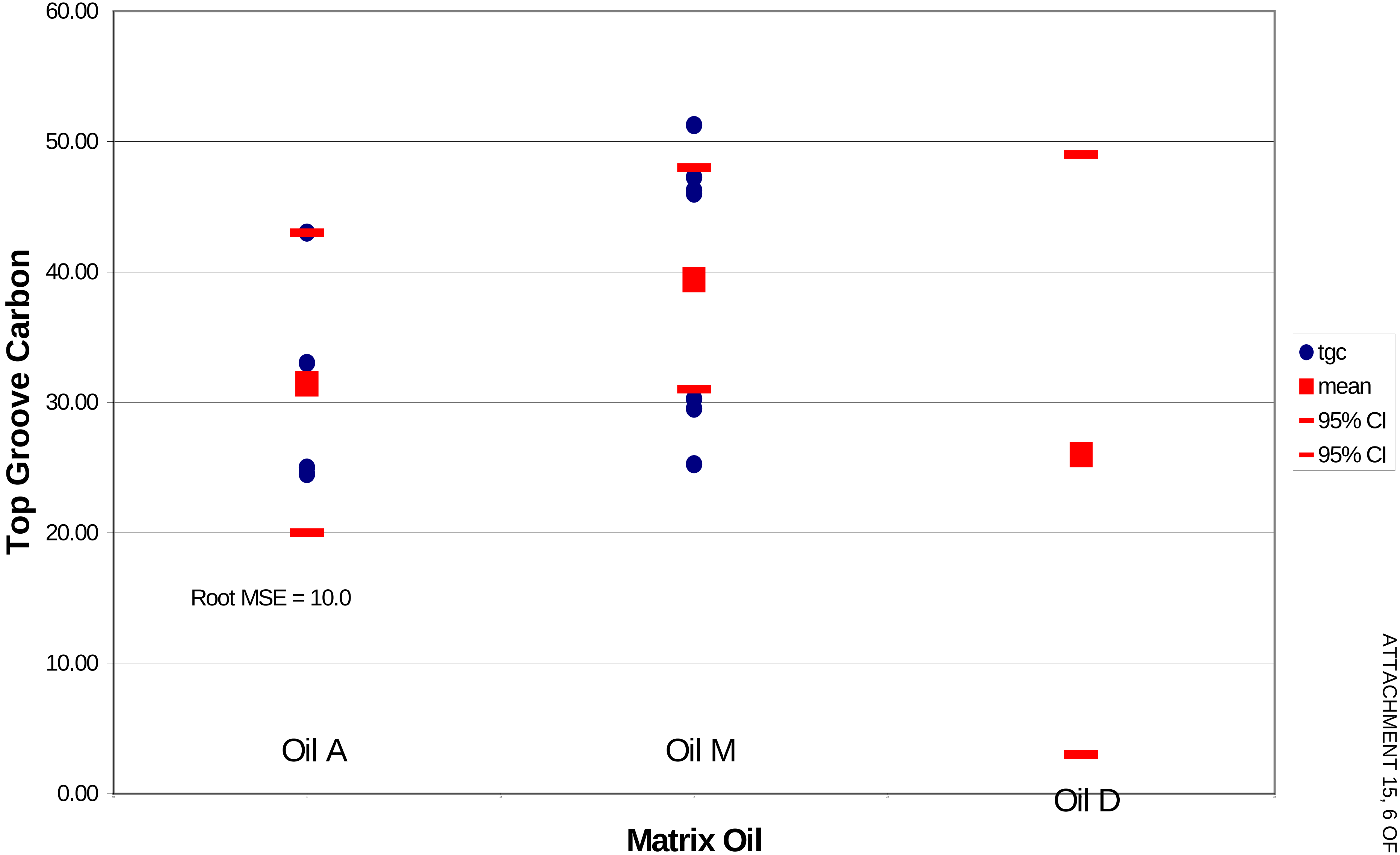
WD	0.68	0.76	-0.01	0.21
0.89	TGC	0.75	0.40	0.52
0.74	**0.87**	TLC	0.00	0.16
0.42	0.72	0.62	OC	**0.91**
0.53	0.71	0.73	**0.89**	ETOC

Raw Data Correlations on Upper Triangle; Partial Correlations on Lower Triangle

Caterpillar 1R Weighted Demerits Matrix Test Results, Means, and Confidence Intervals by Oil

