Committee D02 on PETROLEUM PRODUCTS AND LUBRICANTS

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Issued: January 19, 2011
Reply to: Dan Worcester
Southwest Research Institute
528 Tom Slick Ave
San Antonio, TX 78228
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The unapproved minutes of the 01.18.2011 Sequence VI Surveillance Panel meeting held in San Antonio, Texas.

The meeting was called to order at 9:00 AM by Chairman Charlie Leverett.

Agenda

The Agenda is the included as Attachment 1. Bill Buscher is Motions and Actions Recorder, and those are included as Attachment 2.

Roll Call

The Attendance list is Attachment 3.

<u>Minutes</u>

The minutes from the previous meeting were accepted unanimously

Motion – Accept the minutes from the previous call on 11.16.2010.

Charlie Leverett / Jason Bowden / Passed Unanimously

At the request of Ron Romano, LTMS 2 discussion was covered first.

<u>1.0 LTMS 2 Discussion</u>

1.1	Martin Chadwick gave a presentation of the VID portion of LTMS 2, included as Attachment 4.
1.2	The VID LTMS 2 Task Force had selected a Z_i limit of 2.5. 1010 reference oils were not included, but have been updated for the attachment. Also, the industry limits had been left as "TBD" for the Surveillance Panel to decide. Dan Worcester asked if existing limits could be calculated and entered for this document. That was done as well.
1.3	There was discussion on whether 2.5 was more or less severe than LTMS1. Martin gave a presentation of the target comparisons, included as Attachment 5. In addition, part of the changes will now be added to the test procedure with an Information letter [i.e. reference oil targets, engine/stand acceptance criteria, new stand definition, and stand alarms. Limits for standard deviations, alarms and E_i and Z_i limits for labs and the industry would be in the LTMS 2 document.

Motion – Accept original VID LTMS 2 task force proposal for adoption of LTMS 2 into the VID test, with industry Z_i limits defined as modified today in the original proposal.

Martin Chadwick / Dan Worcester / Passed 7-4-3

Action Item – SP chair will send letters to all negative voters, giving them 2 weeks to submit written responses to SP on reasons for voting negative.

Action Item – SP chair will distribute responses to SP members to give them ≈ 1 week for review.

Action Item – SP chair will schedule a SP conference call in ≈ 3 weeks to review negative voter responses to determine if negative votes are persuasive or non-persuasive and to see if negative and waive voters change their votes to positive.

Action Item – Revised VID LTMS 2 task force proposal to be distributed to SP members and included in meeting minutes.

2.0 Action Items

    2.1   Form a task force to develop a recommendation to the surveillance panel for adopting LTMS 2nd Edition to the Sequence VID. Task force to report to surveillance panel within six weeks of May 13th meeting. **We are here today.**

    2.2   OHT to report VID engine usage and expected depletion date at all surveillance panel meetings. **Completed and will be on-going. One additional engine has been delivered.**

    2.3   VID Engine Rebuild Task Force – Update
    • Dan Worcester is the Task Force Chair and has begun an assembly manual using the GM cam gear replacement procedure as a baseline.
    • This will be sent to lab engineers and any others interested in serving on this Task Force.
    •First conference call held 01/11/11
    At the first call, Bruce Matthews told the Task Force the LY7 engine is still in production. He is reviewing the Bill of Materials to compare the 2009 and 2011 engines. Most changes are in sensors that could be swapped out to the current version, and to make the engine E85 compliant.

    2.4   Introduction of RO-1010. **This has been completed.**

3.0 Old Business

    3.1   Review of LTMS V2 as presented to SP by Task Force. **This meeting.**
    3.2   Time response measurements – **all labs are now up to date.**
    3.3   Update on Engine Build Task Force. **See Action Item 1.3**

4.0 New Business

    3.1   None at this time

 The meeting adjourned at 10:55 AM.

The next meeting will be for LTMS Version 2 review in 3 weeks.

Sequence VI Surveillance Panel
01/18/2011
09:00-17:00 CST
Southwest Research Institute
San Antonio, Texas

Agenda

1.0) Roll Call

2.0) Approval of minutes

2.1) Approve the minutes from 11/16/2010 Teleconference.

3.0) Action Item Review

3.1 Form a task force to develop a recommendation to the surveillance panel for adopting LTMS 2nd Edition to the Sequence VID. Task force to report to surveillance panel within six weeks of May 13th meeting. We are here today.

3.2 OHT to report VID engine usage and expected depletion date at all surveillance panel meetings. **Completed and will be on-going.**

3.3 VID Engine Rebuild Task Force – Update
   • Dan Worcester is the Task Force Chair and has begun an assembly manual using the GM cam gear replacement procedure as a baseline.
   • This will be sent to lab engineers and any others interested in serving on this Task Force.
   •First conference call held 01/11/11

3.4 Introduction of RO-1010.

4.) Old Business

4.1) Review of LTMS V2 as presented to SP by Task Force. All
4.2) Time response measurements – are all up to date?
4.3) Update on Engine Build Task Force

5.) New Business

5.1) ?

6.) Next Meeting

 7.) Meeting Adjourned

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Sequence VIB/D Surveillance Panel
January 18, 2011
9:00AM – 5:00PM
Southwest Research Institute
<u>San Antonio, TX</u>

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

1. Motion – Accept original VID LTMS 2 task force proposal for adoption of LTMS 2 into the VID test, with industry Z_i limits defined as modified today in the original proposal.

   Martin Chadwick / Dan Worcester / Passed 7-4-3

2. Action Item – SP chair will send letters to all negative voters, giving them 2 weeks to submit written responses to SP on reasons for voting negative.

3. Action Item – SP chair will distribute responses to SP members to give them ≈ 1 week for review.

4. Action Item – SP chair will schedule a SP conference call in ≈ 3 weeks to review negative voter responses to determine if negative votes are persuasive or non-persuasive and to see if negative and waive voters change their votes to positive.

