Sequence III Surveillance Panel Teleconference
Meeting Minutes

February 03, 2016

1.0) Attendance

The attendance is shown in **Attachment 1**.

2.0) Approval of minutes

2.1) Minutes from 01/20/2016 Conference Call

The minutes were approved without objection (Glaenzer/Bowden).

3.0) Old Business

3.1) Analysis of IIIF & IIIG run 7-10 data for differences. Stats Group update.

The stats group is still working the issue and will report back at a future meeting.

3.2) Update on IIIH work underway by George Szappanos group

George reported on current activities:

- Engine build workshop is scheduled for February 10-11
- Each lab is sending an engine block to Chrysler for measurement
- Blowby differences are being investigate
- Engine swapping between labs; Afton and SRI swap; results might be available next week

4.0) New Business

4.1) Update on LTMS plans for Sequence IIIH. Stats Group

The stats group provided a draft LTMS, shown in **Attachment 2**.

The stats group questioned how to handle IIIH Matrix MRV data that was made at differing temperatures (4 tests were run at a different temperature). It is too late to rerun the MRV for those four tests. It was noted that those four tests were run correctly by procedure which calls for the different temperature. After discussion, it was agreed to leave the 4 tests in the data analysis (shown in **Attachment 3**) and the stats group was also asked to examine the possibility of using severity adjustments for MRV results. Rich Grundza, TMC, was actioned to see if the colder temperature MRV results are available for the 4 tests in question. The IIIH task force will also review an additional test to see if it is valid for inclusion in the analysis. This discussion will continue in future meetings.

4.2) Seq. IIIF Spark Plug

Table A5.1 of the IIIF test method currently lists an incorrect part number for the spark plug. An Information Letter will be issued to correct it.

5.0) Work Remaining

5.1) Calculate test standard deviation along with oil targets & standard deviations. **Done**

5.2) Set up LTMS. **Underway Suggest Face-to-Face Meeting week of 03/14**

5.3) Determine whether matrix stands can be considered calibrated based on their matrix tests. **TBD**

5.4) Review and finalize the Qi Limits **TBD**

5.5) Determine calibration and referencing protocols. **Surveillance Panel to discuss at face-to-face meeting.**

5.6) Finalize the test procedure including any additional items including anything learned from the review of the matrix. Involve ASTM facilitator. **Haumann; underway. Build manual to also be updated**

5.5) Surveillance Panel recommendation regarding test readiness for the category. **June, 2015**

5.8) Appendix K Update. **Martinez**

5.9) Publish research report **TBD**

6.0) Next Meeting

6.1) Wednesday, February 17, 2016; 11:00 EST

6.2) Possible face-to-face meeting in March, date to be determined.

7.0) Meeting Adjourned - 12:00 pm

ATTACHMENT 1

ASTM Sequence III Surveillance Panel (22 Voting members) date: 02/03/2016

Conf. CALL

Name/Address	Phone/Fax/Email		Signature
Ed Altman	804-788-5279	Voting Member	Present ✓
Jeff Betz	jeff.betz@fcagroup.com	Voting Member	Present
Jason Bowden	440-354-7007	Voting Member	Present ✓
Timothy L. Caudill	606-329-1960 x5708	Voting Member	Present ✓
Richard Grundza	412-365-1031	Voting Member	Present ✓
Jeff Hsu, PE	j.hsu@shell.com	Voting Member	Present
Tracey King	947-517-4107	Voting Member	Present ✓
Teri Kowalski	734-995-4032	Voting Member	Present ✓
Patrick Lang	210-522-2820	Voting Member	Present ✓
Addison Schweitzer	210-706-1586	Voting Member	Present ✓
Bruce Matthews	248-830-9197	Voting Member	Present ✓
David Tsui	973-305-2337	Voting Member	Present
Cliff Salvesen		Voting Member	Present
Andrew Ritchie	908-474-2097	Voting Member	Present ✓
Ron Romano	313-845-4068	Voting Member	Present ✓
Greg Shank	301-790-5817	Voting Member	Present ✓
Kaustav Sinha, Ph.D.	713-432-6642 Robt Stockwell	Voting Member	Present ✓
Thomas Smith	859-357-2766	Voting Member	Present ✓
Scott Stap	scott.stap@tgidirect.com	Voting Member	Present
Mark Sutherland	210-867-8357	Voting Member	Present ✓
George Szappanos	440-347-2352	Voting Member	Present ✓
Haiying Tang	248-512-0593	Voting Member	Present ✓

ASTM Sequence III Surveillance Panel (22 Voting members) date:

Name/Address	Phone/Fax/Email		Signature
Ricardo Affinito	affinito@chevron.com	Non-Voting Member	Present
Art Andrews	856-224-3013	Non-Voting Member	Present
Dan Lanctot	TEI	Non-Voting Member	Present
Doyle Boese	908-474-3176	Non-Voting Member	Present
Adam Bowden	440-354-7007	Non-Voting Member	Present
Dwight H. Bowden	440-354-7007	Non-Voting Member	Present
Matt Bowden	440-354-7007	Non-Voting Member	Present ✓
Jerome A. Brys	440 347-2631	Non-Voting Member	Present
Bill Buscher III	210-240-8990	Non-Voting Member	Present
Bob Campbell	804-788-5340	Non-Voting Member	Present
Chris Castanien	Chris.Castanien@gmail.com	Non-Voting Member	Present
Martin Chadwick	210-706-1543	Non-Voting Member	Present
Jeff Clark	412-365-1032	Non-Voting Member	Present ✓
Sid Clark	586-873-1255	Non-Voting Member	Present ✓
Todd Dvorak	804-788- 6367	Non-Voting Member	Present
Frank Farber	412-365-1030	Non-Voting Member	Present
Joe Franklin	210-523-4671	Non-Voting Member	Present
David L. Glaenzer	804-788-5214	Non-Voting Member	Present ✓
Karin E. Haumann	281-544-6986	Non-Voting Member	Present
Walter Lerche	313-667-1918	Non-Voting Member	Present
Josephine G. Martinez	510-242-5563	Non-Voting Member	Present ✓
Mike McMillan	mmcmillan123@comcast.net	Non-Voting Member	Present
Bob Olree	248-689-3078	Non-Voting Member	Present
Kevin O'Malley	kevin.omalley@lubrizol.com	Non-Voting Member	Present
Christian Porter	804-788-5837	Non-Voting Member	Present
Phil Rabbat	914-785-2217	Non-Voting Member	Present
Allison Rajakumar	440-347-4679	Non-Voting Member	Present
Scott Rajala	srajala@ilacorp.com	Non-Voting Member	Present

ASTM Sequence III Surveillance Panel (22 Voting members) date:

Name/Address	Phone/Fax/Email		Signature
Jim Rutherford	510-242-3410	Non-Voting Member	Present________________
Amol Savant	606-320-1960 x5604	Non-Voting Member	Present________________
Philip R. Scinto	440-347-2161	Non-Voting Member	Present________________
Don Smolenski	248-255-7892	Non-Voting Member	Present________________
Jim Linden		Non-Voting Member	Present________________
Tom Wingfield	wingftm@cpchem.com	Non-Voting Member	Present________________
Charlie Leverett		Non-Voting Member	Present________________
Terry Bates	ASTM Facilitator	Non-Voting Member	Present________________
Chris Taylor	VP Fuels	Non-Voting Member	Present________________

KARIN HAUMANN ✓

JO MARTINEZ ✓

R. Stockwell ✓

C. TAYLOR, VP fuels ✓

ATTACHMENT 2

Sequence IIIH LTMS

Statistics Group

January 2016

Statistics Group

- Arthur Andrews, ExxonMobil
- Doyle Boese, Infineum
- Jo Martinez, Chevron Oronite
- Kevin O'Malley, Lubrizol
- Lisa Dingwell, Afton
- Martin Chadwick, Intertek
- Ricardo Affinito, Chevron Oronite
- Richard Grundza, TMC
- Todd Dvorak, Afton
- Travis Kostan, SwRI

Agenda

- Review IIIH Precision Matrix Results
- Finalize dataset utilized to establish LTMS
- LTMS Basics
- Traditional LTMS applied to the IIIH
- LTMS Improvements applied to the IIIH
- Finalize LTMS

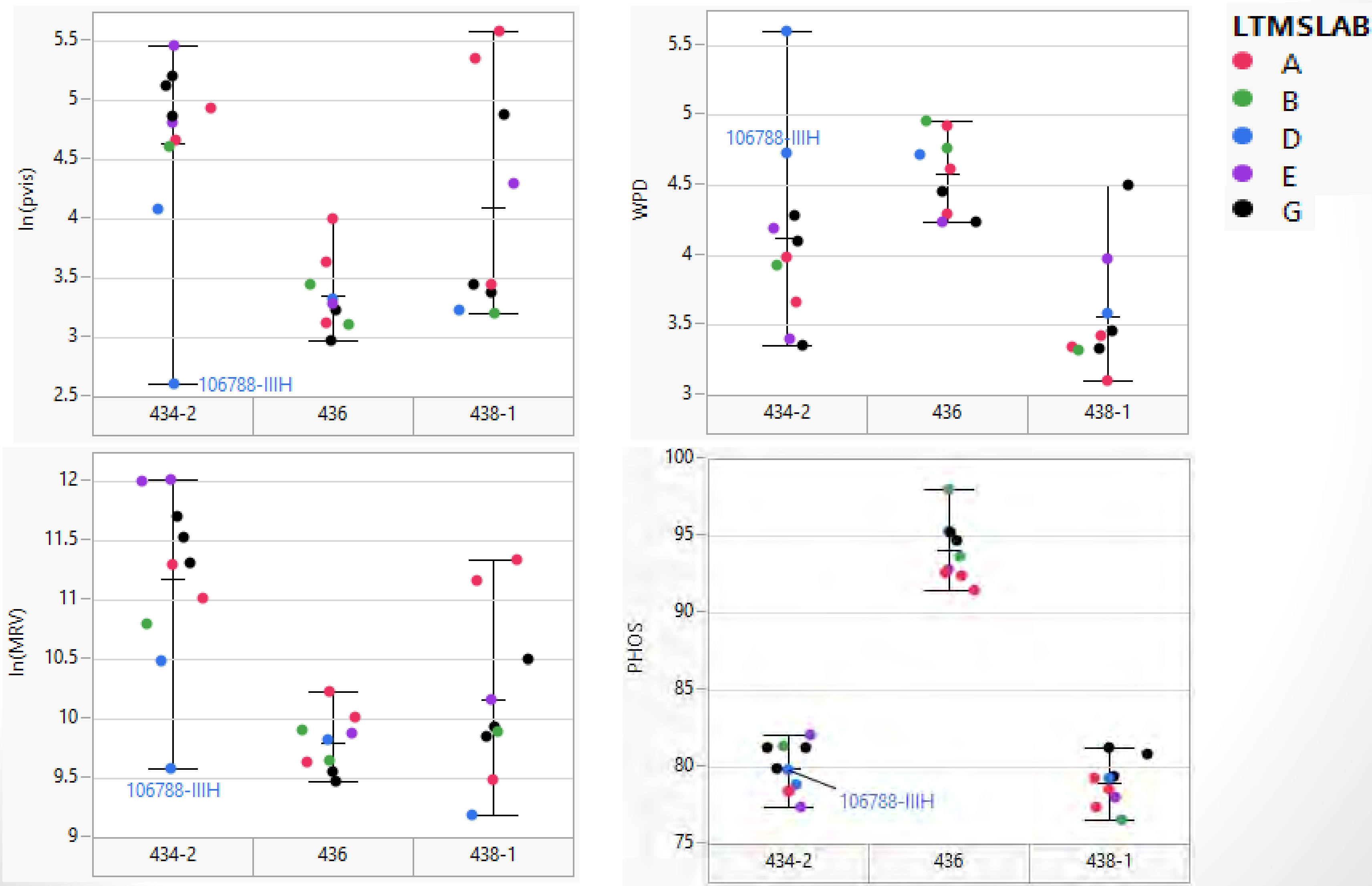
Review IIIH Precision Matrix Results

&

Finalize dataset utilized to establish LTMS

IIIH Precision Matrix Analysis Review

IIIH Task Force passed a motion on 11-30-15 to remove testkey 106788-IIIH from the precision matrix analysis. This testkey was deemed valid during the review of the operational data of precision matrix tests.



IIIH Precision Matrix Analysis Review

n=27	LnPVIS	WPD	LnMRV	Phos
Lab Difference	No significant difference	No significant difference	No significant difference	A<G
Stand(Lab) Difference	A2<A1, G1<G2	No significant difference	A2 < A1	No significant difference
Oil Discrimination	436 < 434-2, 438-1; 438-1 < 434-2	436 > 438-1	436, 438-1 < 434-2	436 > 434-2, 438-1
Precision, s, RMSE	0.4764	0.48	0.4270	1.57

Establishing LTMS based on statistical model estimates in which testkey 106788 is excluded provides a better chance that future data similar to this test get identify in the monitoring system.

However, the surveillance panel should discuss and decided upon the dataset utilized to set up LTMS

IIIH Precision Matrix Analysis Review

ANOVA Factor	P-value			
	LnPVIS	WPD	LnMRV	PHOS
IND	0.00	0.00	0.00	0.00
LTMSLAB	0.07	0.29	0.05	0.05
LTMSAPP[LTMSLAB]	0.01	0.53	0.04	0.74

Stand-based LTMS is appropriate for Sequence IIIH based on the Stand(Lab) factor being significant.