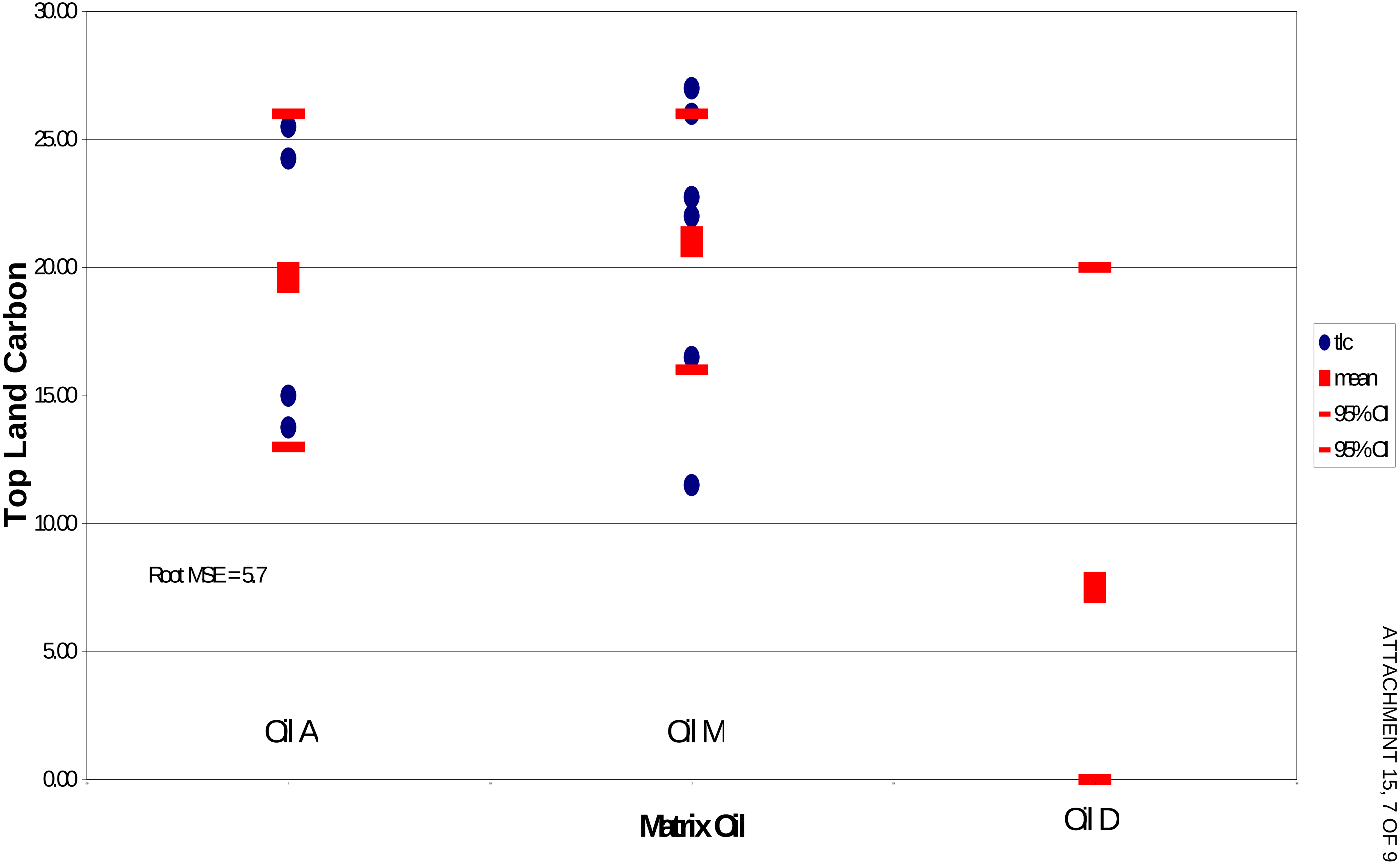


Caterpillar 1R Top Groove Carbon Matrix Test Results, Means, and Confidence Intervals by Oil