5. Action Item – Revised VID LTMS 2 task force proposal to be distributed to SP members and included in meeting minutes.

ASTM SEQUENCE VI SURVEILLANCE PANEL

Name	Address	Phone/Fax/Email	Attendance
Bowden, Jason Voting Member	OH Technologies, Inc. P.O. Box 5039 Mentor, OH 44061-5039	Phone: 440-354-7007 Fax: 440-354-7080 dhbowden@ohtech.com	*(signature)* JHB
Bruce Matthews Voting Member	GM Powertrain Engine Oil Group Mail Code: 483-730-472 823 Joslyn Rd	Pontiac, MI 48340: 248-830-9197 bruce.matthews@gm.com	yes
Andy Ritchie Voting Member	Infineum 1900 East Linden Ave. Linden, NJ 07036-0735	Phone: 908-474- Fax: 908-474-3637	PHONE
Ron Romano Voting Member	Ford Motor Company 21500 Oakwood Blvd POEE Bldg Rm DR 167 MD 44 Dearborn, MI 48121-2053	Phone: 313-845-4068 rromano@ford.com	PHONE
Leverett, Charlie Voting Member	Intertek Automotive Research 5404 Bandera Road San Antonio, TX 78238	Phone: 210-647-9422 Fax: 210-523-4607 charlie.leverett@intertek.com	YES
Grundza, Rich Voting Member	ASTM TMC 6555 Penn Ave. Pittsburgh, PA 15206-4489	Phone: 412-365-1034 Fax: 412-365-1047 Dml@tmc.astm.cmri.cmu.edu	Yes
Miranda, Timothy Voting Member	BP Castrol Lubricants USA 1500 Valley Road Wayne, NJ 07470	Phone: 973-305-3334 Timothy.Miranda@bp.com	PHONE
Mosher, Mark Voting Member	ExxonMobil 600 Billingsport Road Paulsboro, NJ 08066	Phone: 856-224-2132 Fax: 856-224-3628 mark_r_mosher@exxonmobil.com	Yes
Caudill, Timothy Voting Member	Ashland, Inc. 21st and Front Streets Ashland, KY 41101	Phone: 606-329-5708 Fax: 606-329-3009 2644 Tlcaudill@ashland.com	Yes
Dan Worcester Voting Member	Southwest Research Institute (SwRI) 6220 Culebra Road San Antonio, TX 78228	Phone: Fax: dan.worcester@swri.org	YES
Szappanos, George Voting Member	Lubrizol 29400 Lakeland Blvd. Wickliffe, OH 44092	Phone: 440-347- Fax: 440-347-4096 George.Szappanos@lubrizol.com	*(signature)*
Glaenzer, David Voting Member	Afton Research Center 500 Spring Street Richmond, VA 23218	Phone: 804-788-5214 Fax: 804-788-6358 dave.glaenzer@aftonchemical.com	*(signature)*
Sutherland, Mark Voting Member	Chevron Oronite Company LLC 4502 Centerview Ste. 210 San Antonio, TX 78228	Phone: 731-5605 Fax: 731-5621 msut@chevrontexaco.com	*(signature)*
Robert Stockwell Voting Member	ConocoPhillips Lubricants R&D Passenger Car Engine Oil	office 580-767-6894 Robert.T.Stockwell@conocophillips.com	
BOB OLREE MIKE McMILLAN MATT SNIDER			PHONE
TRACEY KING			PHONE

ASTM SEQUENCE VI SURVEILLANCE PANEL

NAME	ADDRESS	CONTACT	HERE
Bob Campbell	AFTON	Bob.Campbell@ AFTONChemical.com	✓
Jeff Clark	TMC	jxc@astmtmc.cmu.edu	✓
Bill Buscher	SwRI		✓
Art Andrews	Exxon Mobil	arthur.t.andrews @exxonmobil.com	✓
Jim Rutherford	Chevron Oronite	JARU@CHEVRON.COM	✓
Phil Scinto	Lubrizol	Phil.Scinto@ Lubrizol.com	✓
Doyle Boese	Infineum	doyle.boese@ infineum.com	✓
Jim Carter	HALTERMANN	JECARTER @JHALTERMANN.com	✓
DWIGHT BOWDEN	OH TECHNOLOGIES	DHBOWDEN@ OHTECH.COM	✓
MARTIN CHADWICK	INTERTEK		✓

Todd Dvorak	Afton	todd.dvorak@ aftonchemical.com	✓
Ed Altman	Afton	Ed.Altman@ Aftonchemical.com	✓

<u>Sequence VID LTMS Requirements (A Stand-Engine Based Severity Adjustment System)</u>

TEST METHOD PORTION

The following are the specific Sequence VID calibration test requirements.

A. <u>Reference Oils and Parameters</u>

The prediction error monitoring parameters are Fuel Economy Improvement at 16 hours (FEI1) and Fuel Economy Improvement at 100 hours (FEI2). The reference oils required for test stand-engine calibration are reference oils accepted by the ASTM Sequence VID Surveillance Panel. The targets for the current reference oils for each parameter are presented below.

FUEL ECONOMY IMPROVEMENT AT 16 HOURS
Unit of Measure: Percent
PREDICTION ERROR MONITORING PARAMETER

Reference Oil	Target
540	1.32
541	0.87
542	1.49
1010	1.31

FUEL ECONOMY IMPROVEMENT AT 100 HOURS
Unit of Measure: Percent
PREDICTION ERROR MONITORING PARAMETER

Reference Oil	Target
540	1.04
541	0.71
542	0.80
1010	1.23

B. <u>Acceptance Criteria</u>

1. New stand-engine combination. A new stand-engine combination is defined as a stand-engine combination that has never previously achieved calibrated status.

a. A minimum of three (3) operationally valid reference and/or matrix tests with no level three e_i alarms (uninterrupted by nonreference oil tests) must be run on each new stand-engine combination.

- Note that industry matrix runs may be included, as well as reference runs, at the discretion of the surveillance panel.

b. Following the necessary tests, check the status of the control charts and follow the prescribed actions.

c. The first (3) tests must be conducted on reference oils 542 (GF5X), 541 (GF5D) and 1010 in order.

2. Existing Stand-Engine in a Lab

a. For an existing stand-engine run one test

b. Following an operationally valid reference oil calibration test, check the status of the control charts and follow the prescribed actions.

3. Reference Oil Assignment

- Once a stand/engine has been accepted into the system, 100% of the scheduled calibration tests should be conducted on reference oils 540, 542, and 1010 or subsequent approved reblends. If possible, the same oil should not be used for successive calibration tests in a stand.

4. Chart Status

The following are the steps that must be taken in the case of exceeding chart limits. The steps are listed in order of priority, although charts should be studied simultaneously to determine the cause(s) of a problem. In the case of multiple alarms, contact the TMC for guidance. The laboratory always has the option of removing any stand or engine from the system.

a. Shewhart Chart of Prediction Error (e_i) for **prediction error monitoring parameters only**

- Level 3

  - Immediately conduct one additional reference test in the stand-engine that triggered the alarm. Do not update the control charts until the follow up reference test is completed and the Excessive Influence (ExI) analysis, per Section 4.c (below), has been performed.

- Level 2

  - Reduce the number of tests allowed in the calibration period in the stand that triggered the alarm to eight (8) full length tests or 1400 engine hours during the first three calibration intervals and six (6) full length tests or 1050 engine hours for subsequent calibration intervals.