Reference Oil Targets

PERCENT VISCOSITY INCREASE

Unit of Measure: LN(PVIS)

IIIH			IIIG		
Reference Oil	LSMean	Standard Deviation	Reference Oil	Mean	Standard Deviation
434-2	4.7292	0.3943	434	4.7269	0.3859
436	3.3308	0.3138			
438-1	3.9773	0.9558	438	4.5706	0.1768

WEIGHTED PISTON DEPOSITS

Unit of Measure: Merits

IIIH			IIIG		
Reference Oil	LSMean	Standard Deviation	Reference Oil	Mean	Standard Deviation
434-2	4.12	0.67	434	4.80	0.96
436	4.62	0.28			
438-1	3.65	0.43	438	3.20	0.33

Lubricant Test Monitoring System (LTMS)

The basics

LTMS Introduction

- LTMS is a robust and flexible control charting system designed to monitor test precision and bias for both abrupt changes and consistent trends over time using common reference oils across all testing facilities
  - LTMS strives for severity adjustment entities to be near enough to each other on the performance scale that we believe they are measuring the same oil characteristics
  - LTMS wants enough data from a severity adjustment entity to know where it is on the performance scale relative to the rest of the industry

LTMS Introduction

- LTMS intentions:
  - Enhance our ability to estimate true capability of candidate oils
    - Provide a level the playing field
  - Bring all results (reference and non-reference test) to parity
  - Increase the value of reference testing
  - Treat large and small labs equitably
  - Strive for standardization across test types with guidelines and criteria defined for deviations
  - Encourage labs to remain on target and improve precision
  - Aid in objective engineering judgments
  - Promote reliability, integrity, and efficiency of testing

LTMS Introduction

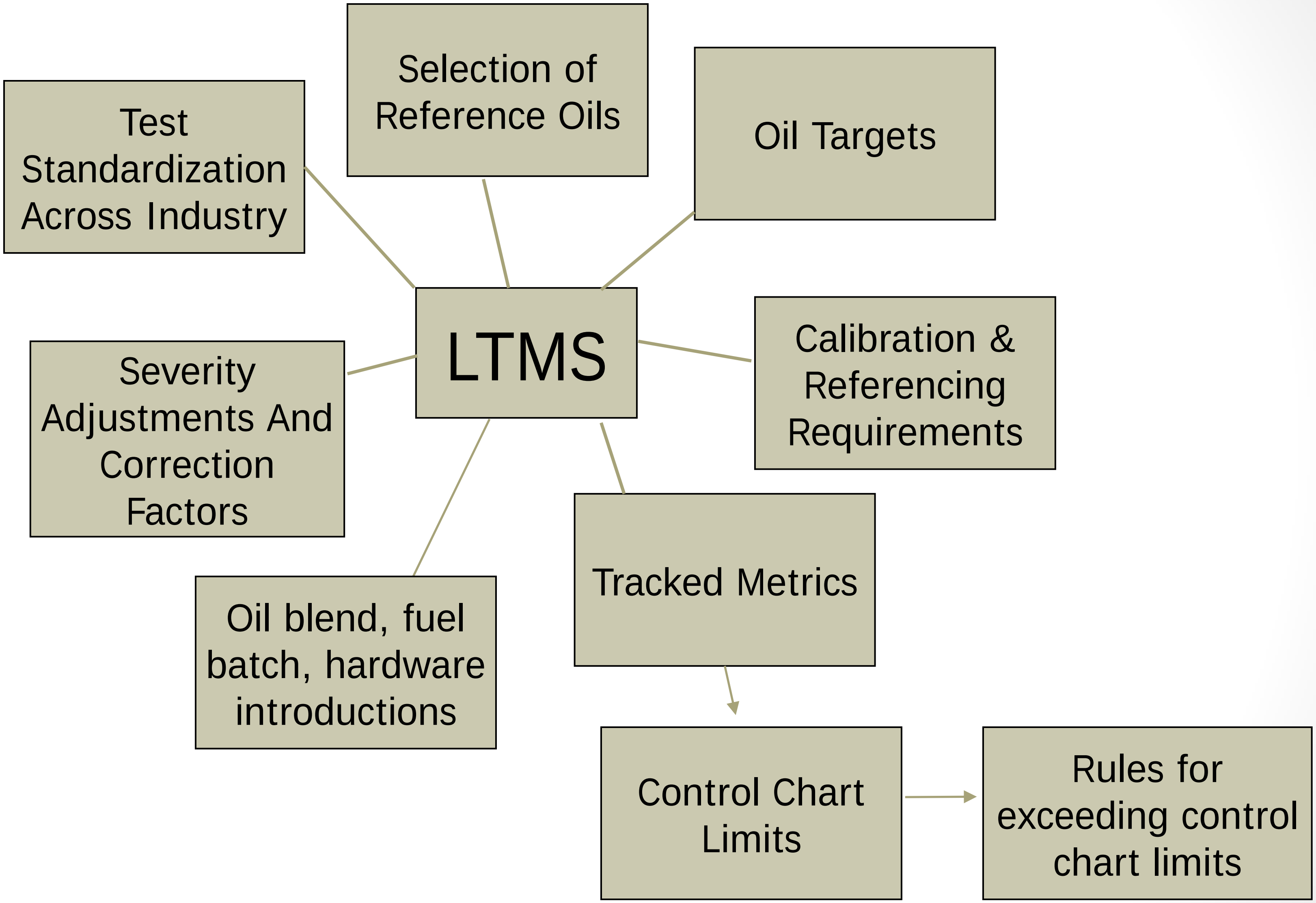
Important Notes:

- LTMS does not solve problems
  - It is a tool to help solve problems
  - It is a tool to facilitate 'fair' testing

- LTMS is at the mercy of bad practices
  - LTMS more effective under sound practices

- LTMS should serve its purpose and should not be altered to accommodate poorly developed and administered tests

Aspects of LTMS Implementation



Traditional LTMS applied to IIIH

Assumption:

- For demonstration purposes, IIIG LTMS constants are used to apply traditional LTMS to the IIIH. These values are not final and are subject to surveillance panel decisions.

IIIG Control Charting Constants Table:

		Severity			Precision	
		EWMA		Shewhart	EWMA	
Chart Level	Limit Type	LAMBDA	K	K	LAMBDA	K
Stand	Action	--	--	2.0 (3.0)[A]	--	--
Lab	Action	0.2	1.65	--	0.2	2.65
Industry	Warning	0.2	2.24	--	0.2	2.00
	Action	0.2	2.88	--	0.2	2.65

[A] 3.0 K-value applies in special cases; see alarm actions below

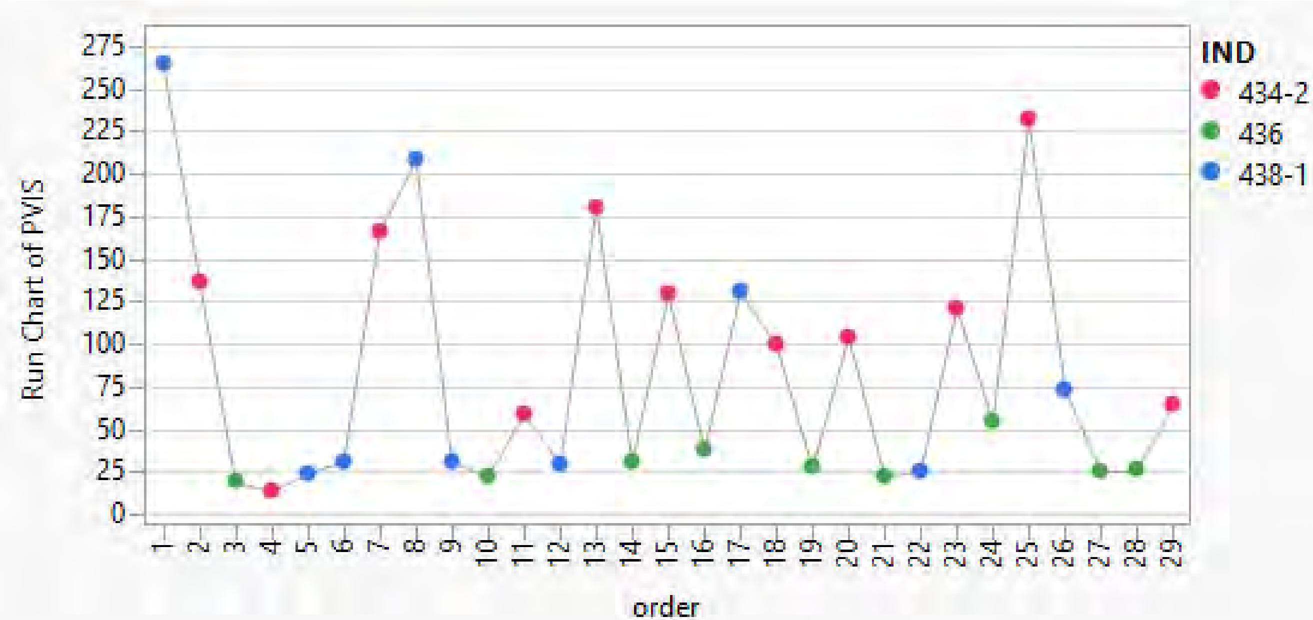
Traditional LTMS applied to IIIH

- The following are metrics used to monitor tests
  - X_i = Test Result
  - T_i = Transformed/Corrected Test Result

    Some test parameters require a transformation (e.g., ln(X))

    Where deemed appropriate, correction factors are applied to X_i
  - Y_i
    - Standardized test results to monitor test severity
  - Z_i
    - Exponentially weighted moving average of Y_i used to monitor test severity
  - R_i
    - Standardized moving difference used to monitor test precision
  - Q_i
    - Exponentially weighted moving average of R_i used to monitor test precision

Traditional LTMS applied to IIIH PVIS Example



The analysis of data suggests use of transformation: ln(PVIS)

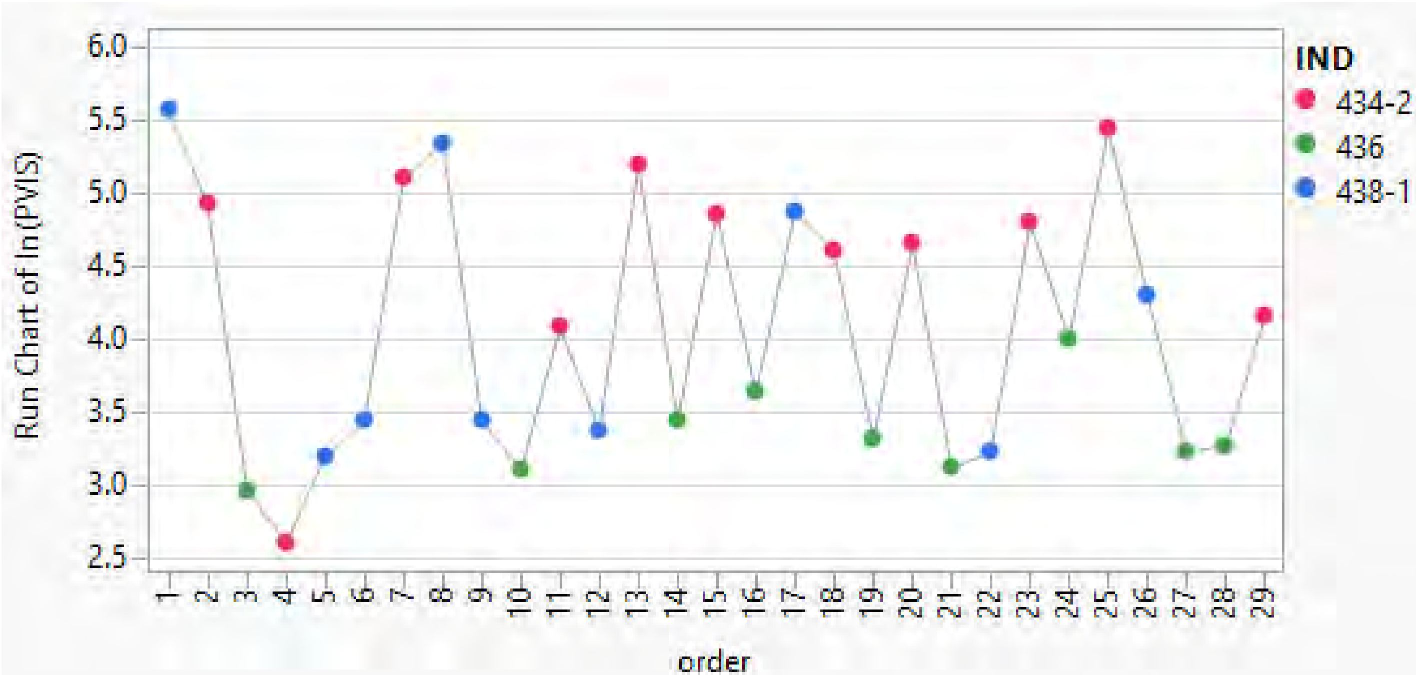
PVISX$_i$

IND	PVIS	TESTKEY
438-1	265.1	106774-IIIH
434-2	137.5	106778-IIIH
436	19.5	106763-IIIH
434-2	13.6	106788-IIIH
438-1	24.6	106797-IIIH
438-1	31.2	106767-IIIH
434-2	166.6	107873-IIIH
438-1	209	107869-IIIH
438-1	31.3	107870-IIIH
436	22.4	106792-IIIH
434-2	59.4	106789A-IIIH
438-1	29.4	106768-IIIH
434-2	180.9	110227-IIIH
436	31.3	106793-IIIH
434-2	129.6	110228-IIIH
436	38	106775-IIIH
438-1	130.9	107872-IIIH
434-2	99.8	106795-IIIH
436	27.8	106786-IIIH
434-2	104.9	106779-IIIH
436	22.7	106776-IIIH
438-1	25.4	106791-IIIH
434-2	121.8	106781-IIIH
436	54.6	106777-IIIH
434-2	232.4	106780-IIIH
438-1	73.6	106785-IIIH
436	25.3	111422-IIIH
436	26.5	106783-IIIH
434-2	64.4	107883-IIIH

Traditional LTMS applied to IIIH PVIS Example

The analysis of data suggests use of transformation: ln(PVIS)

PVIS T_i = ln(PVIS)



Oils have different target values and we want to monitor the test across oils. To do this, we use Y_i which adjusts oil results onto the same scale:

$$Y_i = \frac{(T_i - \text{Reference Oil Mean})}{(\text{Reference Oil Standard Deviation})}$$