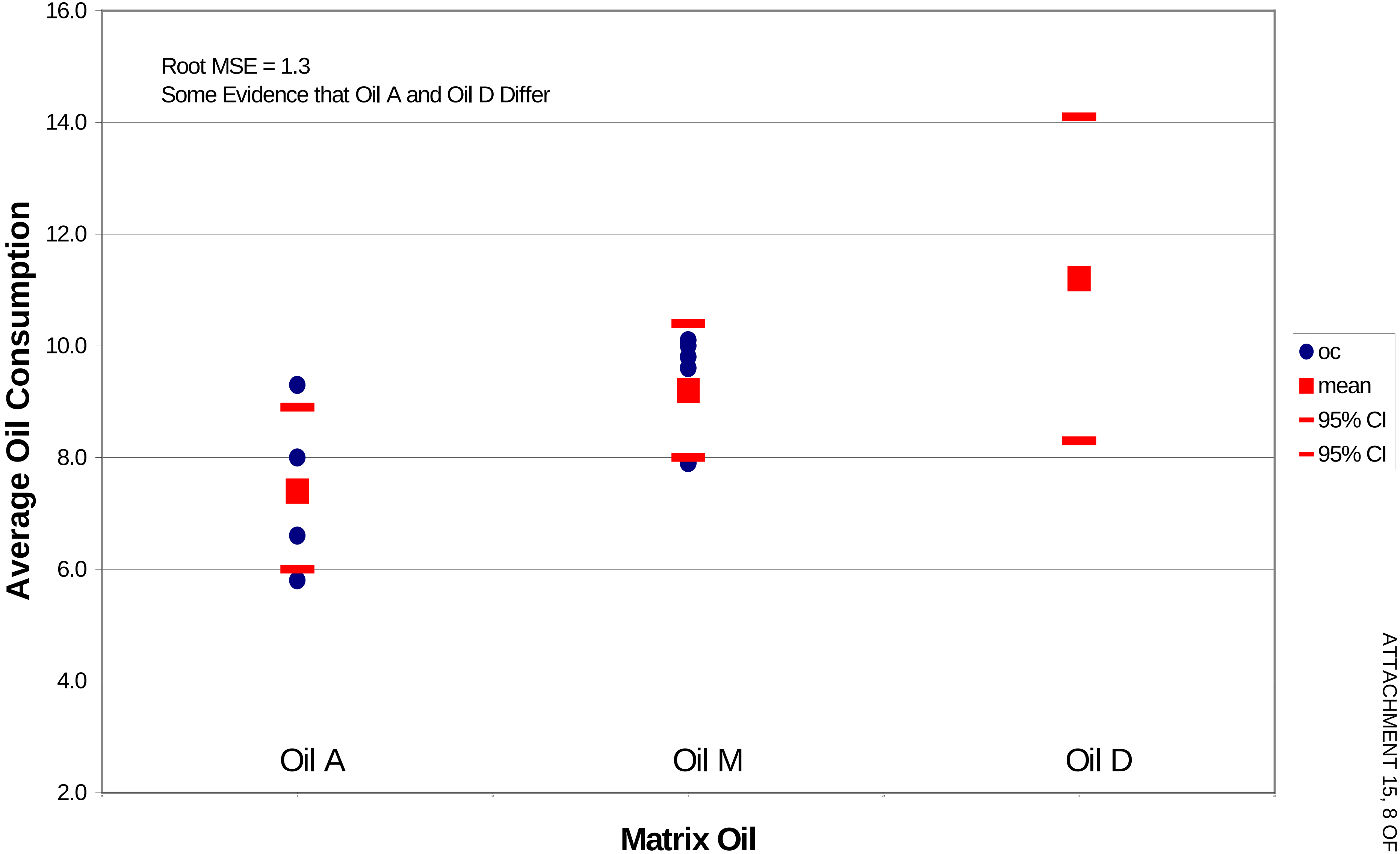
ATTACHMENT 15, 6 OF 9

Caterpillar 1R Top Land Carbon Matrix Test Results, Means, and Confidence Intervals by Oil

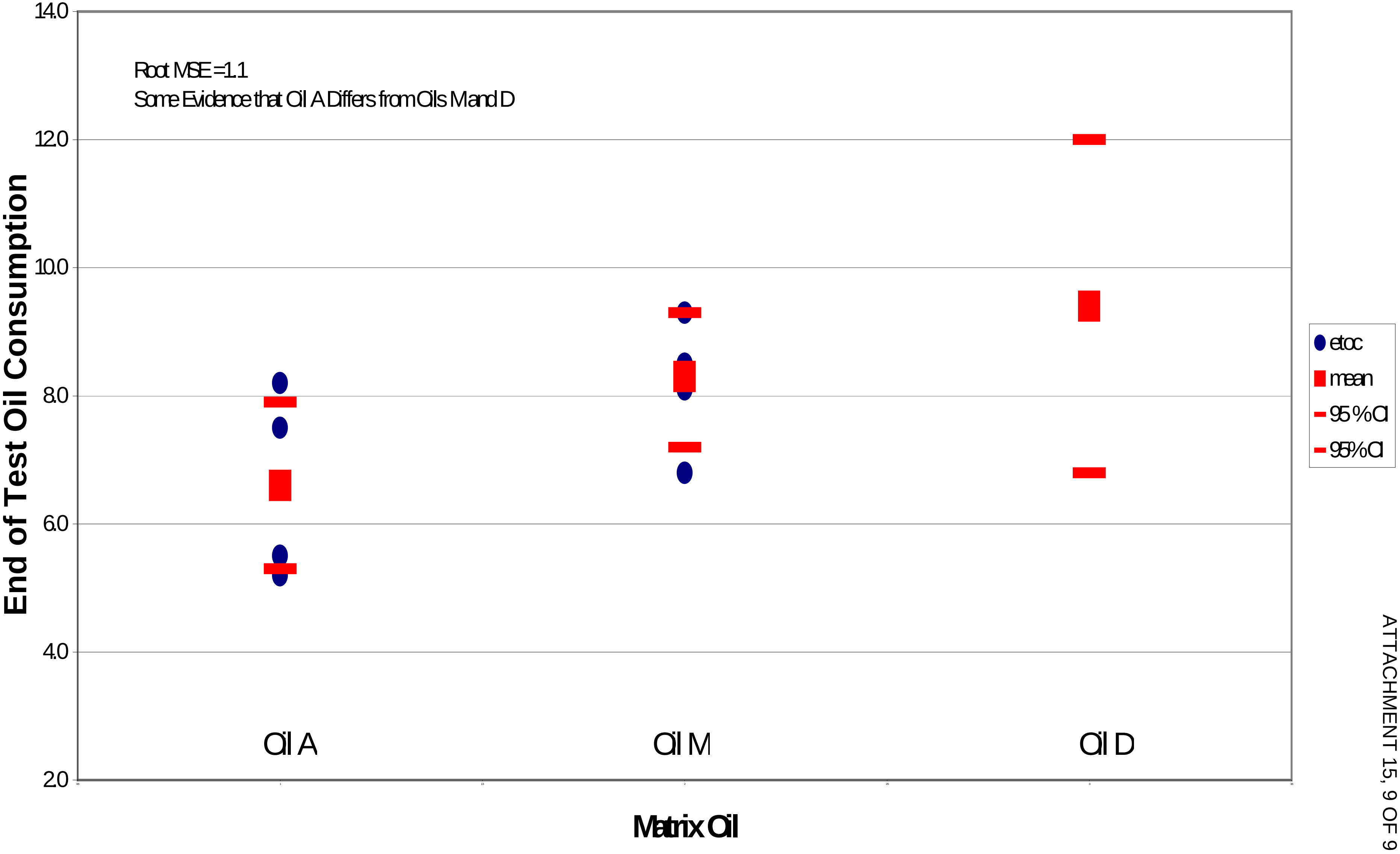


ATTACHMENT 15, 7 OF 9

Caterpillar 1R Average Oil Consumption Test Results, Means, and Confidence Intervals by Oil



Caterpillar 1R End of Test Oil Consumption Matrix Test Results, Means, and Confidence Intervals by Oil