- Level 1

  - The level 1 limit applies in situations that have been pre-determined by the surveillance panel to have a potential impact on test results. These situations may include the introduction of new critical parts, fuel batches, reference oil reblends, or other test components. When these conditions have been met and a level 1 alarm is triggered, immediately conduct one additional reference test in the stand that triggered the alarm.

  - The level 1 limit also applies to a previously calibrated stand-engine that has not run an acceptable reference in the past two years. The stand-engine can calibrate with one test if the level 1 limits are not exceeded. Otherwise, immediately conduct another reference test in the stand-engine. Level 1 limits are used to judge only the first valid reference in situations where it is determined to apply. All subsequent references in the stand-engine are judged against Level 2 and Level 3 limits unless otherwise indicated by the surveillance panel.

b. Reference entity EWMA of Standardized Test Result (Z_i) for **all parameters**

- Level 2

  - Immediately conduct one additional reference test in the stand-engine that triggered the alarm

- Level 1

  - The level 1 limit applies to all reference tests that are control charted, even when other alarms have been triggered. Level 1 uses Z_i to determine the stand-engine severity adjustment (SA). Calculate the stand-engine SA for each parameter as follows and confirm the calculation with the TMC:

    SA = -Z_i x s_{SA}

    where s_{SA} = industry approved severity adjustment standard deviation

c. Excessive influence (ExI) Analysis for **prediction error monitoring parameters only**

  - The ExI analysis is performed anytime that a lab e_i level 3 alarm is triggered. As prescribed in Section 4.a, Level 3, a follow up reference test is run. The following comparisons then determine whether the value of Y_i is modified to limit its influence on LTMS. Y_{i+1} is the next completed reference in the laboratory after the level 3 alarm

i)   If $|Y_i - Y_{i+1}| \leq e_i$ level 3 limit, then Y_i is equal to the value originally determined.

ii)   If $Y_i > Z_{i-1}$ and $Y_i - Y_{i+1} > e_i$ level 3 limit, then let
$$Y_i = e_i \text{ level 3 limit} + Z_{i-1}.$$

iii)   If $Y_i \leq Z_{i-1}$ and $Y_i - Y_{i+1} < -e_i$ level 3 limit, then let
$$Y_i = -e_i \text{ level 3 limit} + Z_{i-1}.$$

iv)   If none of i), ii), or iii) is true, then Y_i is equal to the value originally determined.

Where: i = test that originally triggered level 3 alarm,
$i-1$ = test prior to alarm trigger, and
$i+1$ = test immediately following alarm trigger.

Once the proper Y_i value has been determined, update the charts. Confirm calculations with the TMC. The laboratory and the TMC maintain a record of the modification.

d. Industry EWMA of Standardized Test Result (Z_i) for **all parameters**

- Level 2

   – TMC informs the surveillance panel that the limit has been exceeded. The surveillance panel then investigates and pursues resolution of the alarm.

- Level 1

   – The TMC investigates whether severity adjustments are adequately addressing the trend, investigates the possible causes, and communicates as appropriate with industry.

TMC COMPENDIUM PORTION

The following are the specific Sequence VID calibration test requirements.

A. Reference Oils and Parameters

The prediction error monitoring parameters are Fuel Economy Improvement at 16 hours (FEI1) and Fuel Economy Improvement at 100 hours (FEI2). The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM Sequence VID Surveillance Panel. The standard deviations for the current reference oils for each parameter are presented below.

FUEL ECONOMY IMPROVEMENT AT 16 HOURS
Unit of Measure: Percent
PREDICTION ERROR MONITORING PARAMETER

Reference Oil	Standard Deviation
540	0.12
541	0.12
542	0.12
1010	0.12

FUEL ECONOMY IMPROVEMENT AT 100 HOURS
Unit of Measure: Percent
PREDICTION ERROR MONITORING PARAMETER

Reference Oil	Standard Deviation
540	0.14
541	0.14
542	0.14
1010	0.14

B. Monitoring and Adjustment Parameters

The constants used for the construction of the control charts for the Sequence VID, and the adjustment and monitoring chart limits, are shown below.

Stand-Engine Shewhart Limits for Prediction Error Monitoring Parameters

FUEL ECONOMY IMPROVEMENT AT 16 HOURS	
Shewhart Chart of Prediction Error $e_i = Y_i - Z_{i-1}$	
Limit Type	Limit
Level 3	2.126
Level 2	1.784
Level 1	1.390

FUEL ECONOMY IMPROVEMENT AT 100 HOURS	
Shewhart Chart of Prediction Error $e_i = Y_i - Z_{i-1}$	
Limit Type	Limit
Level 3	2.126
Level 2	1.784
Level 1	1.390

Stand-Engine EWMA Limits for Each Severity Adjustment Parameter

FUEL ECONOMY IMPROVEMENT AT 16 HOURS		
EWMA of Standardized Test Result $Z_i = \lambda(Y_i) + (1 - \lambda)Z_{i-1}$		
Limit Type	λ	Limit
Level 2 Upper Limit	0.3	2.5
Level 2 Lower Limit	0.3	-2.5
Level 1	0.3	0

FUEL ECONOMY IMPROVEMENT AT 100 HOURS		
EWMA of Standardized Test Result $Z_i = \lambda(Y_i) + (1 - \lambda)Z_{i-1}$		
Limit Type	λ	Limit
Level 2 Upper Limit	0.3	2.5
Level 2 Lower Limit	0.3	-2.5
Level 1	0.3	0

Stand-Engine Severity Adjustment Standard Deviation for Each Severity Adjustment Parameter

PARAMETER	s_{SA}
FUEL ECONOMY IMPROVEMENT AT 16 HOURS	0.12
FUEL ECONOMY IMPROVEMENT AT 100 HOURS	0.14

Industry EWMA Limits for Each Severity Adjustment Parameter

FUEL ECONOMY IMPROVEMENT AT 16 HOURS		
EWMA of Standardized Test Result $Z_i = \lambda(Y_i) + (1 - \lambda)Z_{i-1}$		
Limit Type	λ	Limit
Level 2 Upper Limit	0.2	0.858
Level 2 Lower Limit	0.2	-0.858
Level 1 Upper Limit	0.2	0.653
Level 1 Lower Limit	0.2	-0.653