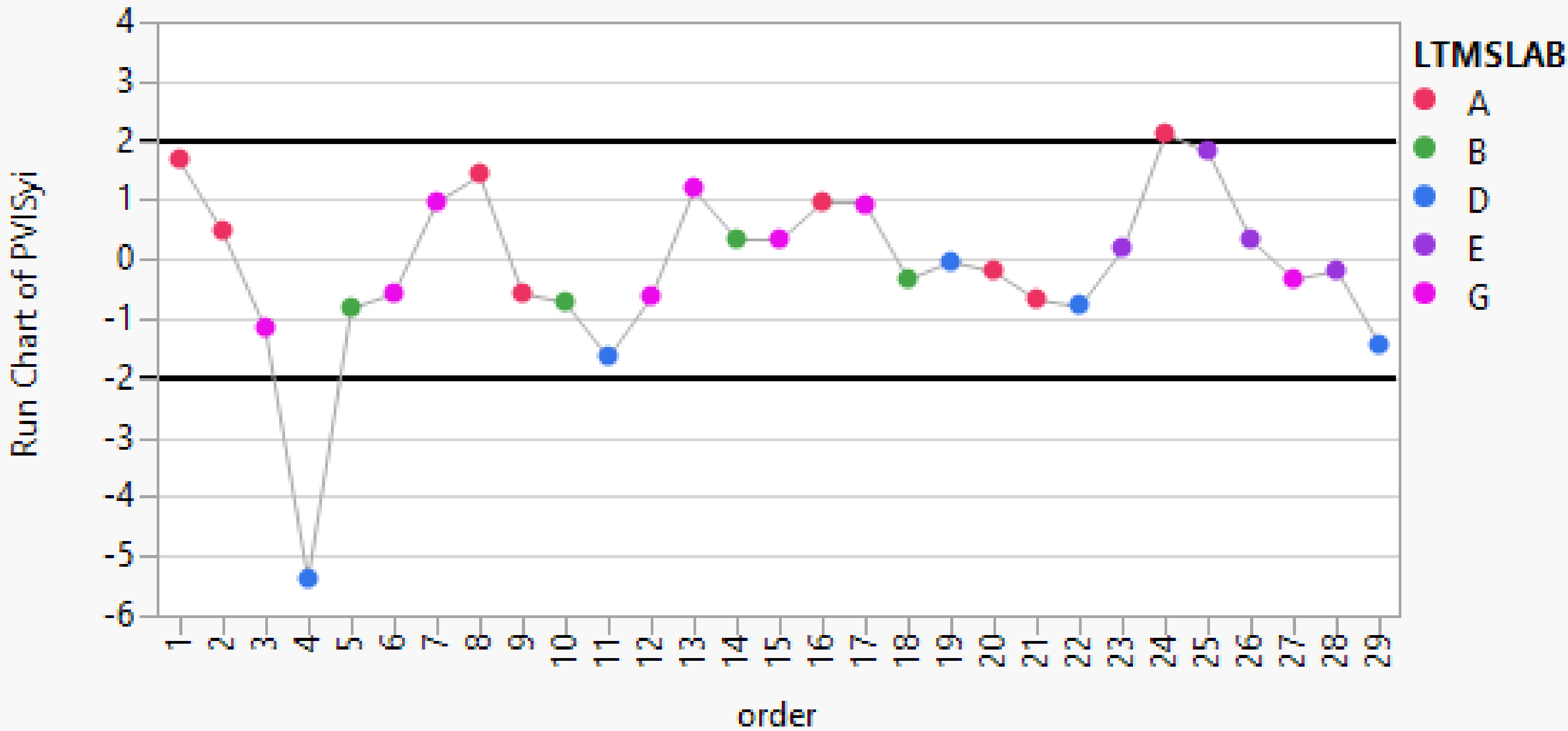
PERCENT VISCOSITY INCREASE

Unit of Measure: LN(PVIS)

Oil Targets for ln(PVIS):

IIIH			IIIG		
Reference Oil	LSMean	Standard Deviation	Reference Oil	Mean	Standard Deviation
434-2	4.7292	0.3943	434	4.7269	0.3859
436	3.3308	0.3138			
438-1	3.9773	0.9558	438	4.5706	0.1768

Traditional LTMS applied to IIIH
PVIS Example
PVIS Yi



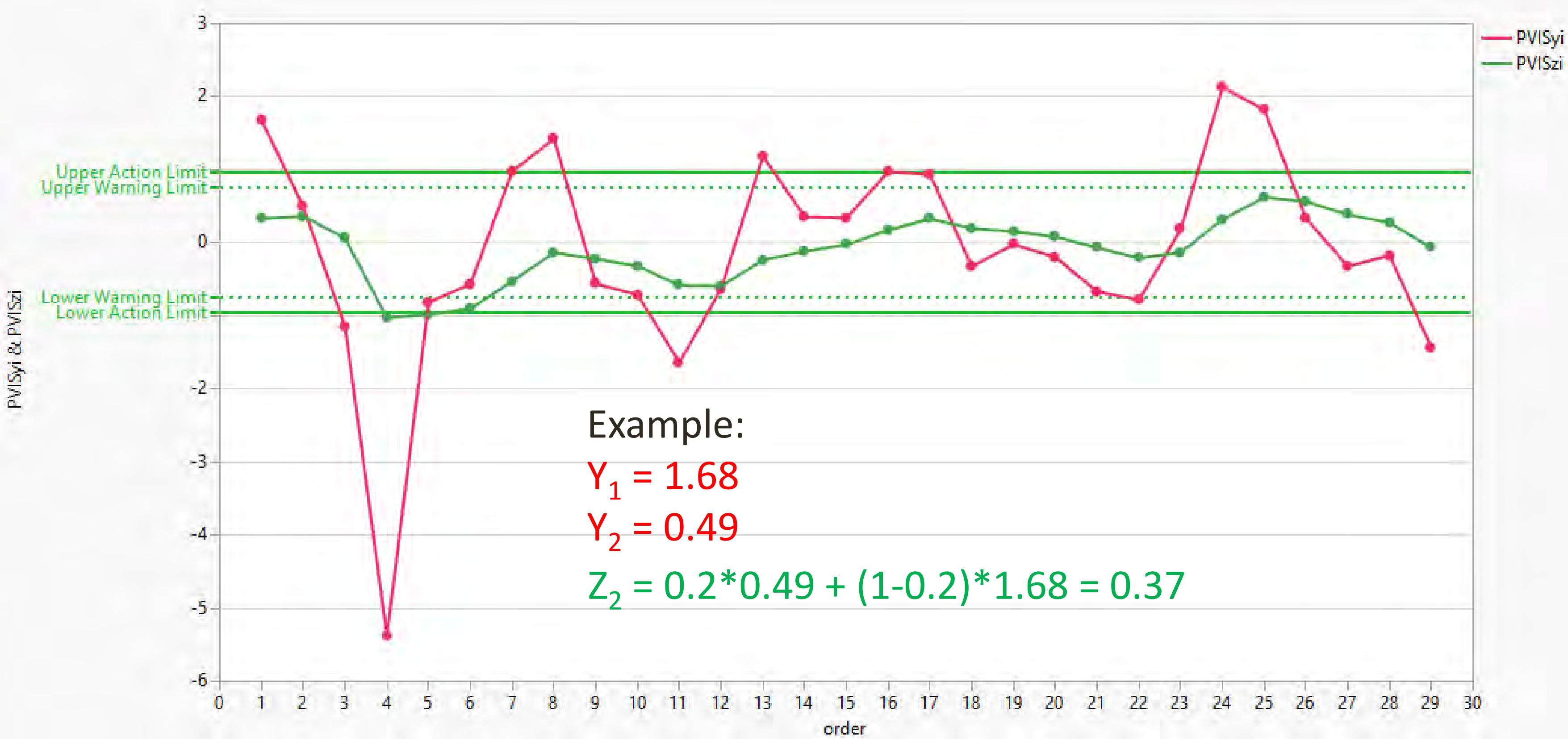
The limits ($\pm$ K)shown are for demonstration purposes only. These limits along with the rules for what happens when they are exceeded are surveillance panel decisions.

Traditional LTMS applied to IIIH
PVIS Example
PVIS Zi

We also use Z_i to monitor test severity. It is an exponentially weighted moving average of the Y_i's.

$Z_i = (\lambda) Y_i + (1 - \lambda) Z_{i-1}$ where λ is a tuning parameter between 0 and 1

Z_i is an estimate for where we believe the test to be operating at any given time



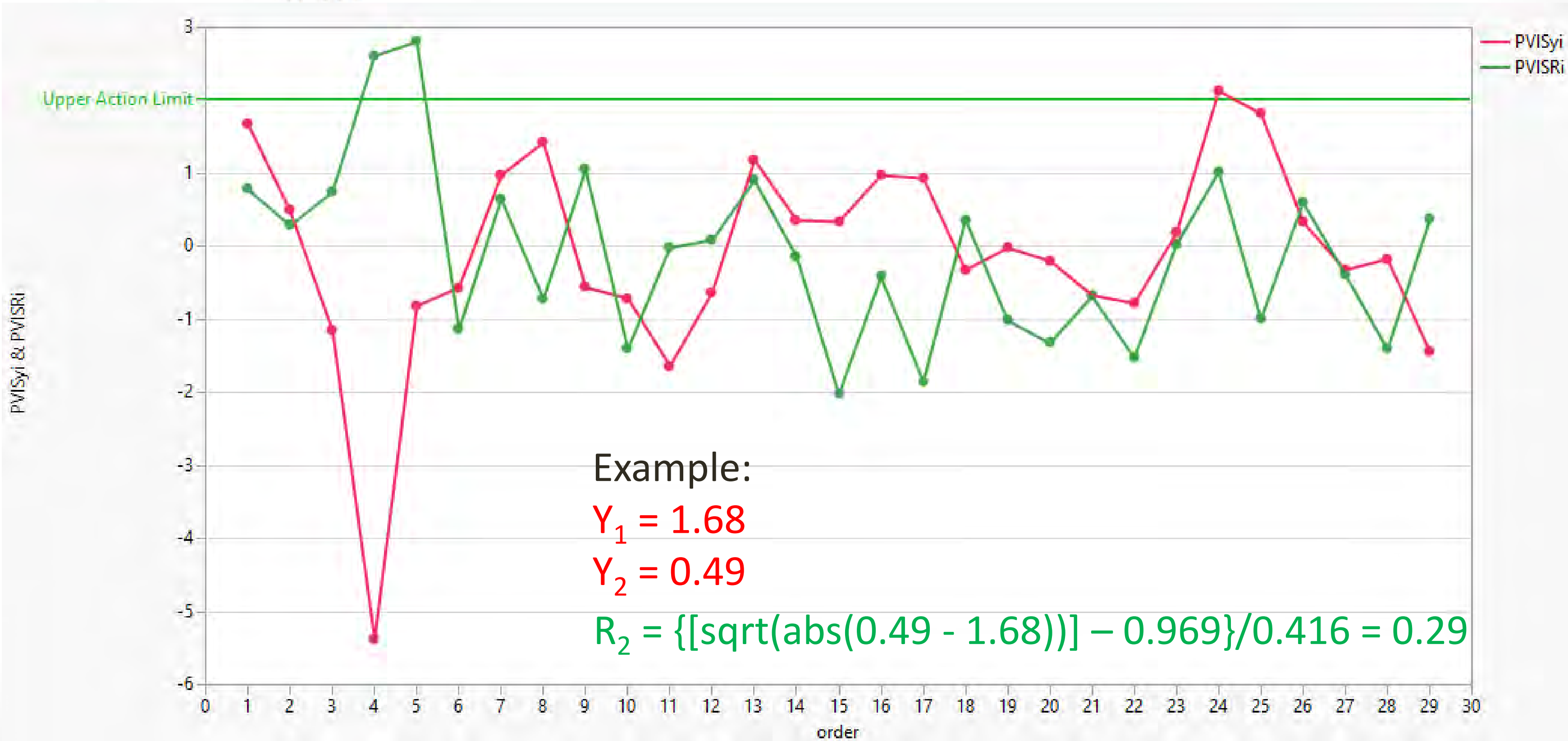
The limits ($0 \pm K\sqrt{\frac{\lambda}{2-\lambda}}$)shown are for demonstration purposes only. These limits along with the rules for what happens when they are exceeded are surveillance panel decisions.

Traditional LTMS applied to IIIH
PVIS Example
PVIS Ri

R_i is used to monitor test precision

$$R_i = \frac{\sqrt{|Y_i - Y_{i-1}|} - 0.969}{0.416}$$

R_i is a standardized moving difference of the absolute Y_i



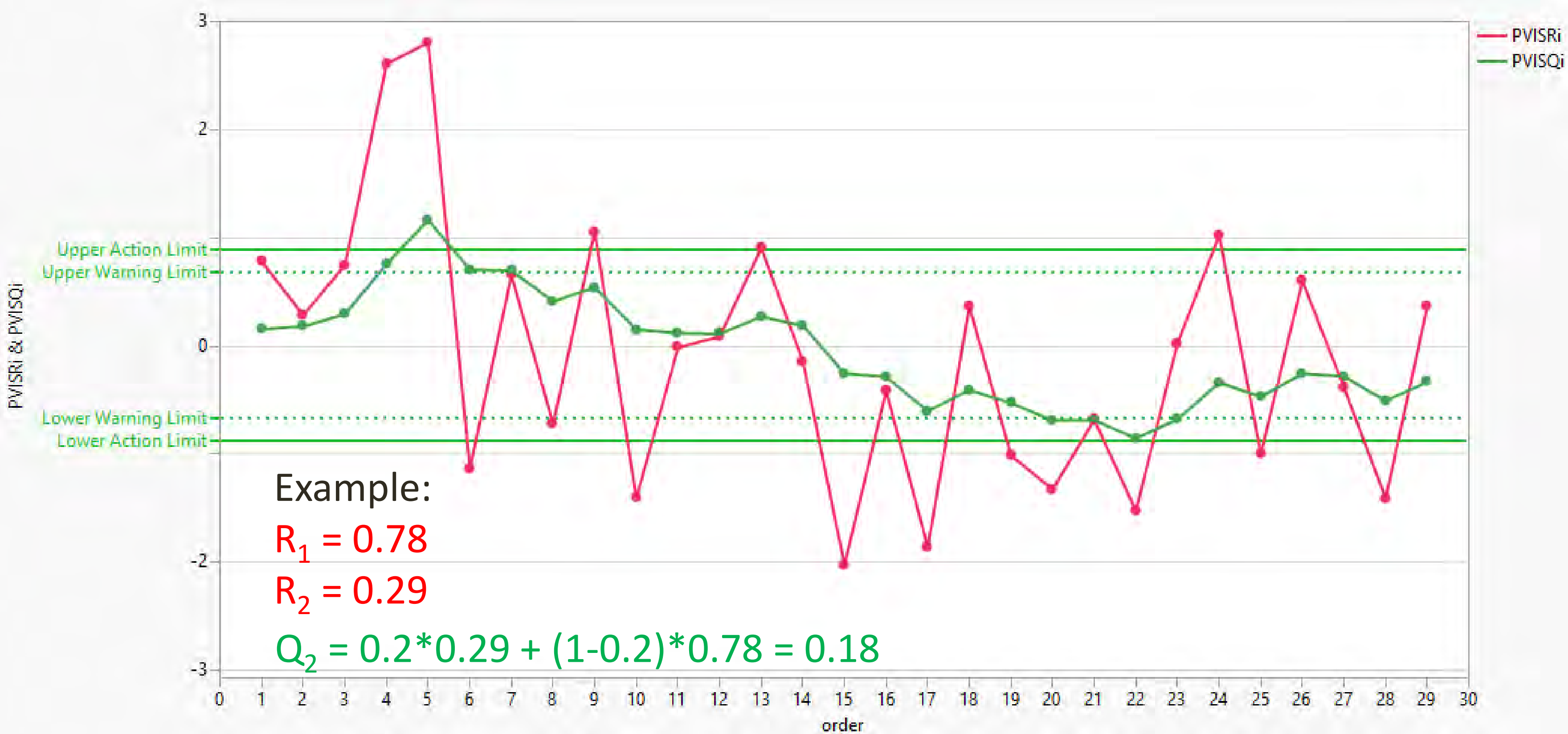
The limit (0 + K) shown is for demonstration purposes only. This limit along with the rule(s) for what happens when it is exceeded are surveillance panel decisions.