ATTACHMENT 15, 9 OF 9

Caterpillar 1N

- Although less sensitive than the 1P test at CH-4 limits, the 1N test at CG-4 limits is a difficult hurdle for the higher SASH / TBN oils anticipated for PC-9 formulations.
- Data shared by Caterpillar at the July 11 HDEOCP meeting suggests that "PC-9 type" oils, while showing increased levels of Top Groove Fill and Crownland Carbon, can still control oil consumption.
  - Caterpillar has requested additional 1N data with "PC-9 type" oils.
- Infineum suggests relaxed limits for WDN, TGF and CLC compared to CG-4, while maintaining oil consumption at CG-4 limits.
  - This relaxation should NOT impact backward compatibility, as performance should be based category to category, not test to test.
  - PC-9 oils offer enhanced overall performance in terms of soot induced wear protection, deposit control, corrosion protection and low temperature pumpability compared to CG-4 oils.

ATTACHMENT 16

CATERPILLAR 1N TEST RESULTS

August 15, 2001

ATTACHMENT 17, 1 OF 6

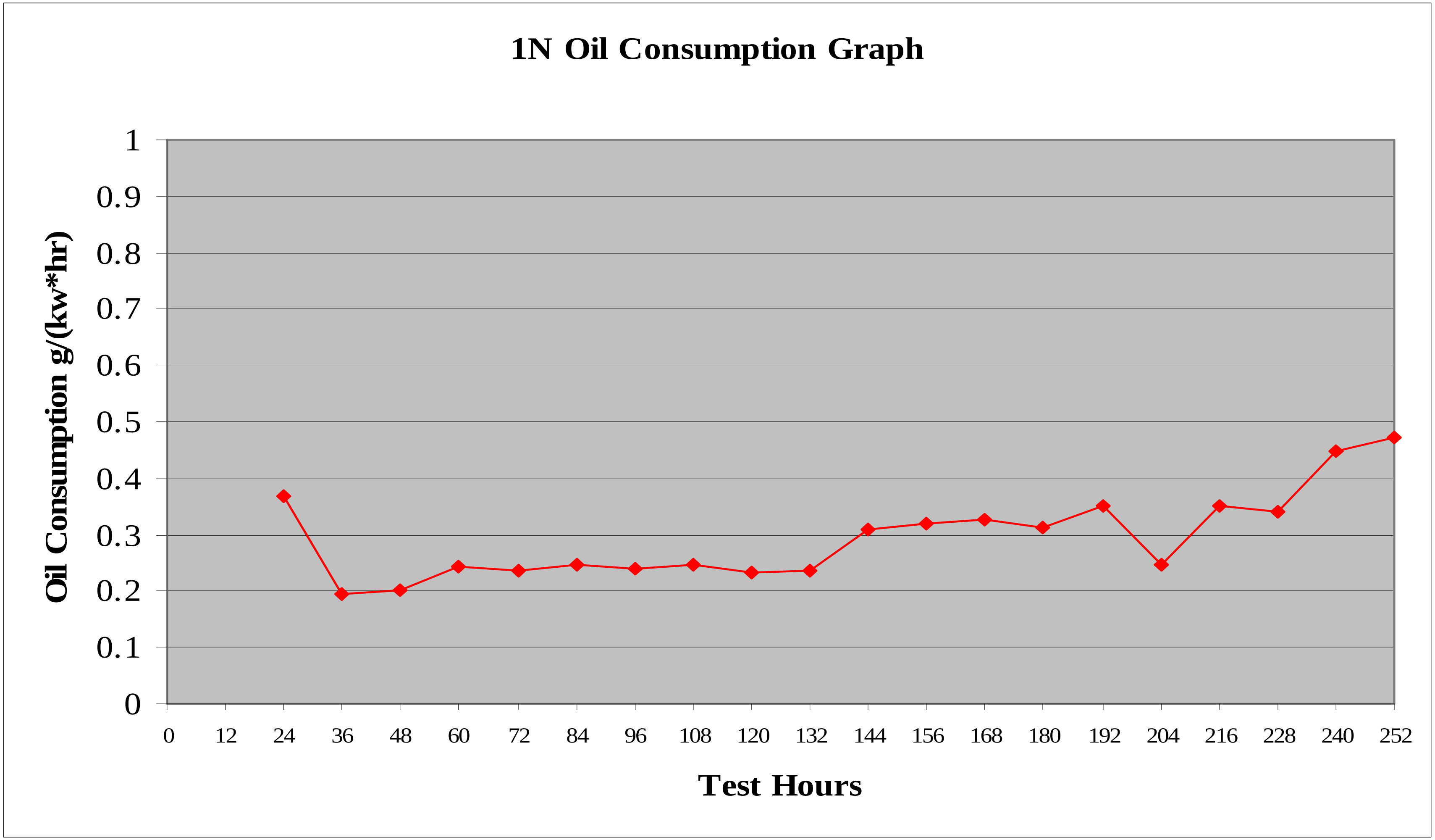
CATERPILLAR 1N TEST RESULTS

Ethyl

- A Caterpillar 1N test was run on Matrix Oil PC-9A
  - Feature oil, Mack T-10 Matrix
  - One of the Feature oils, Caterpillar 1R Matrix
- Caterpillar 1N results (API CG-4 one-test limits)
  - WDN, 236.6 demerits (286.2 max)
  - TGF, 25% (20% max)
  - TLHC, 0% (3% max)
  - Oil Consumption, 0.296 g/kW-hr (0.5 max)