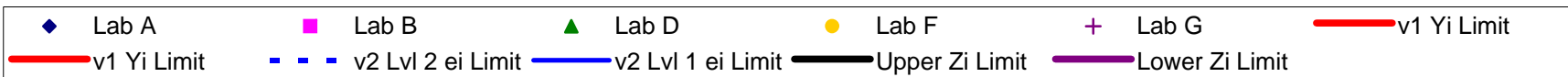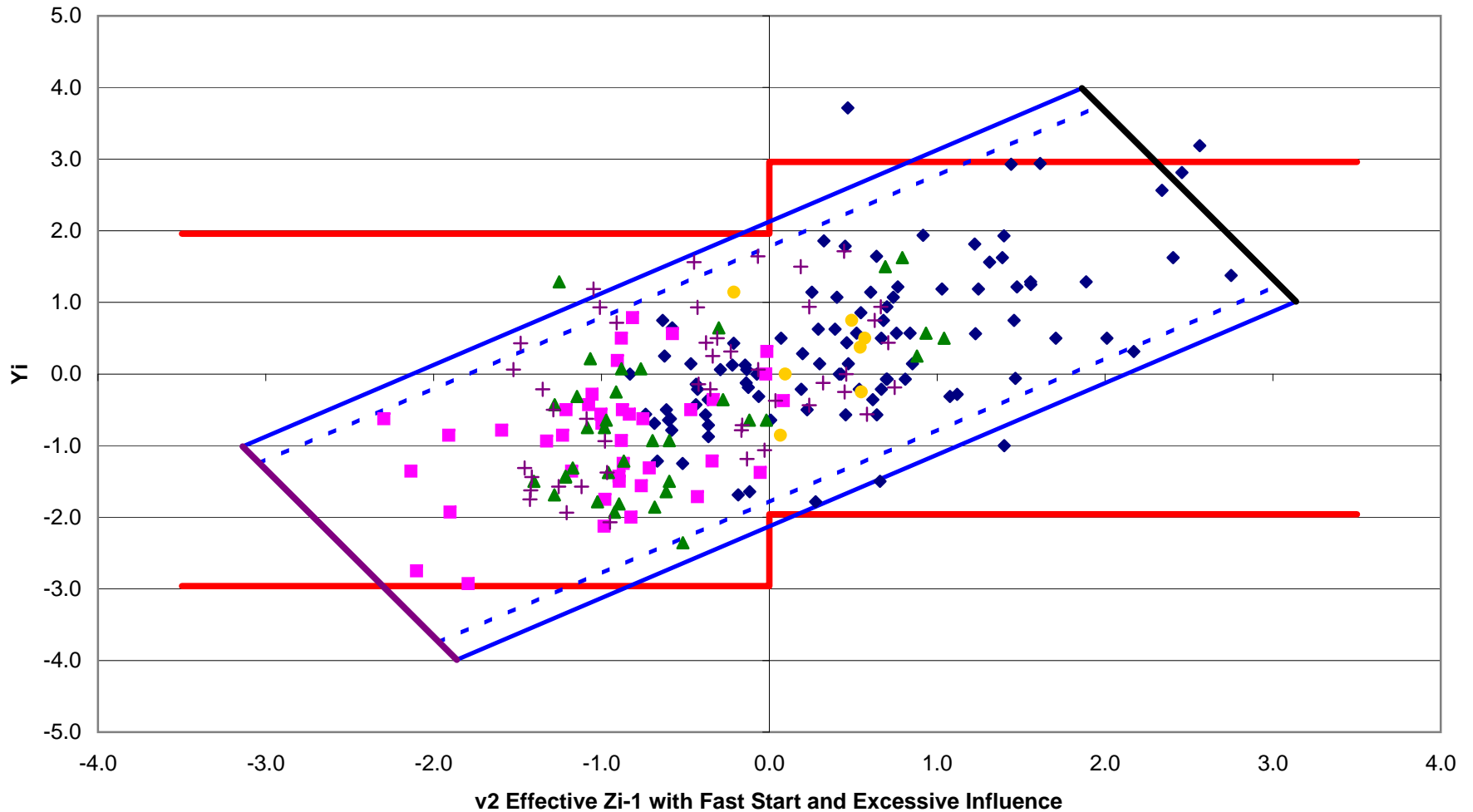| FUEL ECONOMY IMPROVEMENT AT 100 HOURS		
EWMA of Standardized Test Result $Z_i = \lambda(Y_i) + (1 - \lambda)Z_{i-1}$		
Limit Type	λ	Limit
Level 2 Upper Limit	0.2	0.858
Level 2 Lower Limit	0.2	-0.858
Level 1 Upper Limit	0.2	0.653
Level 1 Lower Limit	0.2	-0.653