Traditional LTMS applied to IIIH
PVIS Example
PVIS Qi

Q_i is also used to monitor test precision

$$Q_i = (\text{LAMBDA})\, R_i + (1 - \text{LAMBDA})\, Q_{i-1}$$; where λ is a tuning parameter between 0 and 1

Q_i is the exponentially weighted moving average of R_i



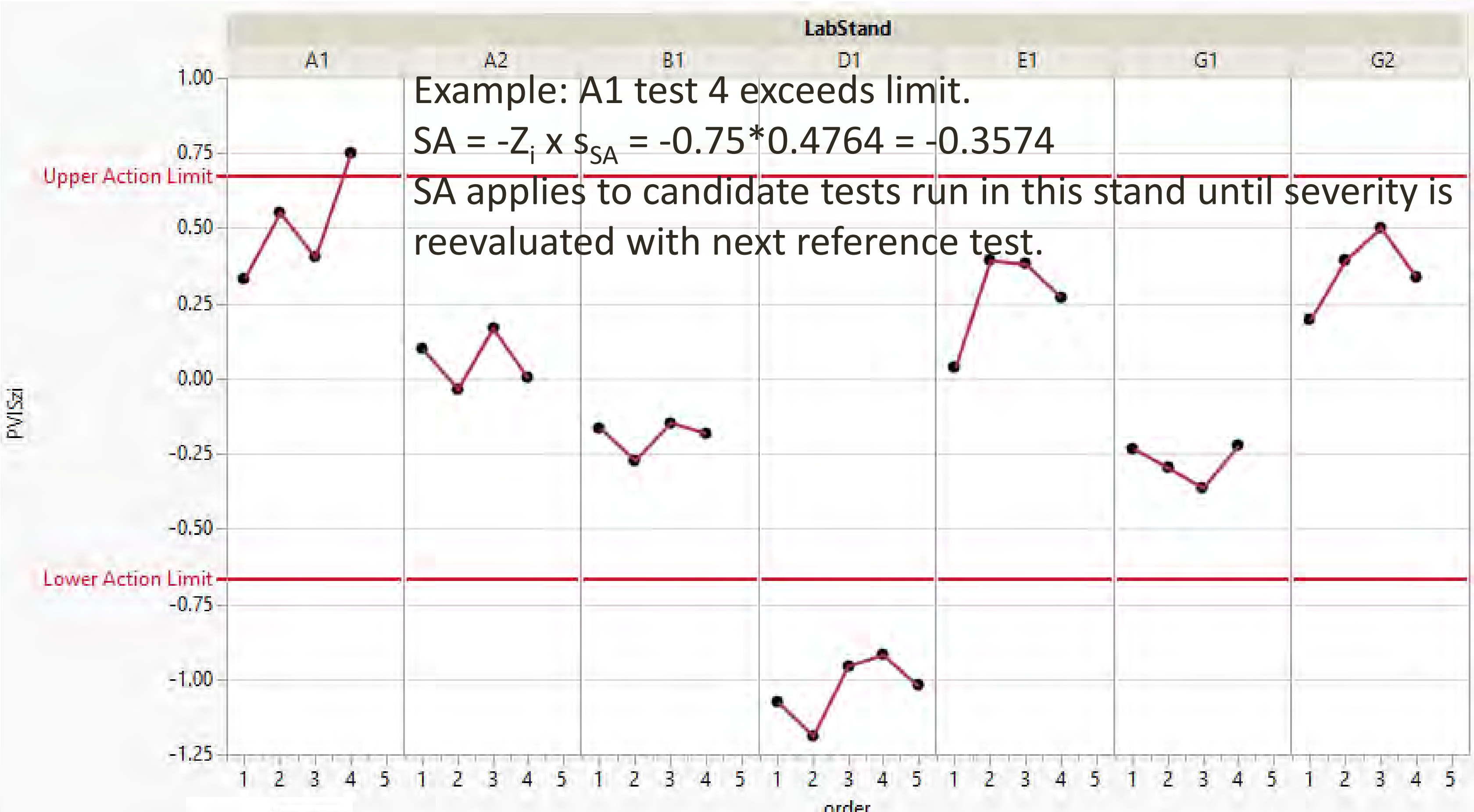
The limits ($0 \pm K\sqrt{\frac{\lambda}{2-\lambda}}$)shown are for demonstration purposes only. These limits along with the rules for what happens when they are exceeded are surveillance panel decisions.

Traditional LTMS applied to IIIH
PVIS Example
Severity Adjustments

- Severity adjustments (SAs) can be applied to candidate results
    - They are not applied to reference results
- The intent of a SA is to adjust for differences in bias
- Applying severity adjustments (SAs)
    - One option is to continuously calculate and apply SAs to candidates every time a reference oil is tested
    - Another option is only calculate and apply SAs to candidates if a Z_i control limit is exceeded (most PC tests are set up this way in the traditional system; exceptions are VID and EOAT)
    - $SA = -Z_i \times s_{SA}$, where s_{SA} = industry approved severity adjustment standard deviation
- The development task force or surveillance panel sets up rules for applying SAs

Traditional LTMS applied to IIIH PVIS Example Severity Adjustments

Z_i is calculated by stand and shown on the plot below. Recall, the analysis of the matrix data indicated stand differences.



Example: A1 test 4 exceeds limit.

SA = $-Z_i \times s_{SA}$ = -0.75*0.4764 = -0.3574

SA applies to candidate tests run in this stand until severity is reevaluated with next reference test.

The limits ($0 \pm K\sqrt{\frac{\lambda}{2-\lambda}}$) shown are for demonstration purposes only (lambda=0.2 & K=2). These limits along with the rules for what happens when they are exceeded are surveillance panel decisions.

Traditional LTMS applied to IIIH

- Control Charting Rules:
  - Similar calculations and plots can be generated for lab or stand level monitoring. Calculations to monitor WPD can be done as well.
  - Similar to industry level monitoring, the limits along with the rules for what happens when they are exceeded are surveillance panel decisions
  - Constants for calculations and rules for when limits are exceeded get incorporated in the LTMS requirements in the LTMS.PDF file

Lubricant Test Monitoring System (LTMS) Improvements

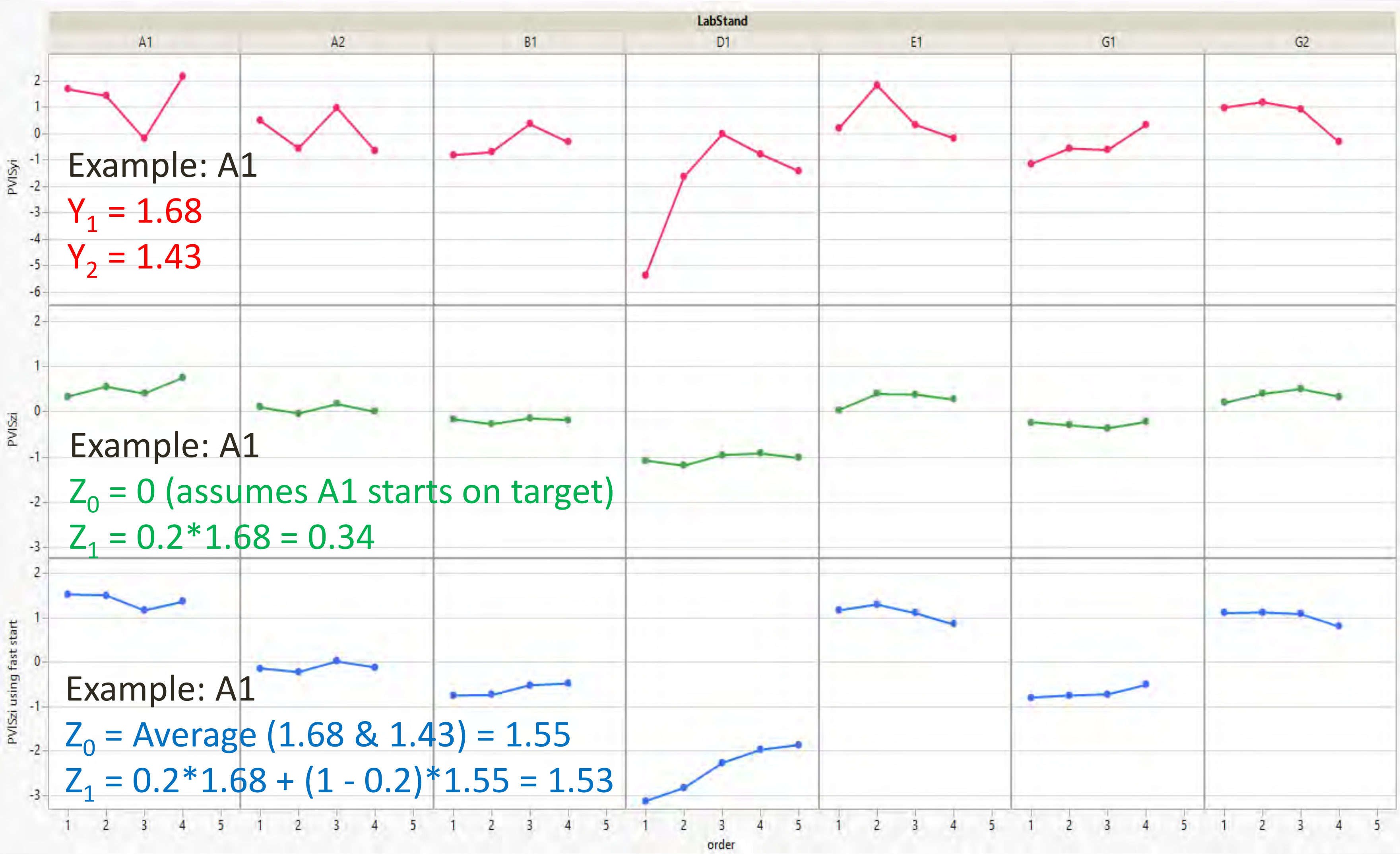
LTMS Improvements

- Checklist
  - Fast Start for Z_i
  - Continuous severity adjustment
  - Excessive Influence and e_i (use of R_i & Q_i are discontinued)

LTMS Improvements
Fast Start for Z_i

- Z_i is an estimate for where the industry/lab/stand/engine is operating at any given time.
- The incorporation of fast start provides a better estimate for where the industry/lab/stand/engine is operating when its monitoring begins
- The tests used to establish the starting point can align with surveillance panel decisions regarding requirements for calibration.
- For example, 2 valid IIIH tests could be used to calibrate a stand. The average of these 2 tests would then be utilized as the starting point (Z_0).
  - Without fast start Z_0=0 and Z_1=lambda*Y_1
  - With fast start Z_0=average(Y_1, Y_2) and Z_1=lambda*Y_1 + (1-lambda)*Z_0

LTMS Improvements
Fast Start for Z_i (lambda=0.2 is assumed)