ATTACHMENT 17, 2 OF 6

CATERPILLAR 1N TEST RESULTS



ATTACHMENT 17, 3 OF 6

CATERPILLAR 1N TEST RESULTS

Ethyl

- A Caterpillar 1N test was run on an Ethyl PC-9 development oil number 1 (Group I)
- Caterpillar 1N results (API CG-4 one-test limits)
  - WDN, 208.3 demerits (286.2 max)
  - TGF, 26% (20% max)
  - TLHC, 0% (3% max)
  - Oil Consumption, 0.140 g/kW-hr (0.5 max)

ATTACHMENT 17, 4 OF 6

CATERPILLAR 1N TEST RESULTS

Ethyl

- A Caterpillar 1N test was run on an Ethyl PC-9 development oil number 2 (Group II)
- Caterpillar 1N results (API CG-4 one-test limits)
  - WDN, 271.5 demerits (286.2 max)
  - TGF, 25% (20% max)
  - TLHC, 0% (3% max)
  - Oil Consumption, 0.190 g/kW-hr (0.5 max)

ATTACHMENT 17, 5 OF 6

SUMMARY

Ethyl

- **Three Caterpillar 1N tests on PC-9-quality oils give acceptable API CG-4-level WDN and TLHC performance**
- **However, these oils do not meet the one-test API CG-4 limit for TGF (results are at or near the three-test limit)**
- **Without relief, we believe multiple Cat 1N tests will be required on PC-9 oils -- to what effect??**