Sequence VID FEI1 Effective Yi Limits for LTMSv2

for ei limits of 1.784 and 2.126 and Zi limits of -2.50 and +2.50

Sequence VID FEI2 Effective Yi Limits for LTMSv2

for ei limits of 1.784 and 2.126 and Zi limits of -2.50 and +2.50

Sequence VID FEI1 Effective Yi Limits for LTMSv2

for ei limits of 1.390 and 1.784 and Zi limits of -1.75 and +1.75

Yi

v2 Effective Zi-1 with Fast Start and Excessive Influence

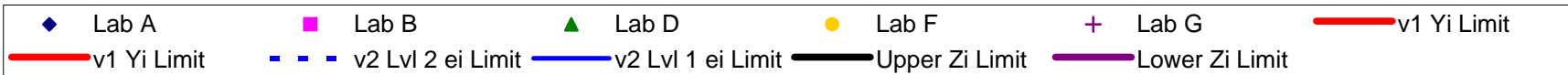| ◆ Lab A | ■ Lab B | ▲ Lab D | ● Lab F | + Lab G | ▬ v1 Yi Limit |
| ▬ v1 Yi Limit | ▬ ▬ v2 Lvl 2 ei Limit | ▬ v2 Lvl 1 ei Limit | ▬ Upper Zi Limit | ▬ Lower Zi Limit | |
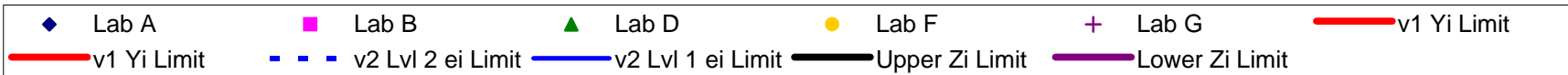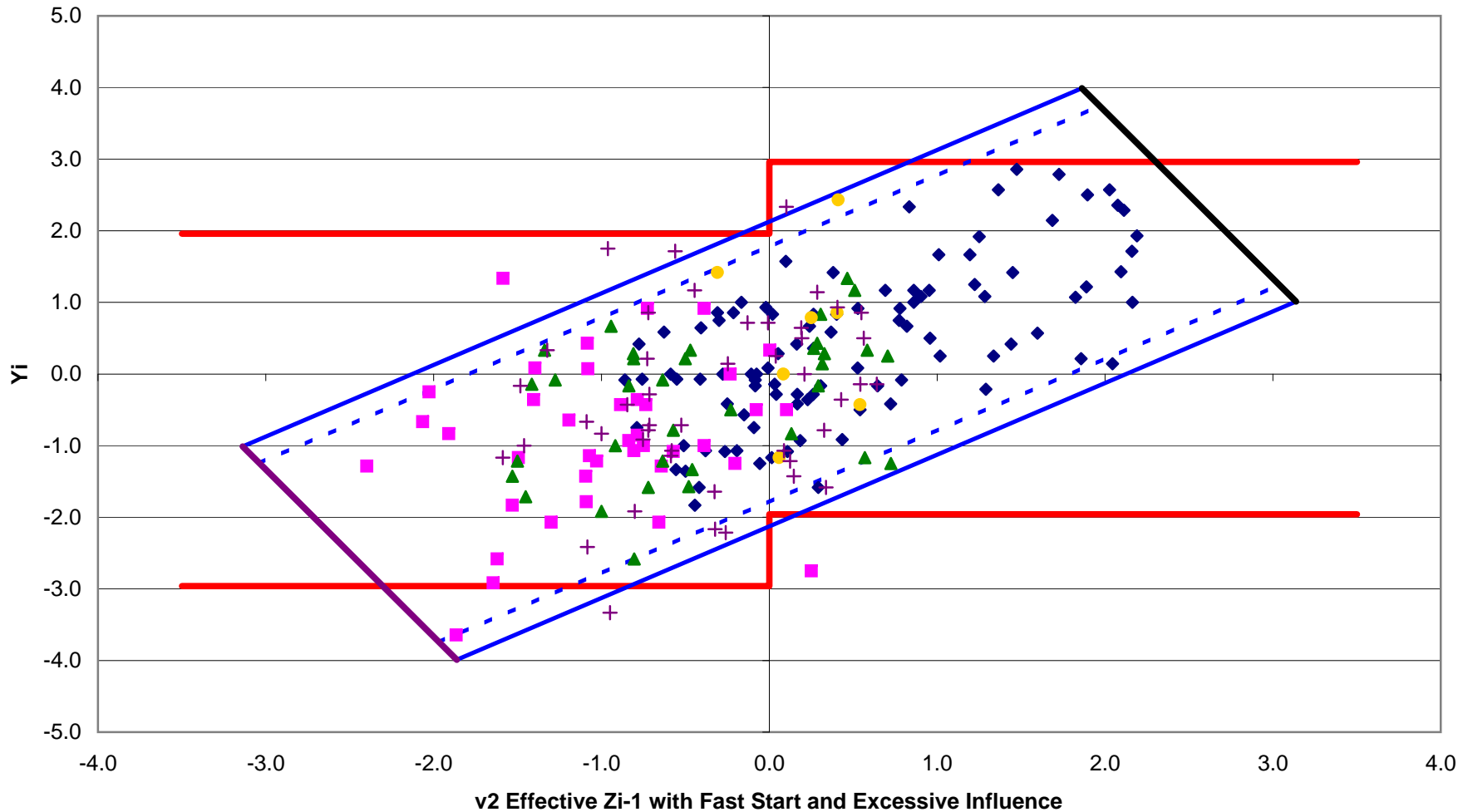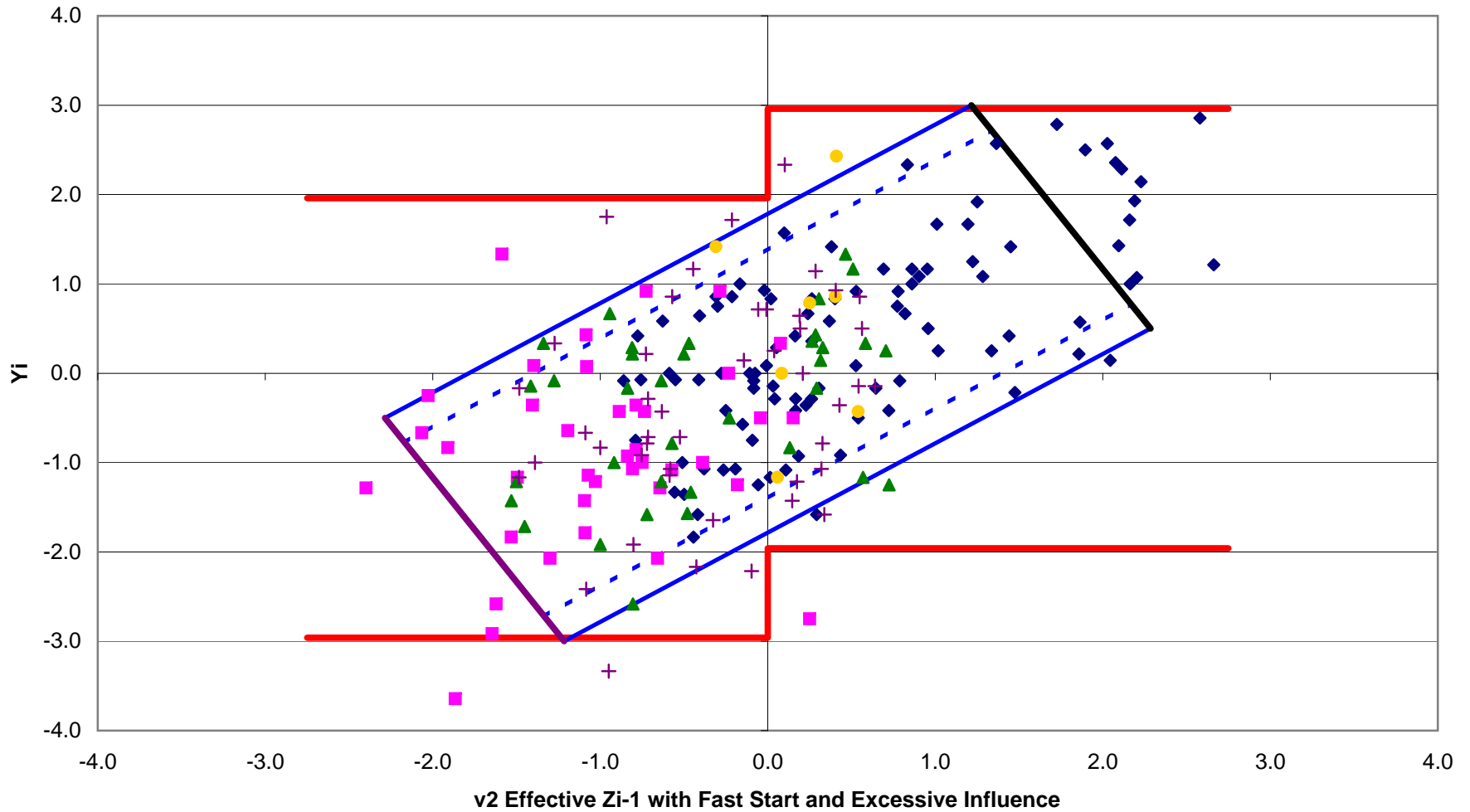
Sequence VID FEI2 Effective Yi Limits for LTMSv2