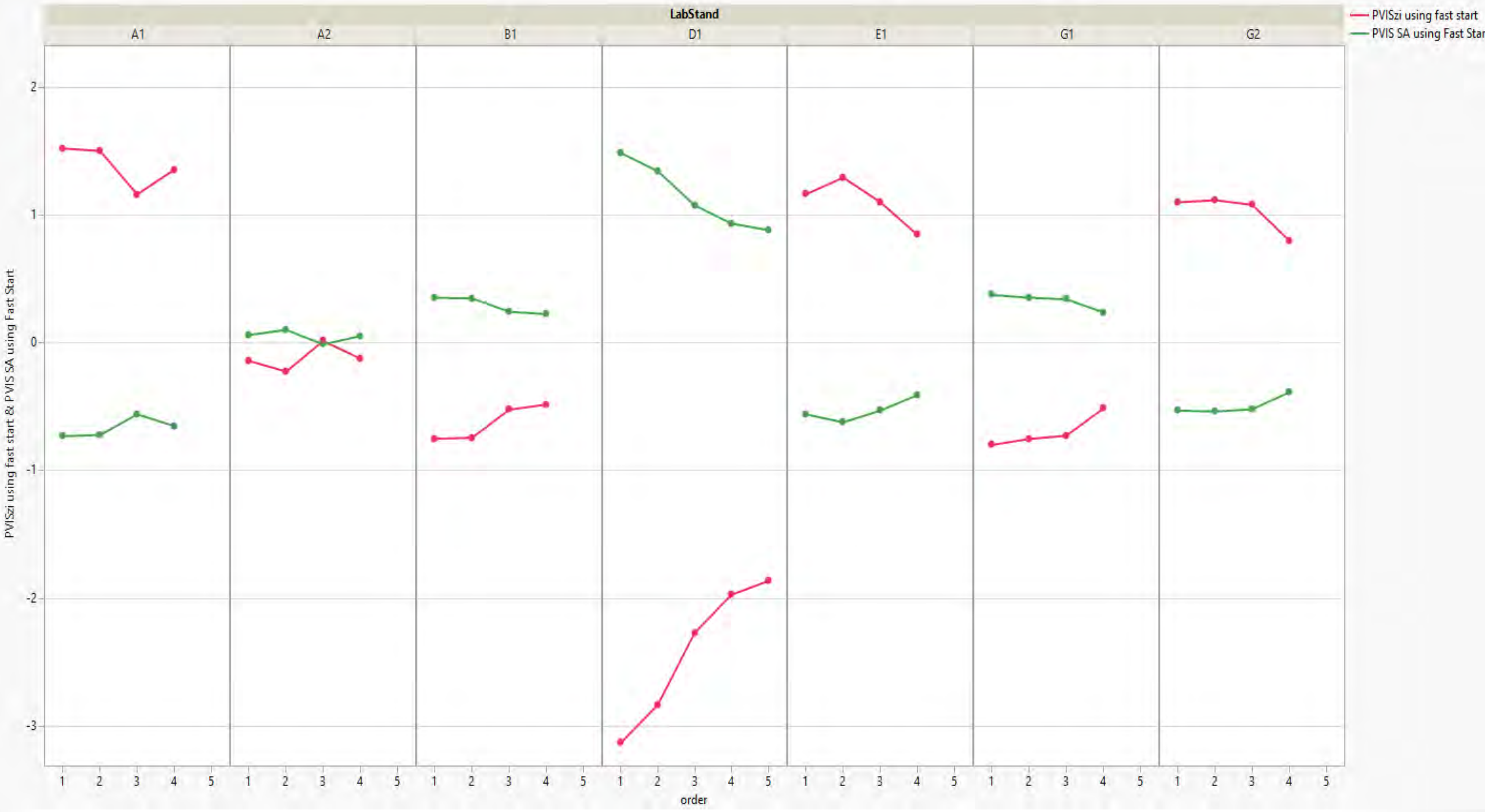


LTMS Improvements
Continuous SA

- Z_i is an estimate for where the lab/stand/engine is operating at any given time.

- Adjust candidate results using our best guess of where we believe the lab/stand/engine is operating

LTMS Improvements
Continuous SA

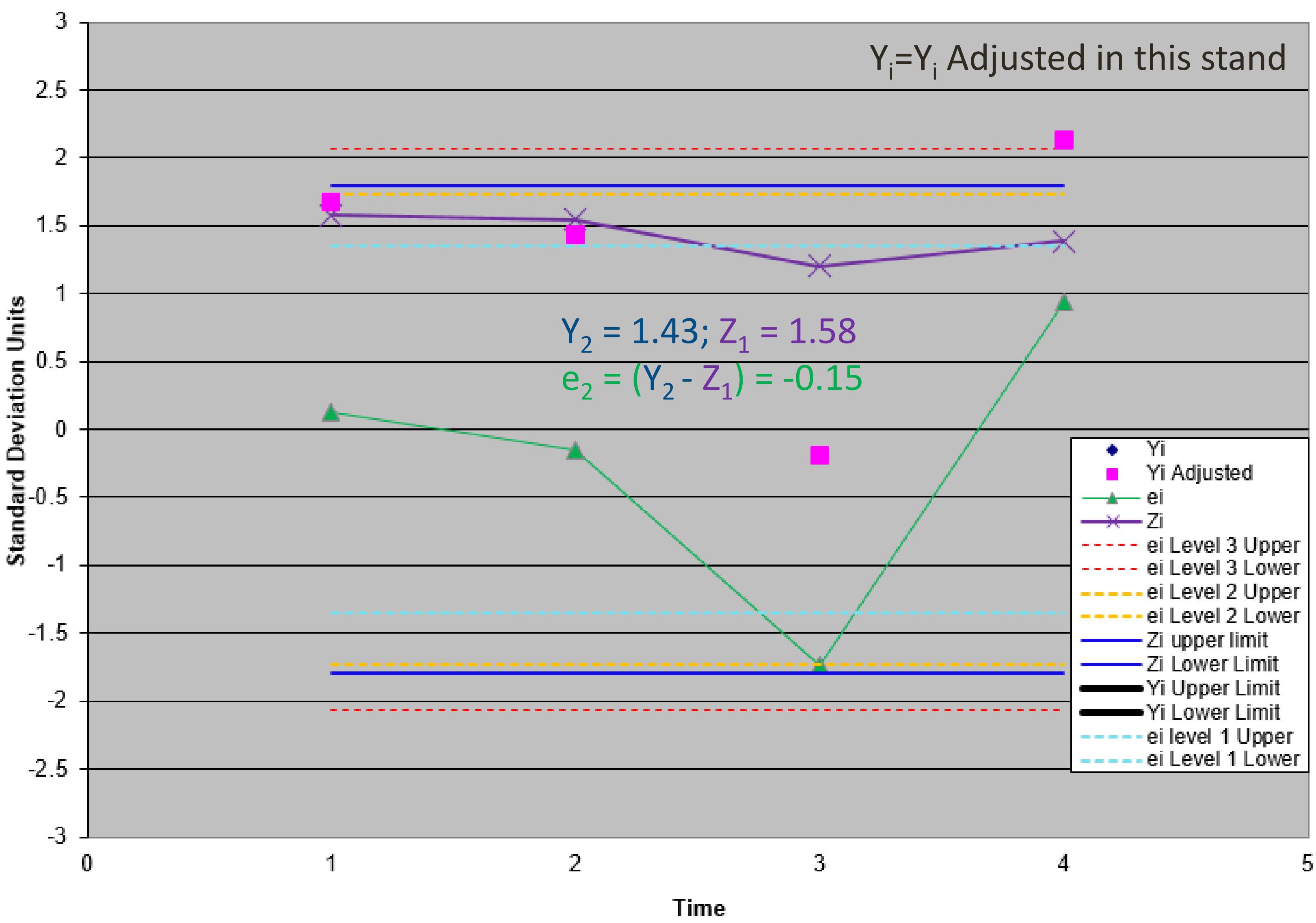


LTMS Improvements Prediction Error (e_i)

- e_i is a measure of how far a new test result is from where we estimate it to be
  - It is the difference between the Y_i of a new test result versus our estimate of where the engine has been operating ($e_i = Y_i - Z_{i-1}$)
- e_i will allow for additional monitoring of test severity with the benefit of also monitoring test precision
- While we strive for lab agreement, we must acknowledge the fact that labs are not always on target
  - In fact, it is likely that labs are never truly on target
  - e_i will monitor the test at the severity adjustment entity level

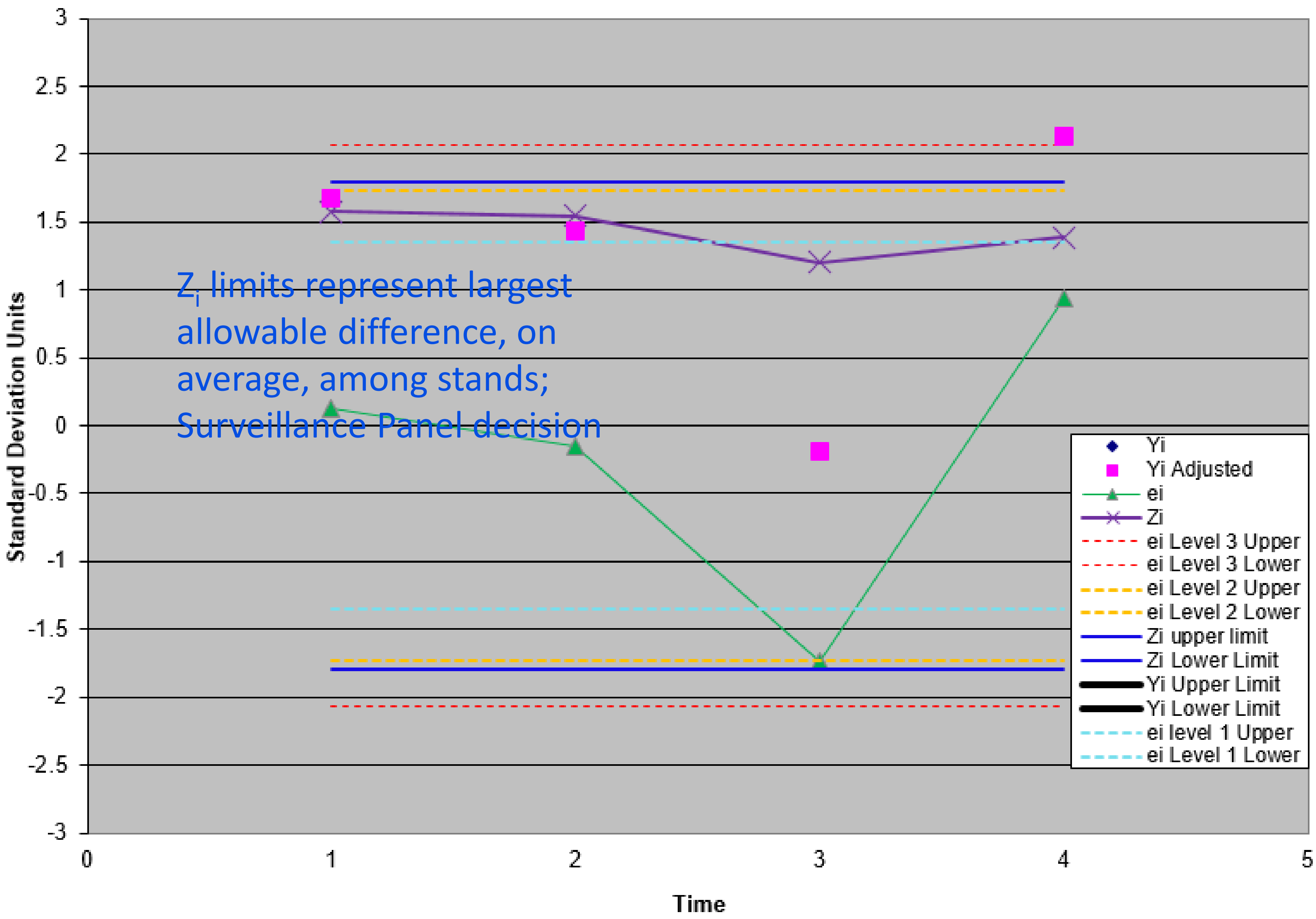
LTMS Improvements
Prediction Error (e_i)

- Example: Lab A Stand 1



LTMS Improvements Prediction Error (e_i)

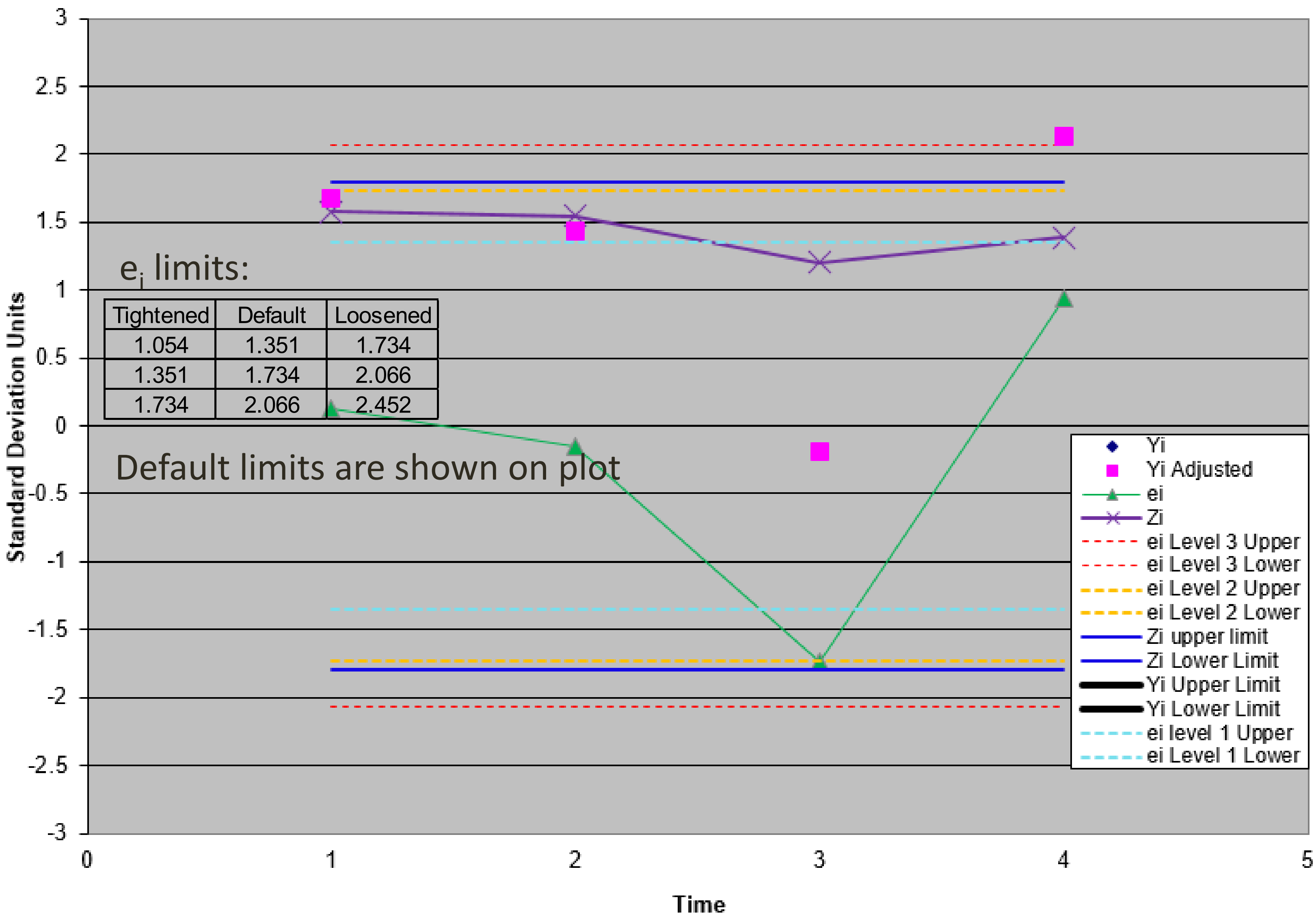
- Example: Lab A Stand 1



Z_i limits represent largest allowable difference, on average, among stands; Surveillance Panel decision

LTMS Improvements
Prediction Error (e_i)

- Example: Lab A Stand 1



e_i limits:

Tightened	Default	Loosened
1.054	1.351	1.734
1.351	1.734	2.066
1.734	2.066	2.452

Default limits are shown on plot

LTMS Improvements Summary

- Utilize fast start
- Industry Z_i used to monitor industry severity
- Z_i calculated for each stand
  - Limits set to represent largest allowable difference between stands
  - Continuous severity adjustments are calculated by stand and applied to candidate tests
- e_i is calculated for each stand and used to monitor stand severity and precision
- Recommended limits are available; Surveillance Panel decides on limits and rules for exceeding them

LTMS Improvements Rules

- Industry Z_i exceeded:

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.