- **Ethyl would like to see relief on TGF (25-30%)**

ATTACHMENT 17, 6 OF 6

M11 Low Temperature Flow

Presentation to

HDEOCP

August 16, 2001

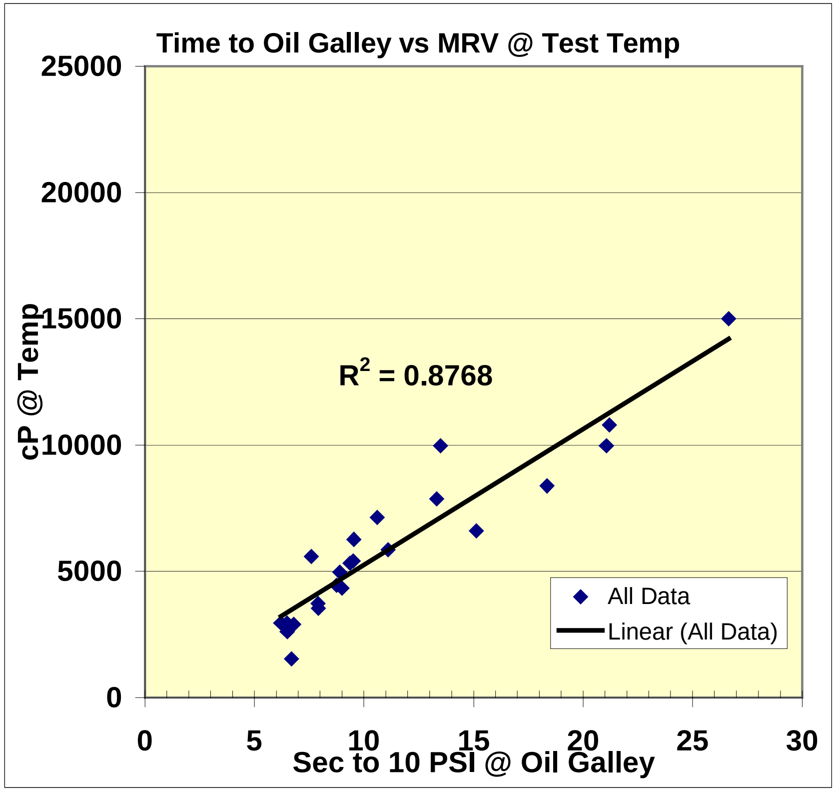
David M Stehouwer

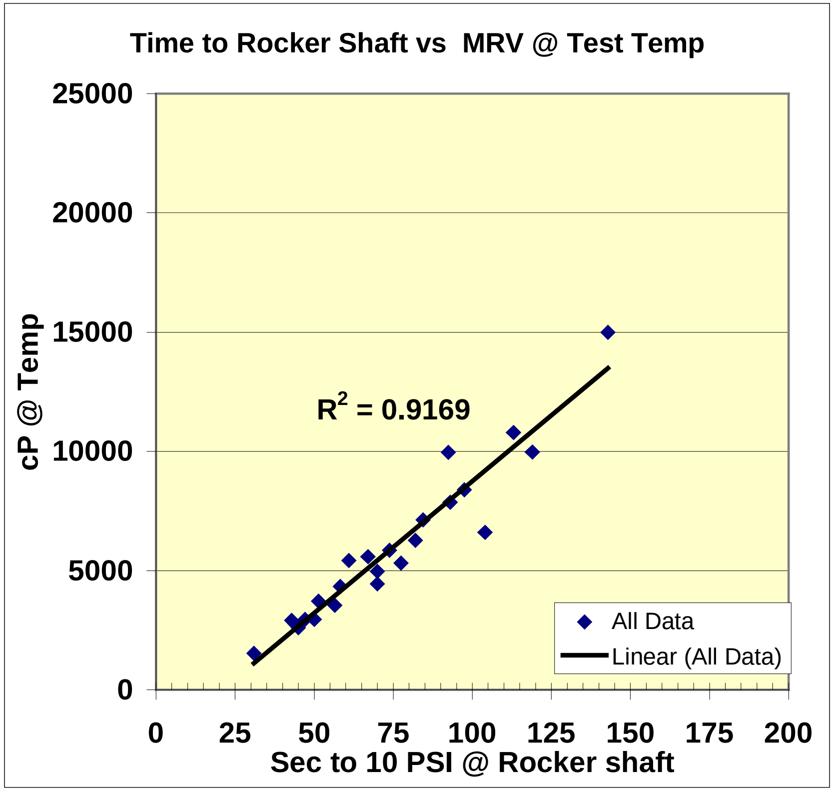
ATTACHMENT 18, 1 OF 6

Preliminary Conclusions

- It is possible for poorly dispersed soot to increase viscosity dramatically
- Well dispersed soot increases lube viscosity as soot increases
- For well dispersed soot in lubricants, and for fresh lubricants pumping time through the engine correlates with MRV viscosity.
- Based on very limited data, correlation seems best with modified MRV.

Correlation of MRV to Engine Flow





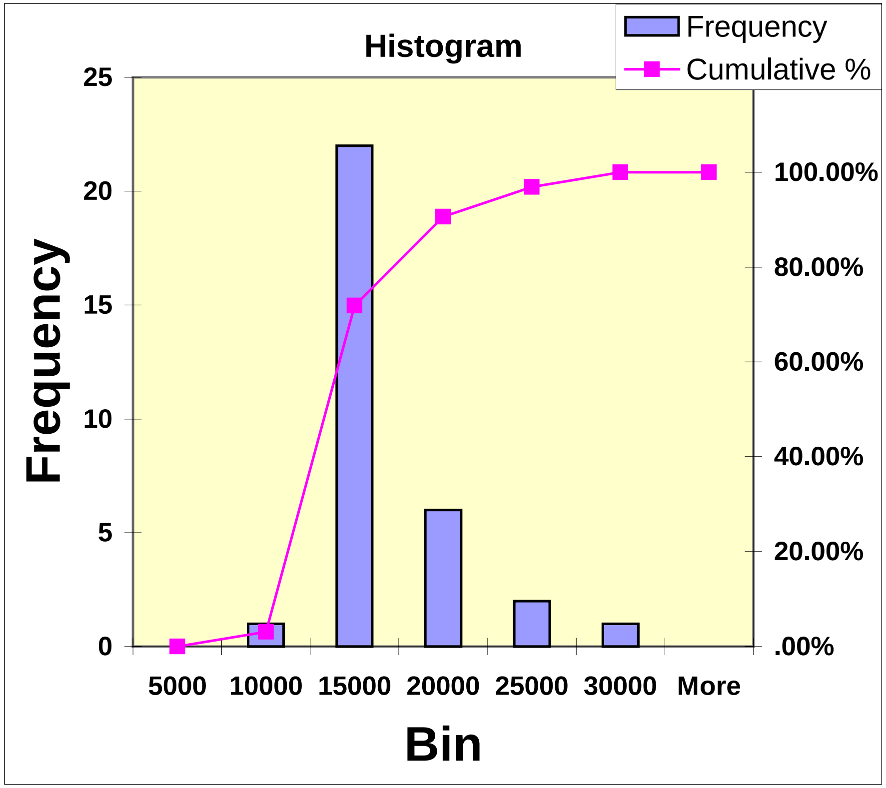
ATTACHMENT 18, 3 OF 6

M-11 Low Temp Pumpability

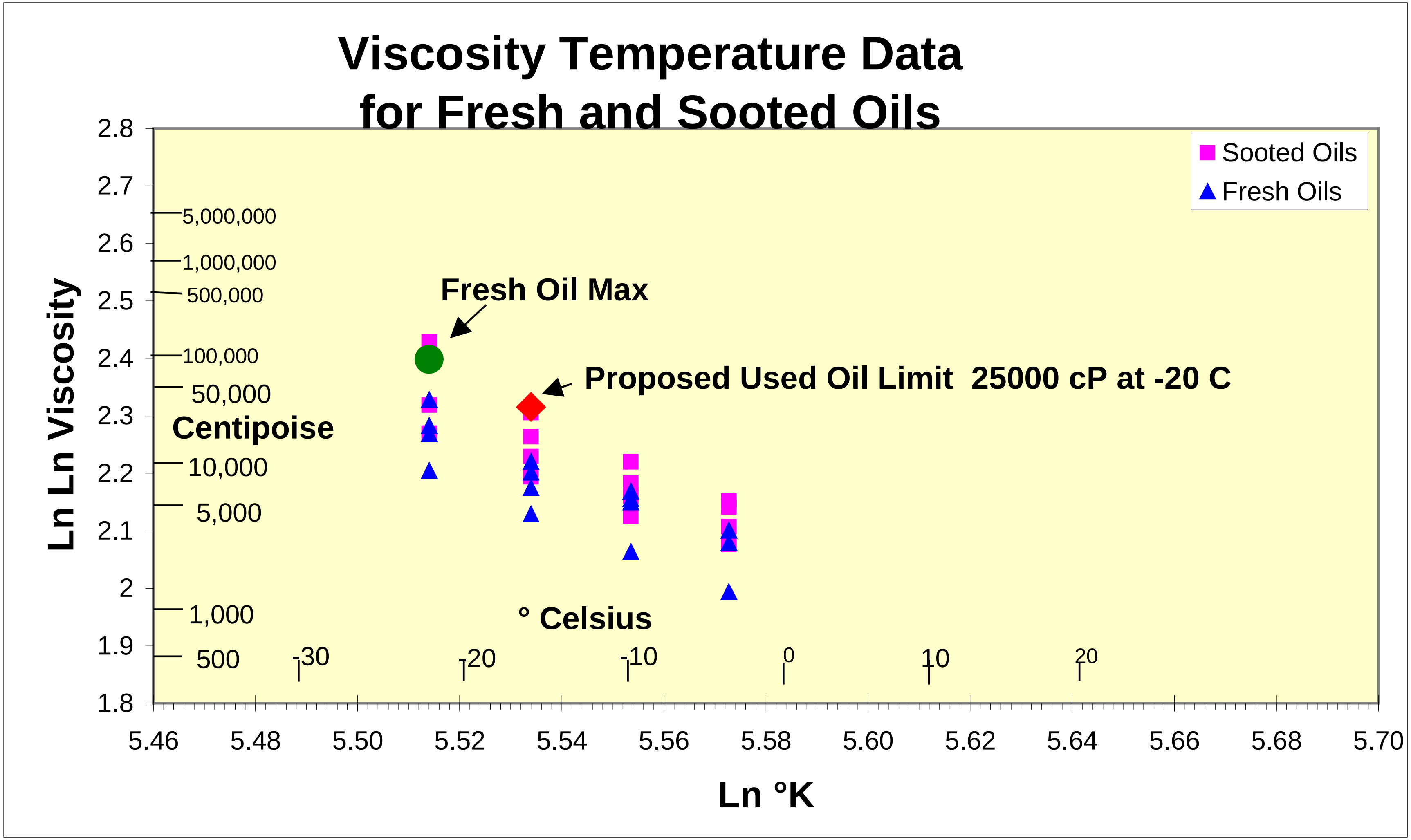
- Oils at -25 C would not allow the engine to crank
- This suggests 20 000 cP as a critical viscosity
- Given results from C. May LOTRUO data 25 000 cP seemed reasonable
- SWRI Data shows:
  - ✓ 72% of oils below 15,000 cP @ 75 hrs
  - ✓ 97 % of oils below 25,000 cP