for ei limits of 1.390 and 1.784 and Zi limits of -1.75 and +1.75
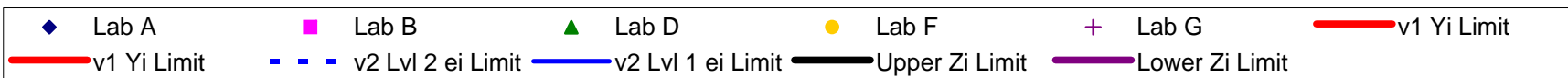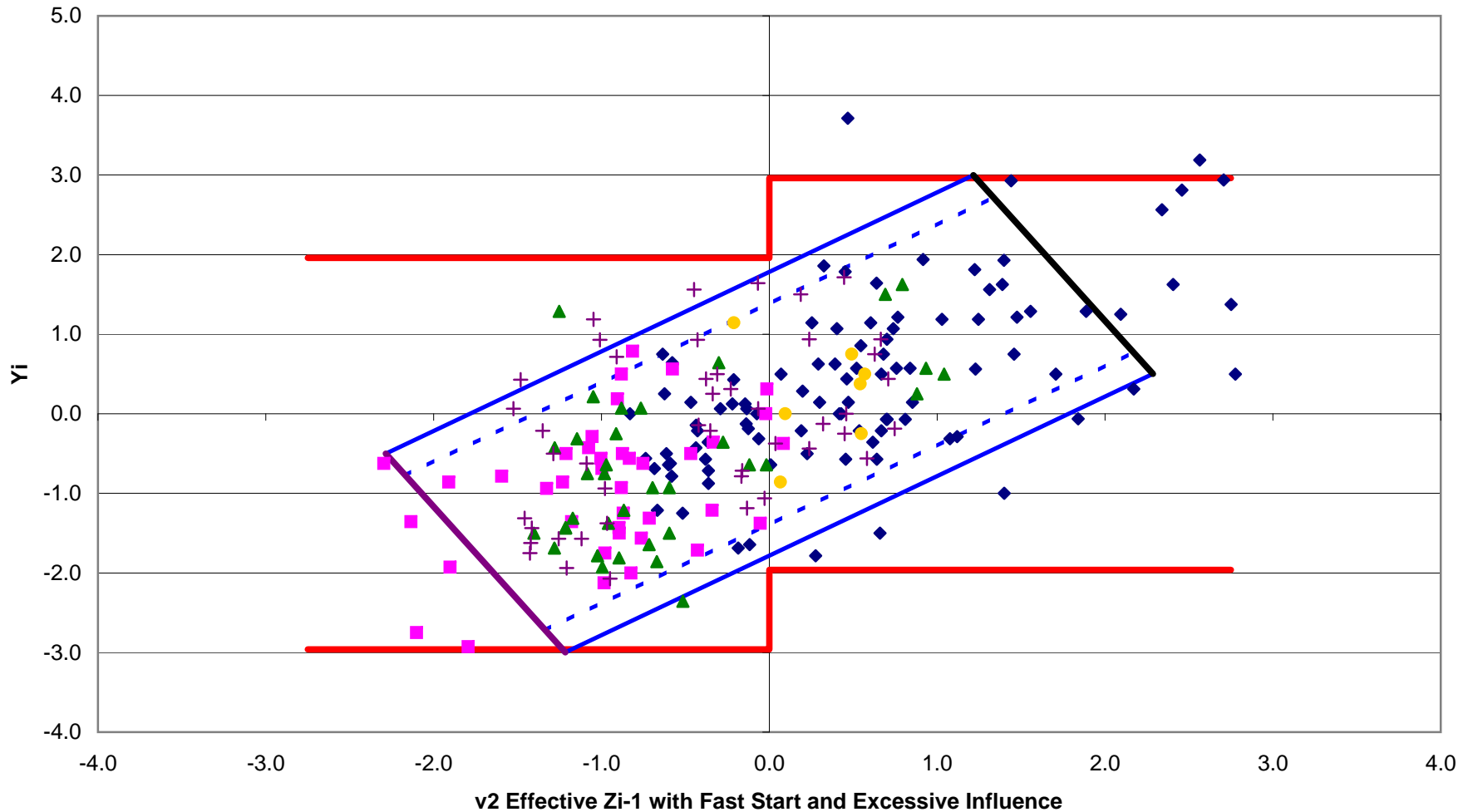
Potential SA Error = Current test Z_i minus next test Y_i