LTMS Improvements
Rules

- Stand Z_i exceeded:

Level 2:

- Immediately conduct one additional reference test in the stand that triggered the alarm. The stand that triggered the alarm is not qualified for non-reference tests until the Level 2 alarm is cleared.
- In instances where surveillance panel has deemed that industry-wide circumstances are impacting the Level 2 alarm, the TMC may be asked to review stand calibration status in accordance with the surveillance panel's findings.

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 severity adjustment (SA). Calculate the stand SA as follows and confirm the calculation with the TMC:

  Percent Viscosity Increase (ln(PVIS)): SA = $(-Z_i)$ x (0.4764)
  Weighted Piston Deposits (WPD): SA = $(-Z_i)$ x (0.48)

If level 1 limit = 0,
then continuous SA

LTMS Improvements Rules

- Stand e_i exceeded:

Level 1:

- The Level 1 limit also applies to stand in an existing test lab that has not run an acceptable reference in the past two years. The stand can calibrate with one test if the Level 1 limits are not exceeded. Otherwise, immediately conduct another reference test in the stand.

Level 2:

- The Level 2 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 2 alarm is triggered, immediately conduct one additional reference test in the stand that triggered the alarm.

Level 3:

- Immediately conduct one additional reference test in the stand that triggered the alarm. Do not update the control charts until the follow up reference test is completed and the Excessive Influence has been performed.

LTMS Improvements
Excessive Influence

- We now have two recent reference test (Y_i and Y_{i+1})

- If the difference in Y_i and $Y_{i+1} \leq$ level 3 limit, then assumption is stand severity has changed
  - Don't adjust Y_i or Y_{i+1}, calculate SA, and update control charts

- If the difference in Y_i and Y_{i+1} > level 3 limit and Y_{i+1} aligns with results prior to Y_i, then the assumption is that Y_i was an anomaly and is adjusted to minimize its impact on the SA
  - Adjust Y_i, calculate SA, and update control charts

LTMS Improvements
Next Steps

- Surveillance panel discussion of LTMS improvements
  - Other visualization tools are available

- Surveillance discussion of other LTMS requirements
  - Oil Targets - Done
  - Lab/stand calibration rules
  - Reference oil assignments including target for percent of time oils are tested
  - Removal of lab/stand (in IIIG)?
  - Introduction of reference oils (in IIIG)?

- Finalize LTMS requirements

- Issue motion of acceptance of LTMS requirements

APPENDIX

How Does LTMS Work?

Very high level view:

1. New industry standardized tests are developed based on OEM need statements
    1. Test Development Task Forces are put together and typically include one or more development lab(s) working in conjunction with the OEM
2. These tests have reference oils that all labs run using a common test procedure
    1. The reference oils are chosen from oils included in a matrix (set of structured, designed tests)
3. These test results are reported to the Test Monitoring Center (TMC) who collects and stores these data
4. Valid test results are used to calculate metrics to help the industry identify whether labs/stands/engines have shifted in their precision or bias
    1. These metrics can be plotted over time on control charts to visualize test results relative to warning and action limits associated with the various metrics
5. The surveillance panel is tasked with the upkeep of these tests over the lifetime of the test
6. From time to time the surveillance panel will request a review of the reference data to assess whether test precision and bias have changed
    1. These reviews can lead to the implementation or update of severity adjustments and correction factors

Test Standardization Across Industry

Standardizing tests across the industry involves:

- The use of the same test procedure
- Consistency among engines, hardware, fuel supplies, oil blends, etc.
- Lab visits to identify and address inconsistencies
- Review of test operational data
  - Use of a common reporting template among the labs:
    - Includes layout of parameter data, frequency of data reported, units in which data are reported
    - Encompasses how the data are complied, stored, and shared
  - Qi limits for controlled tests parameters are developed
- Understanding major sources of variation in tests
  - Engine, parts, practice, rebuild, etc.
- Surveillance Panels resolve test issues through engineering efforts
- Matrix MOA requirements are met
- Statistically designed experiments (e.g., precision matrix) to:
  - Establish precision and LTMS targets in reference technology oils;
  - Identify outliers and needed data transformations;
  - Determine sources of variability which will help determine level of monitoring and control (lab, stand, engine); and

Reference Oil Selection

Guidelines for reference oil selection:

- Have adequate mean and precision estimates at the onset of LTMS implementation
  - Potential reference oils need to be a part of a precision matrix during the course of test development
- Be similar in chemistry to anticipated candidates
- Perform near pass fail limits
  - Note: When more than one reference oil is selected to monitor a given test, there is a balance between selecting oils near the pass/fail limit and estimating & monitoring precision and bias across the range of performance
- Reference oils should meet the chemical and physical limits of the category and pass limits.
  - If a pass limit is tied to a particular viscosity grade, base oil type, chemical element, or other characteristic, the reference oil should meet those chemical and physical limits.
- Reference oils do not need to pass every parameter for the test, but they should be around various pass/fail limits.
- Adding new reference oils for an existing test should be done very cautiously.
- Reference oil performance should be similar across laboratories. If it is not similar, then one of the following are recommended:
  - Try to identify and fix the problem.
  - It may be appropriate to consider removing the reference oil from the test.

Reference Oil Targets

- Reference oil targets used to standardize reference oil results to monitor tests
  - These Y_i calculations are subsequently used in other monitoring metrics

- It's a recommendation to have a minimum of 10 tests per reference oil technology and 8 tests per reference oil to initially set reference oil targets
  - These estimates need to be based on a statistical analysis of precision matrix test results (or a combined precision & BOI/VGRA design when appropriate)
    - Reference oil test results from stands not participating in the precision matrix but completed at the time of the precision matrix can also be considered
    - Bias due to interactions, such as between reference oil and laboratory, should not be incorporated into LTMS targets

- Subsequent updates to oil targets are at the discretion of the surveillance panels
  - At a minimum, standard deviations for each of the reference oils should be reviewed when 10, 20, and 30 tests have been completed
  - Standard deviations should be subsequently reviewed periodically to estimate current variability in addition to ASTM Test Monitoring Center (TMC) semiannual reports containing variability estimates

Calibration and Referencing Requirements

- Calibration and referencing requirements are determined upon review of the matrix analysis
- These requirements define the length of reference periods and the calibration of new or modified engines

- Example: COAT
  - Calibration periods: The preferred ratio of the two oils K:G is 2:1.
    - 1st period = 2 candidate tests
    - 2nd period = 4 candidate tests
    - 3rd period = 6 candidate tests
    - 4th period and subsequent = 9 candidate tests
  - Brand New Stand (3 tests to begin; Reference oils K, G, K)
  - Rebuilt or new engine with existing stand (2 tests to begin; Reference oils K, G)
  - Critical components replaced
    - Terminate current calibration period. Run Reference oil K and restart the calibration period.
      - Example: if a component is changed in the 4th period after 3 tests. Run the reference oil K then go back to the beginning of Period 4.
    - Critical components: Included in the procedure.
      - Examples: micromotion, research valve (regulator), heated line

Correction Factors

- The surveillance panel is responsible for monitoring tests throughout their life
- From time to time, when limits are exceeded or trends are observed in the control charts, formal reviews of the data are done to evaluate the need for correction factors
- The intent of a correction factor is adjust both candidate and reference data
  - This correction is made because the analysis suggests the severity of the test has changed
  - Correction factors are developed to correct the current state of the test back to original oil targets (original test control)
- Recall:

  T_i = Transformed/Corrected Test Result

ATTACHMENT 3

Sequence IIIH Precision Matrix Statistical Analysis

Statistics Group

December 4, 2015

Statistics Group

- Arthur Andrews, ExxonMobil
- Doyle Boese, Infineum
- Jo Martinez, Chevron Oronite
- Ricardo Affinito, Chevron Oronite
- Kevin O'Malley, Lubrizol
- Martin Chadwick, Intertek
- Richard Grundza, TMC
- Lisa Dingwell, Afton
- Todd Dvorak, Afton
- Travis Kostan, SwRI

IIIH Matrix Status:
27 out of 28 tests analyzed

IIIH Matrix Test Status

Excluded → (Run Order 1, D-1: 434-2 106788-IIIH)

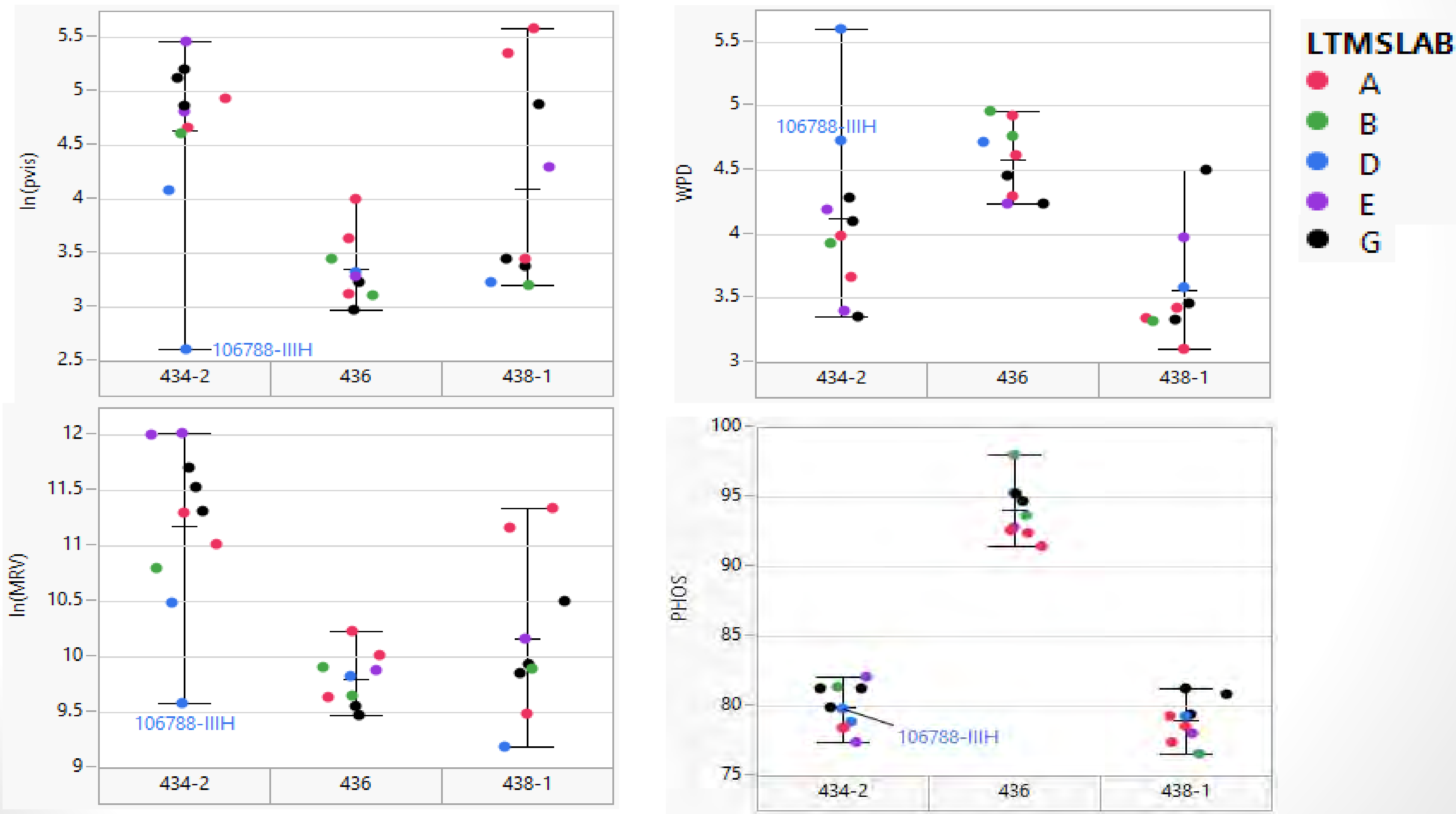
Run Order	Lab-Stand	D-1	E-1	B-1	G-1	G-2	A-1	A-2
	1	434-2 106788-IIIH ✓	438-1 106784-IIIH Low MAP and Fuel Flow	438-1 106796-IIIH Oil Leak	36 106763-IIIH ✓	436 106764-IIIH Low MAP & Erratic Fuel Flow	438-1 106774-IIIH ✓	434-2 106778-IIIH ✓
			438-1 106785-IIIH ✓	438-1 106797-IIIH ✓		436 111422-IIIH ✓		
	2	434-2 106789-IIIH Loss of Oil Pressure	436 106782-IIIH Low MAP & Fuel Flow	436 106792-IIIH ✓	438-1 106767-IIIH ✓	434-2 107873-IIIH ✓	438-1 107869-IIIH ✓	438-1 107870-IIIH ✓
		434-2 106789A-IIIH ✓	436 106783-IIIH ✓					
	3	436 106786-IIIH ✓	434-2 106781-IIIH ✓	436 106793-IIIH ✓	438-1 106768-IIIH ✓	434-2 110227-IIIH ✓	434-2 106779-IIIH ✓	436 106775-IIIH ✓
	4	438-1 106791-IIIH ✓	434-2 106780-IIIH ✓	434-2 106795-IIIH ✓	434-2 110228-IIIH ✓	438-1 107872-IIIH ✓	436 106777-IIIH ✓	436 106776-IIIH ✓

✓ Indicates operation task force has reviewed operational data and found the test to be operationally valid.