SWRI MRV data on 75 hr samples

	Bin	Frequency	Cumulative %
0 to	5000	0	.00%
5001 to	10000	1	3.13%
10001 to	15000	22	71.88%
15001 to	20000	6	90.63%
20001 to	25000	2	96.88%
25001 to	30000	1	100.00%
	More	0	100.00%



Proposed Limits for MRV @ -20



David M Stehouwer, Cummins Inc. **Confidentail Information**

T-8E Relative Viscosity

- Infineum supports the change from 50% to 100% DIN shear as the initial viscosity to calculate relative viscosity.
- However, it should be noted that all of the Mack soot-handling tests, the T-7, T-8, and T-8E were developed to prevent pumability failures at LOW TEMPERATURE with “heavily sooted” used oils.
- In the PC-9 category there is a test for low temperature pumpability with approximately 5% soot loading of the oil.
  - This is a direct measurement of a parameter only implied by the T-8E.
- The EO-M PLUS limit for relative viscosity is 1.8 maximum.
  - The move to 100% DIN shear increases severity about 0.1 RV units.
- Infineum suggests 1.9 Relative Viscosity maximum, as the T-8E pass / fail target for PC-9 using 100% DIN shear value as the initial viscosity.

ATTACHMENT 19

Mack T8E for PC9
% Shear for Relative Viscosity

Greg Shank

August 15, 2001

Newer HD Engines Shear Oils to a Greater Extent

- Newer HD engines such as the N-14 and E-tech (1998-2000 vintage) have design changes which shear oils more effectively
- Older Mack and Cummins engines (1994-1997 vintage) show a lower level of shear
- Current limit of 50% DIN shear loss to calculate T-8E Relative Viscosity is no longer sufficient to predict field usage

Current Cummins N-14 Field Tests

- Tests use 1998-1999 N-14 engines with 435 HP
- Data includes eight engines run on 15W-40 oils
- Four oils and two Viscosity Modifier chemistries are represented
- Oil Drain intervals range from 15k to 50k miles

Current Mack E-7 Field Test

- Test is running on 1999-2000 E-Tech engines with 350 and 427 HP
- Data include five engines run on 15W-40 oils
- Five oils and two Viscosity modifier chemistries are represented
- Oil Drain intervals range from 10k-50k miles

Used Oil Viscosities from Current N-14 and E-7 Field Tests

- The 100 C kinematic viscosity (KV) from engines in these two field tests were measured
- Approximately half of the samples had KV's at or below the oil's DIN shear viscosity
- Approximately 80% of the samples had KV's below the 50% DIN shear value

Viscosity Data from Older Field Tests

- A 1997 test using V-Mack engines and a 1994 test using N-14 engines show a much lower level of shearing than the current tests
- These data include six engines run on five oils
- Less than 20% of the samples had KV’s at or below the oil’s DIN shear viscosity

Proposal

- To better match the amount of shearing seen with newer engines, the viscosity used for the T-8E Relative Viscosity calculation in the PC-9 Category should be moved from a 50% to 100% DIN shear value
- This change will increase T-8 test severity about 0.1 RV units for oils with 25-35 SSI polymer

Recommendation for T8E Pass/ Fail

Because Increase in Soot Levels in EPA 02 EGREngines

Relative Viscosity (100 % DIN) @ 4.8 % Soot

1.8 for PC 9

ATTACHMENT 20, 8 OF 8

Infineum's Comment on the Proposed 3.5 cP Minimum HTHS for Fresh 10W30 Oils

Presented to HDEOCP

August 15, 2001

Infineum

Blend Information:

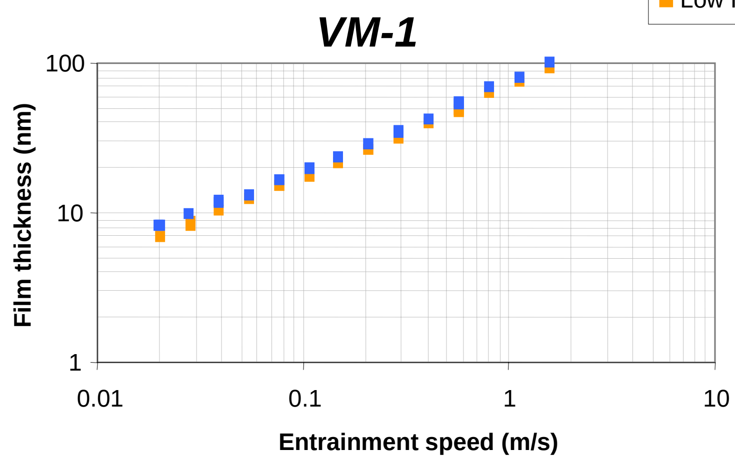
- 10W30 and 10W40 grades
- Same base stocks were used in all blends.
- PC-9 prototype DI at constant treat rate.
- Identical LOFI at constant treat rate.

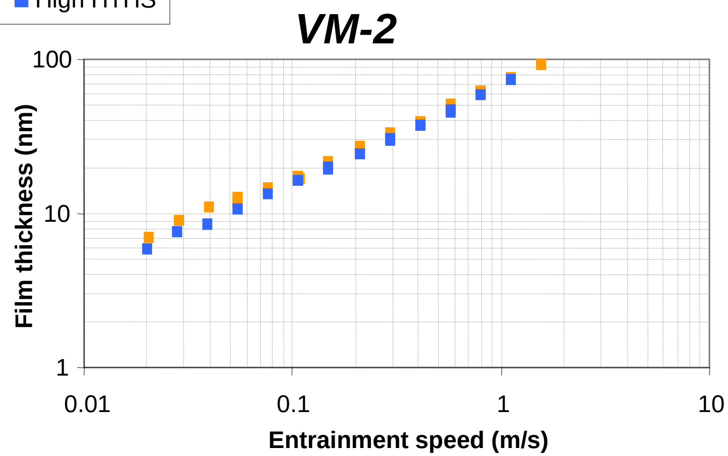
Blend Viscometrics

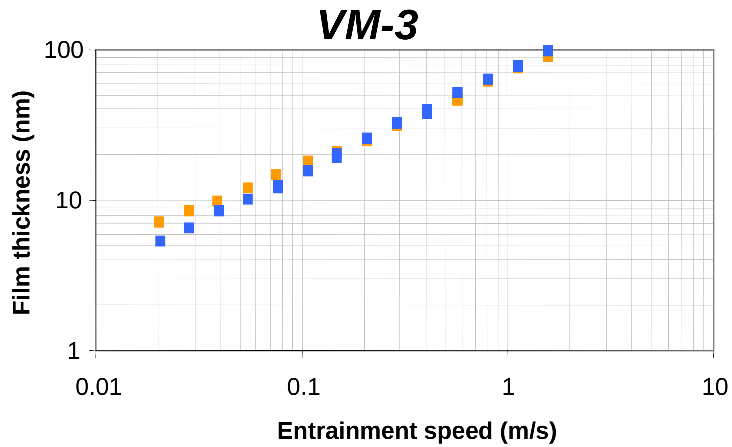
Low HTHS	***VM-1***	***VM-2***	***VM3***
HTHS @ 150C (cP)	3.24	3.22	3.24
KV100 (cSt)	10.66	10.42	10.38
CCS @ -25C (cP)	6817	6704	6933
High HTHS	***VM-1***	***VM-2***	***VM3***
HTHS @ 150C (cP)	3.94	3.93	3.90
KV100 (cSt)	15.18	14.88	13.84
CCS @ -25C (cP)	7239	6874	7239

Contact Film Thickness vs. Entrainment Speed under High Pressure (Elastohydrodynamic [EHD] Regime)

Low HTHS High HTHS







HTHS of an oil has essentially no impact on contact film thickness.

All film thickness measurements were carried out at 100 ºC.

ATTACHMENT 21, 3 OF 4

Closing Remark:

- Incorporation of more polymer into formulation to raise HTHS does not guarantee increased contact film thickness.

PC-9 Elastomer Exit Ballot Negative on Adjudication

- One known negative is based on having no detail or process in place for appealing results of Elastomer tests that may unfairly discriminate against a candidate oil due to changes in elastomers. Possible options include:

- The EMA have agreed in principle to review questioned results in an expeditious fashion (Current thinking is Lube Committee meetings)
- API 1509 is currently undergoing revision. API 1509 could include wording for adjudication of elastomer test results.
  - Adjudication could be noted on API license forms and candidate data packages

PC-9 Elastomer Exit Ballot Negative on Adjudication (con't)

- ASTM D 4485 could footnote an adjudication process for elastomer results
  - Test sponsor could make presentation to EMA Lube Committee either through letter or in person for adjudication.
  - Elastomer Surveillance Panel could be kept informed for any actions in case a number of changes take place

- If ASTM B0 HDEOCP agrees to any of these options, a letter to API under the signatures of the chairs of HDEOCP and BO could be appropriate to give advance notice of potential action