	Standardized Units						FEI using pooled s					
	A	B	D	F	G	Total	A	B	D	F	G	Total
Current LTMS												
References that allow candidate testing	27	9	11	1	17	65						
Average of v1 FEI1 Pot SA Error	0.39	-0.36	0.06	-2.02	0.04	0.10	0.05	-0.04	0.01	-0.24	0.00	0.01
Average of v1 FEI1 abs(Pot SA Error)	0.76	1.00	0.92	2.02	1.06	0.92	0.09	0.12	0.11	0.24	0.13	0.11
Max of v1 FEI1 abs(Pot SA Error)	1.88	2.92	1.74	2.02	2.23	2.92	0.23	0.35	0.21	0.24	0.27	0.35
Average of v1 FEI2 Pot SA Error	0.38	-0.08	-0.03	0.80	-0.43	0.04	0.05	-0.01	0.00	0.11	-0.06	0.01
Average of v1 FEI2 abs(Pot SA Error)	0.69	0.83	0.76	0.80	1.07	0.82	0.10	0.12	0.11	0.11	0.15	0.11
Max of v1 FEI2 abs(Pot SA Error)	2.16	1.32	2.54	0.80	2.24	2.54	0.30	0.18	0.36	0.11	0.31	0.36
v2 with Default ei +2.5/-2.5 Zi												
References that allow candidate testing	35	17	13	1	17	83						
Average of v2 FEI1 Pot SA Error	0.34	-0.26	-0.05	-2.02	-0.26	0.00	0.04	-0.03	-0.01	-0.24	-0.03	0.00
Average of v2 FEI1 abs(Pot SA Error)	0.76	0.87	0.88	2.02	1.07	0.88	0.09	0.10	0.11	0.24	0.13	0.11
Max of v2 FEI1 abs(Pot SA Error)	1.90	2.92	1.74	2.02	2.71	2.92	0.23	0.35	0.21	0.24	0.33	0.35
Average of v2 FEI2 Pot SA Error	0.41	-0.18	0.01	0.80	-0.46	0.05	0.06	-0.03	0.00	0.11	-0.06	0.01
Average of v2 FEI2 abs(Pot SA Error)	0.73	0.72	0.87	0.80	1.10	0.83	0.10	0.10	0.12	0.11	0.15	0.12
Max of v2 FEI2 abs(Pot SA Error)	2.16	1.38	2.54	0.80	2.24	2.54	0.30	0.19	0.36	0.11	0.31	0.36
v2 with Tightened ei +2.5/-2.5 Zi												
References that allow candidate testing	30	17	11	1	14	73						
Average of v2 FEI1 Pot SA Error	0.38	-0.26	-0.08	-2.02	-0.05	0.05	0.05	-0.03	-0.01	-0.24	-0.01	0.01
Average of v2 FEI1 abs(Pot SA Error)	0.75	0.87	0.88	2.02	1.04	0.87	0.09	0.10	0.11	0.24	0.12	0.10
Max of v2 FEI1 abs(Pot SA Error)	1.90	2.92	1.74	2.02	2.71	2.92	0.23	0.35	0.21	0.24	0.33	0.35
Average of v2 FEI2 Pot SA Error	0.38	-0.18	0.15	0.80	-0.29	0.09	0.05	-0.03	0.02	0.11	-0.04	0.01
Average of v2 FEI2 abs(Pot SA Error)	0.67	0.72	0.88	0.80	1.07	0.79	0.09	0.10	0.12	0.11	0.15	0.11
Max of v2 FEI2 abs(Pot SA Error)	2.16	1.38	2.54	0.80	2.24	2.54	0.30	0.19	0.36	0.11	0.31	0.36

Past Performance is No Guarantee of Future Results

References Required to Calibrate a New Engine

Lab	Eng	v1 New Eng Ref	v2 New Eng Ref (def ei +/- 2.5 Zi)	v2 New Eng Ref (def ei +/- 2.0 Zi)	v2 New Eng Ref (def ei +/- 1.5 Zi)	v2 New Eng Ref (tight ei +/- 2.0 Zi)	v2 New Eng Ref (tight ei +/- 1.75 Zi)	Total ref	
A	6B	8	3	NA	NA	NA	NA	8	7 matrix runs
A	10B	9	3	6	8	9	NA	10	7 matrix runs
A	1C	3	3	3	3	3	3	5	
A	4C	3	3	3	3	3	3	6	
A	9C	3	4	4	4	4	4	5	
A	12C	3	3	3	3	3	3	5	
A	16C	3	3	3	3	3	3	5	
A	18C	3	3	3	3	3	3	4	
A	3D	3	3	3	3	3	3	5	
A	4D	3	3	3	3	3	3	4	
A	5D	3	3	3	3	3	3	5	
A	6D	3	3	3	3	3	3	5	
A	7D	3	3	3	3	3	3	3	
A	15D	3	3	3	3	3	3	3	
A	16D	3	3	3	3	3	3	5	
A	17D	3	3	3	3	3	3	4	
A	18D	3	3	3	3	3	3	3	
A	19D	5	4	4	6	4	5	6	
A	20D	3	3	3	3	3	3	3	
A	29D	3	3	3	3	3	3	3	
B	3A	3	3	3	3	3	3	5	3 matrix runs
B	3B	4	3	3	3	3	3	6	
B	3C	3	3	3	3	3	3	4	
B	5C	6	3	5	6	5	6	7	
B	7C	5	4	4	4	4	4	6	
B	9D	4	3	3	NA	3	3	7	
B	10D	3	3	3	3	3	3	4	
D	10A	3	3	3	3	3	3	4	3 matrix runs
D	13B	3	3	3	3	3	3	6	3 matrix runs
D	13C	3	3	3	3	4	4	4	
D	1D	3	3	3	3	3	3	5	
D	2D	5	3	3	3	3	3	6	
D	21D	3	3	3	3	3	3	6	
D	22D	3	3	3	3	3	3	4	
F	11A	3	3	3	3	3	3	4	
F	12B	3	3	3	3	3	3	3	
G	8A	3	3	3	3	3	3	7	7 matrix runs
G	13A	4	4	4	4	5	5	8	7 matrix runs
G	14A	3	3	3	3	3	3	5	
G	6C	3	3	3	3	3	3	5	
G	11C	3	3	3	3	3	3	4	
G	19C	3	3	3	3	3	3	6	
G	12D	4	4	4	4	5	5	5	
G	13D	4	3	3	3	3	3	5	
	Engines	44	44	43	42	43	42	44	
	References	157	137	139	141	145	138	223	