Test Reported (green) Invalid (red)

Summary

IIIH Task Force passed a motion on 11-30-15 to remove testkey 106788-IIIH from the precision matrix analysis. This testkey was deemed valid during the review of the operational data of precision matrix tests.



Summary

Removing a data point without being able to identify a procedural change that would minimize the likelihood of a similar occurrence in future tests is of concern.

- If there is an assignable cause for the results of 106788, then the risk is that the variability this induces in the test could be observed in future testing affecting stand calibration and oil discrimination at the labs.
- If the results of 106788 are indicative of inherent test variability, then test precision, oil targets, and LTMS will be misrepresented by its removal.

If the industry chooses to move forward with this test without redevelopment, then these issues need to be kept in mind when setting reference intervals and acceptance criteria, and when establishing candidate pass limits. Robust reference and candidate limits could minimize any potential problems caused by the problems observed in the matrix data while providing a larger data set that can be used to refine the test further.

As more data are gathered, LTMS should be updated to reflect the current variability of the test.

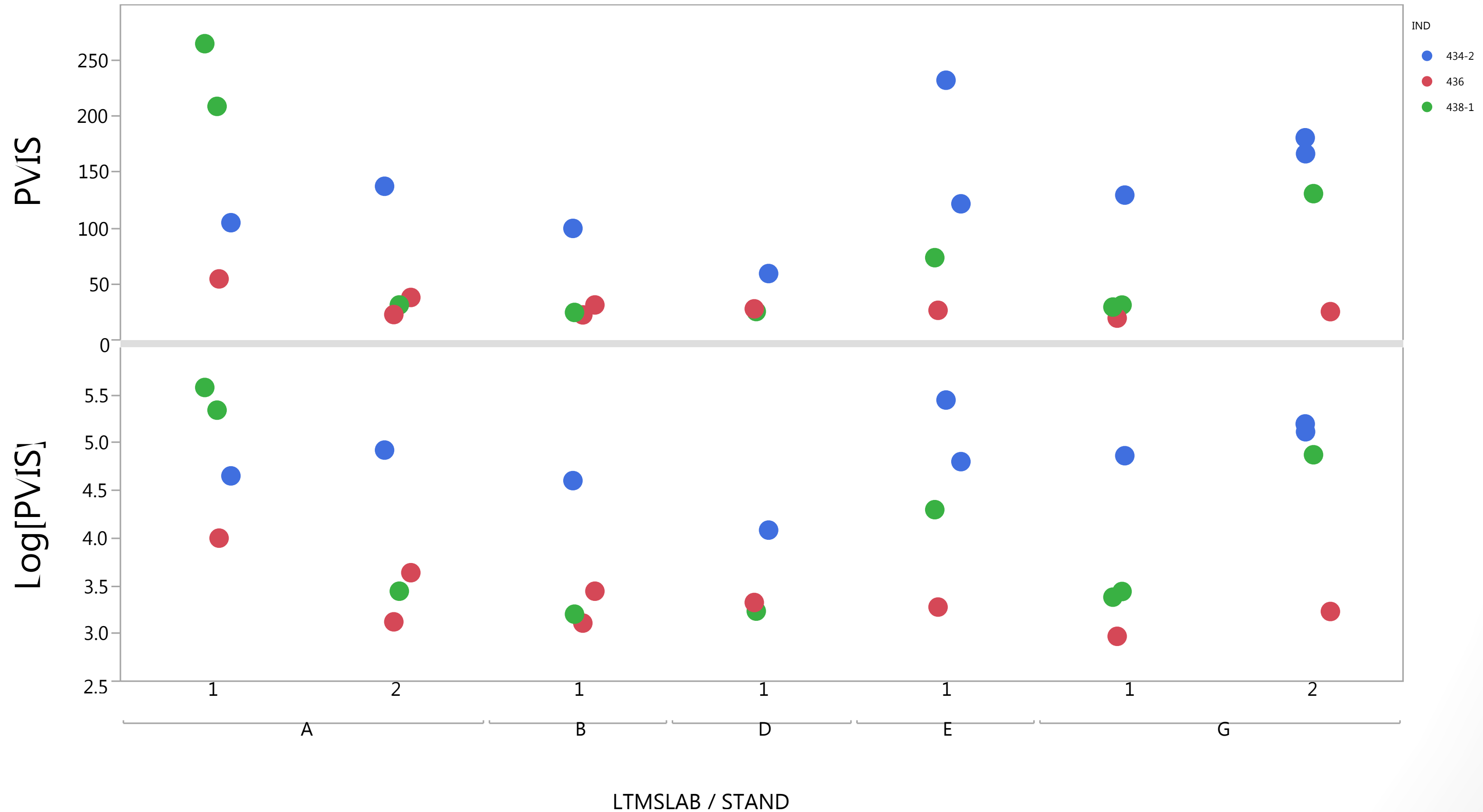
Effort in finding assignable cause(s) for the results of 106788 should continue.

- The industry should consider operational and build data not currently acquired.

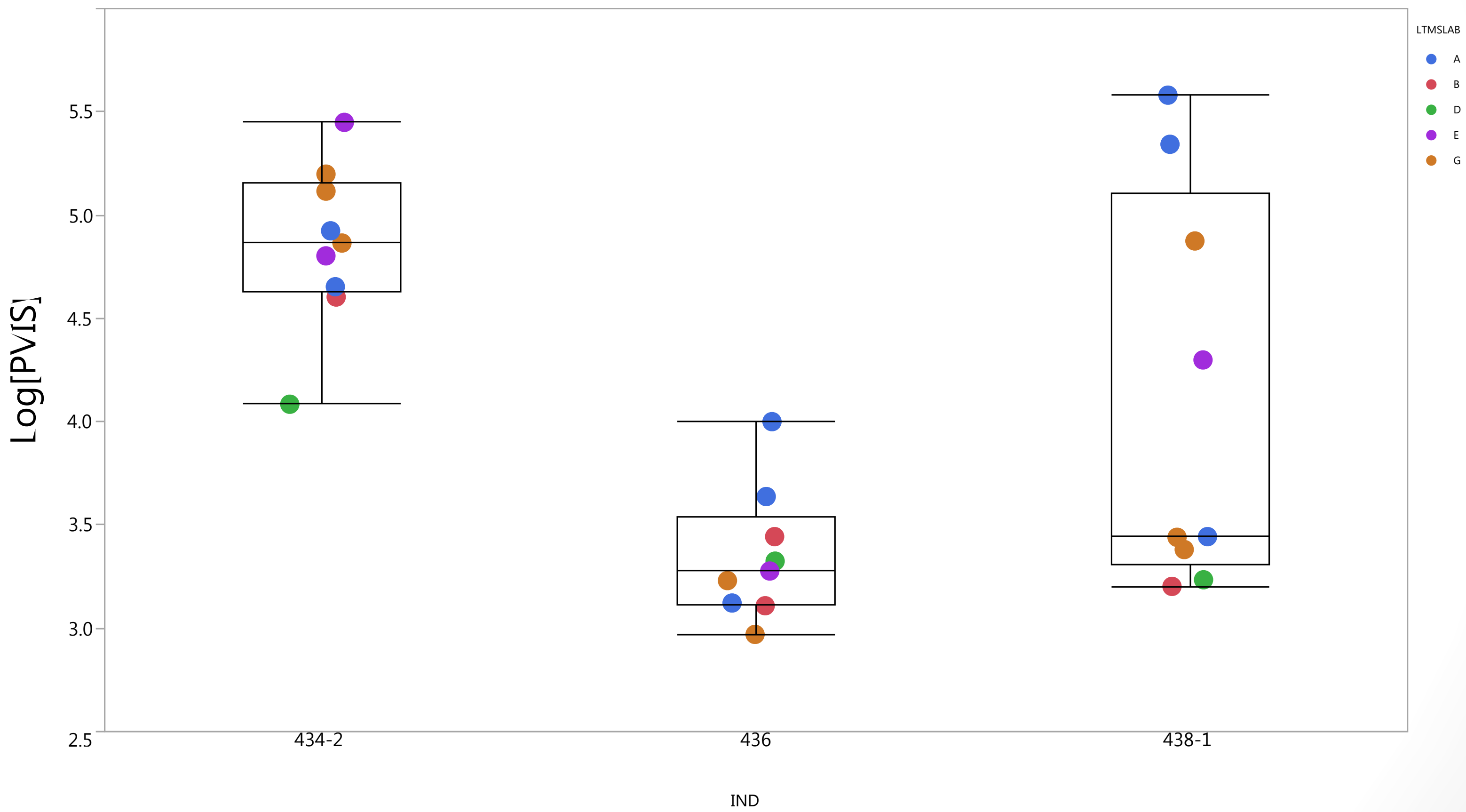
Summary

n=27	LnPVIS	WPD	LnMRV	Phos
Lab Difference	No significant difference	No significant difference	No significant difference	A<G
Stand(Lab) Difference	A2<A1, G1<G2	No significant difference	A2 < A1	No significant difference
Oil Discrimination	436 < 434-2, 438-1; 438-1 < 434-2	436 > 438-1	436, 438-1 < 434-2	436 > 434-2, 438-1
Precision, s, RMSE	0.4764	0.48	0.4270	1.57

Percent Viscosity Increase



LnPVIS



LnPVIS ANOVA

Summary of Fit

RSquare	0.791392
RSquare Adj	0.698678
Root Mean Square Error	0.47638
Mean of Response	4.096557
Observations (or Sum Wgts)	27

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	15.496788	1.93710	8.5358
Error	18	4.084886	0.22694	**Prob > F**
C. Total	26	19.581674		<.0001*

Effect Tests

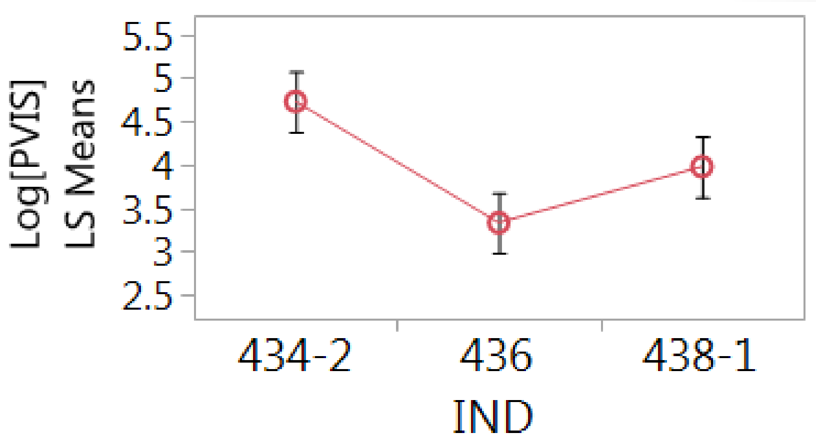
Source	DF	Sum of Squares	F Ratio	Prob > F
IND	2	8.3274921	18.3475	<.0001*
LTMSLAB	4	2.3754503	2.6168	0.0696
LTMSAPP[LTMSLAB]	2	2.8959191	6.3804	0.0080*

LnPVIS Oil Discrimination

436 is significantly lower than 434-2

436 is significantly lower than 438-1

438-1 is significantly lower than 434-2

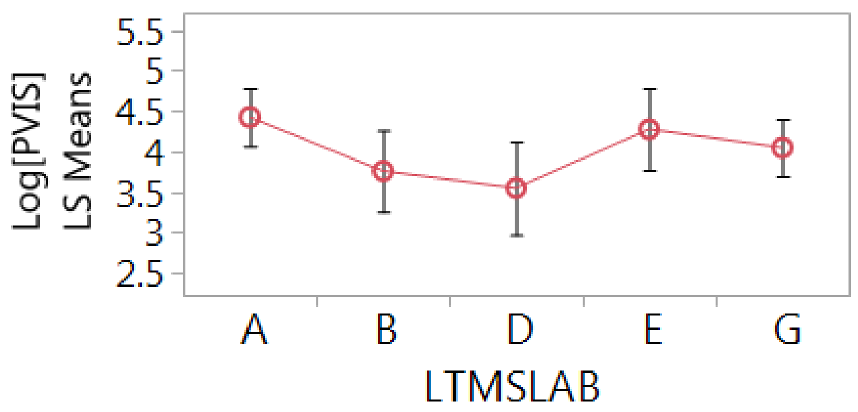


Oil1	Oil2	Difference	p-Value
434-2	436	1.3985	0.00
438-1	436	0.7519	0.01
434-2	438-1	0.6465	0.03

Oil	LnPVIS LS Mean	PVIS LS Mean
434-2	4.7292	113
436	3.3308	28
438-1	3.9773	53

LnPVIS Lab Difference

No significant lab difference



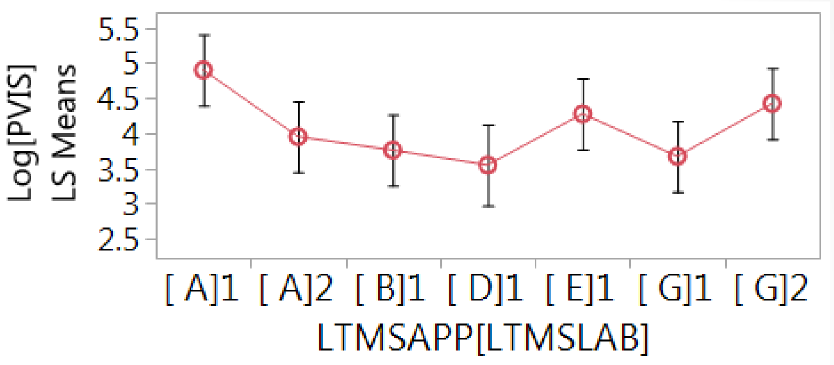
Lab1	Lab2	Difference	p-Value
A	D	0.8794	0.09
E	D	0.7294	0.31
A	B	0.6674	0.2
E	B	0.5174	0.57
G	D	0.5011	0.54
A	G	0.3783	0.53
G	B	0.2891	0.86
E	G	0.2283	0.93
B	D	0.212	0.98
A	E	0.15	0.99