44 total engines
11 eng needed more than 3 ref in LTMSv1
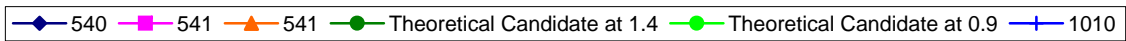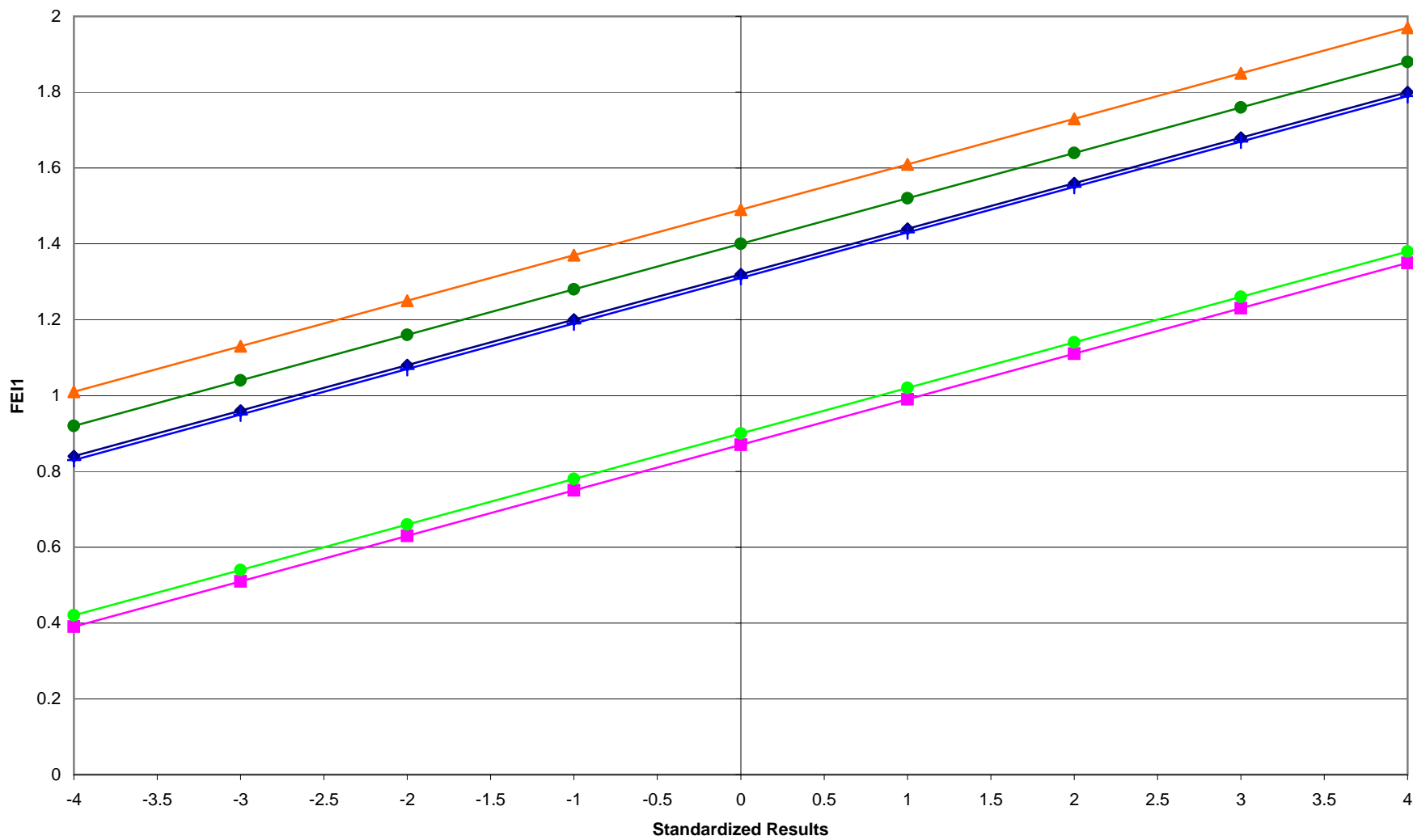**5 need more than 3 in LTMSv2 (default, +/-2.5)**
8 need more than 3 in LTMSv2 (default, +/-2.0), 1 never calibrates
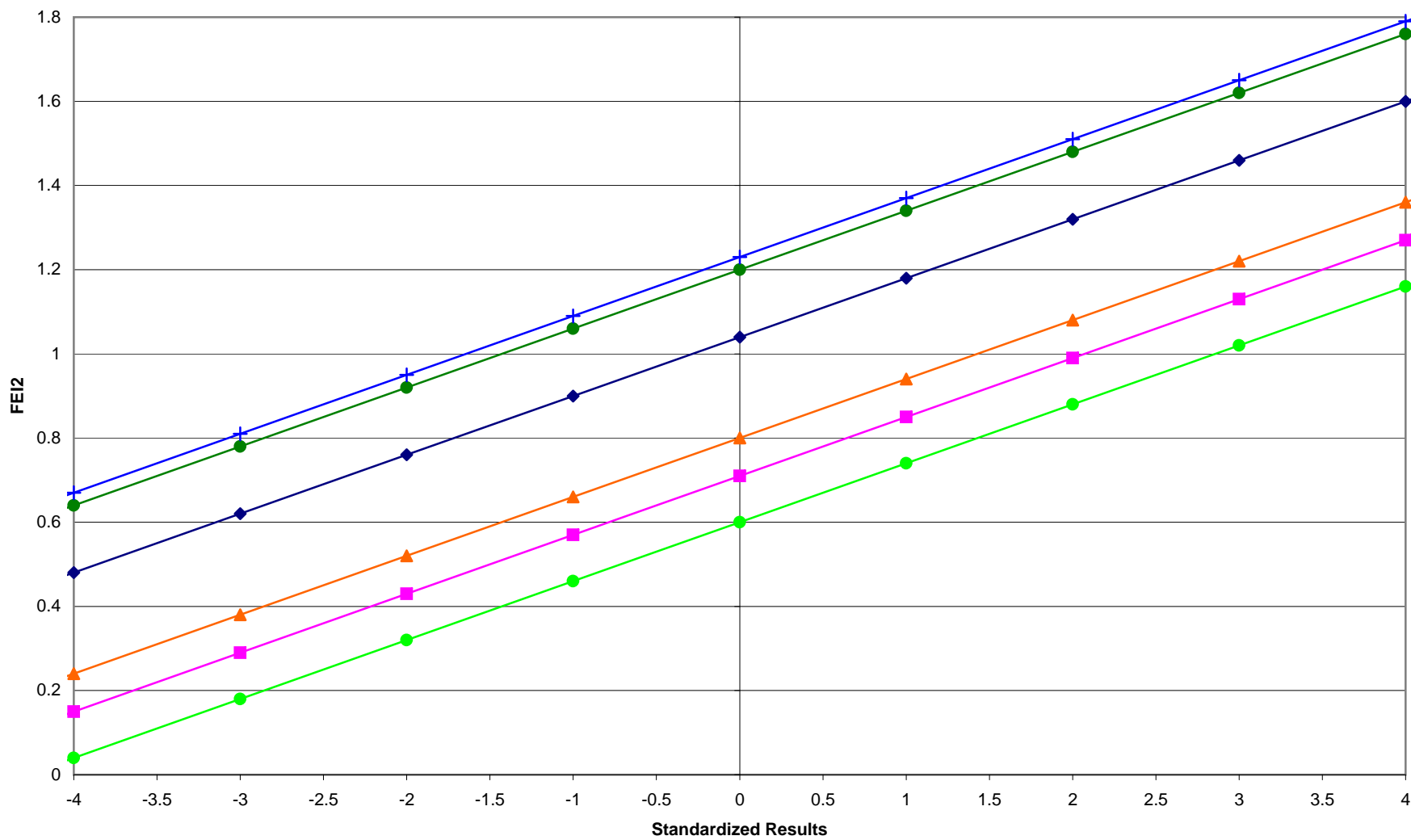**9 need more than 3 in LTMSv2 (default, +/-1.5), 2 never calibrate**
9 need more than 3 in LTMSv2 (tight, +/-2.0)
9 need more than 3 in LTMSv2 (tight, +/-1.75), 2 never calibrate

Sequence VID FEI1 Standardized vs. Measured Results

Sequence VID FEI2 Standardized vs. Measured Results

Legend: 540 · 541 · 541 · Theoretical Candidate at 1.2 · Theoretical Candidate at 0.6 · 1010