Lab	LnPVIS LS Mean	PVIS LS Mean
A	4.4274	84
B	3.7601	43
D	3.548	35
E	4.2775	72
G	4.0492	57

LnPVIS Stand(Lab) Difference

Stand A2 is significantly lower than Stand A1

Stand G1 is significantly lower than Stand G2



Lab/Stand1	Lab/Stand2	Difference	p-Value
[A]1	[A]2	0.9504	0.01
[G]2	[G]1	0.7526	0.04

Lab/Stand	LnPVIS LS Mean	PVIS LS Mean
[A]1	4.9027	135
[A]2	3.9522	52
[G]1	3.6729	39
[G]2	4.4255	84

LnPVIS Precision

Model: Oil, Lab, Stand(Lab)

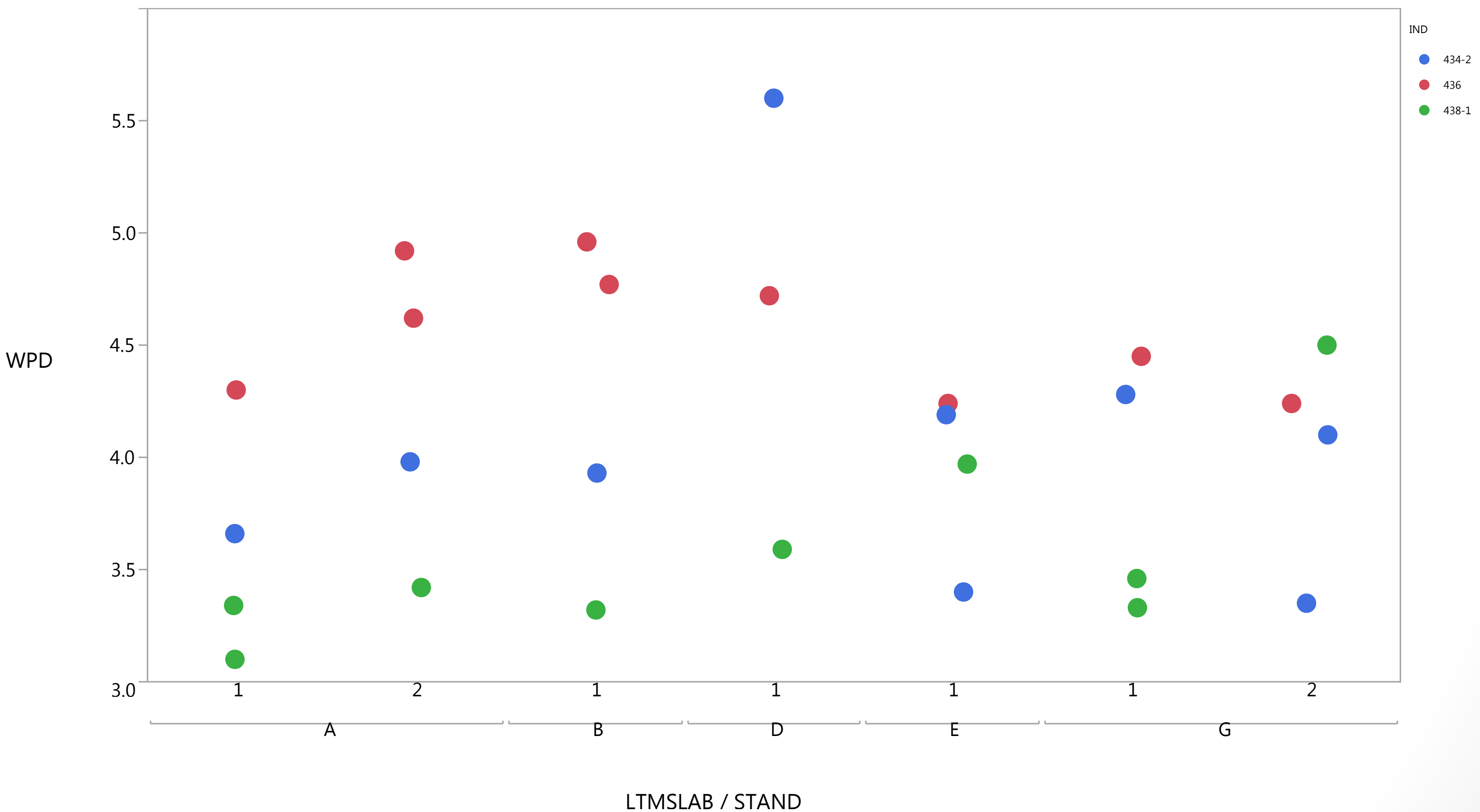
Model RMSE	Repeatability	Reproducibility
• s = 0.4764 • IIIH Prove-out s=0.61 • IIIG Precision Matrix s=0.2919 • IIIG recent data s=0.54-0.63	• s = 0.4764 • r = 1.3205	• s = 0.6238 • R = 1.7291

PVIS Precision

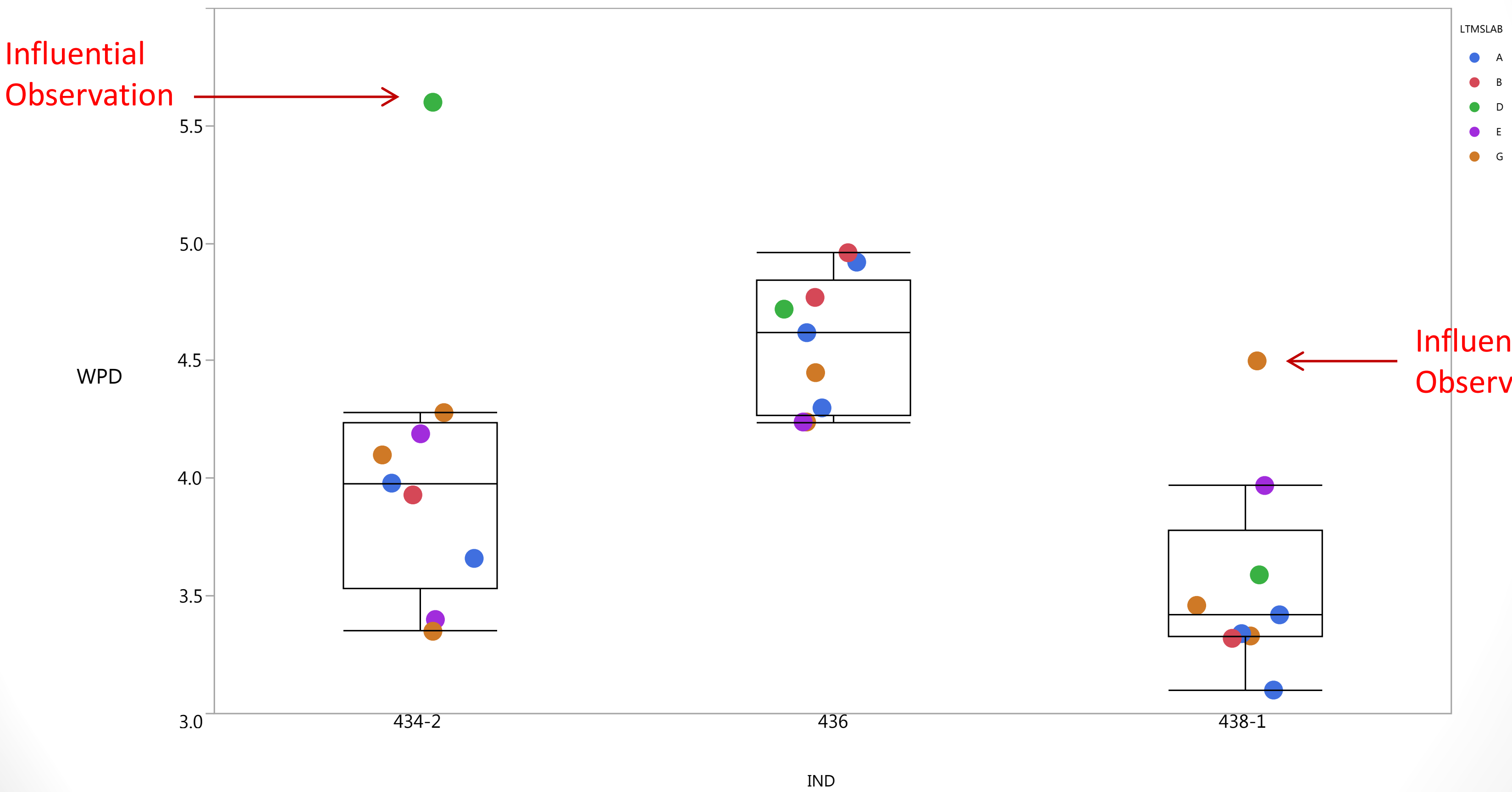
Based upon the Seq. III pooled standard deviations (s_r) and ASTM's repeatability (r) definition for the *maximum allowable difference between successive test results*, there is no significant difference between a PVIS result[1] of *150% - 562%* for the IIIH and *150% - 337%* for the IIIG.

Note 1: A PVIS of 150% was arbitrarily selected in the calculations as the lower pass/fail limit.

Weighted Piston Deposit



WPD



Influential Observation
Influential Observation
LTMSLAB
A
B
D
E
G
WPD
5.5
5.0
4.5
4.0
3.5
3.0
434-2
436
438-1
IND

WPD ANOVA

Summary of Fit

RSquare	0.601774
RSquare Adj	0.424785
Root Mean Square Error	0.478543
Mean of Response	4.064444
Observations (or Sum Wgts)	27

Analysis of Variance

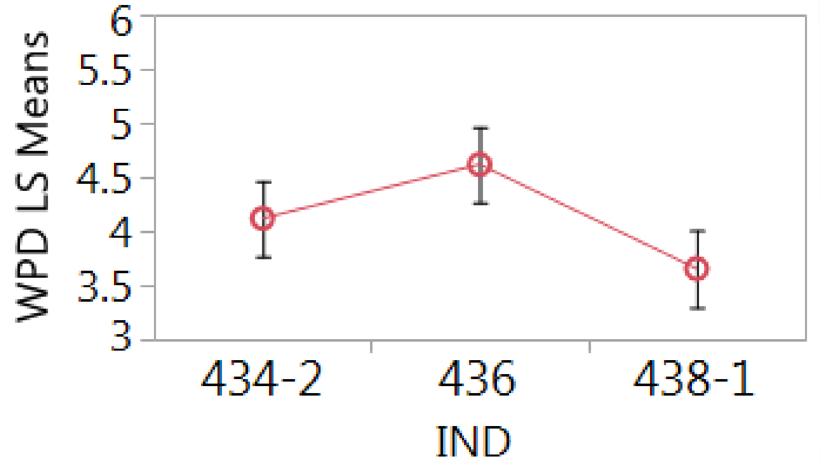
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	6.229002	0.778625	3.4001
Error	18	4.122065	0.229004	**Prob > F**
C. Total	26	10.351067		0.0148*

Effect Tests

Source	DF	Sum of Squares	F Ratio	Prob > F
IND	2	3.9474770	8.6188	0.0024*
LTMSLAB	4	1.2340817	1.3472	0.2911
LTMSAPP[LTMSLAB]	2	0.3058781	0.6678	0.5251

WPD Oil Discrimination

436 is significantly higher than 438-1

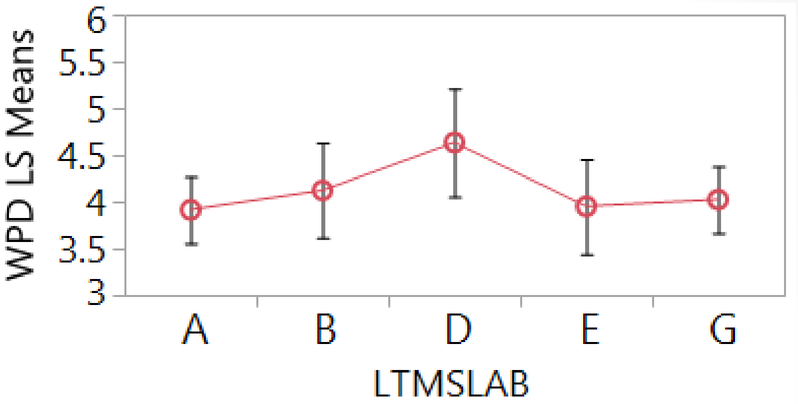


Oil1	Oil2	Difference	p-Value
436	438-1	0.96	0.00
436	434-2	0.5	0.11
434-2	438-1	0.46	0.14

Oil	WPD LS Mean
434-2	4.12
436	4.62
438-1	3.65

WPD Lab Difference

No significant lab difference

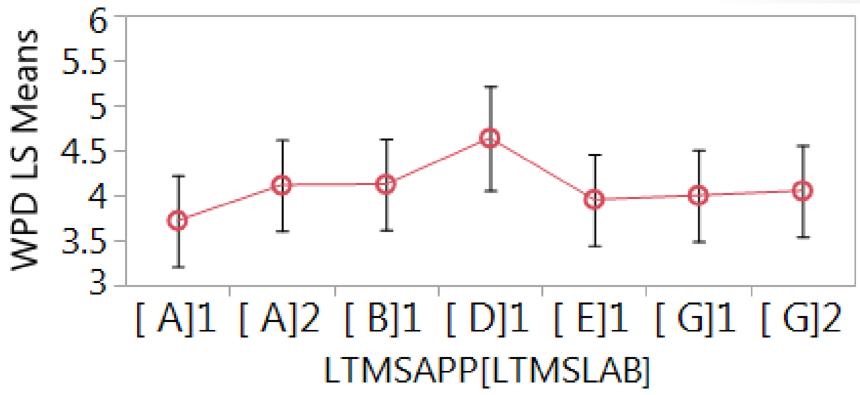


Lab1	Lab2	Difference	p-Value
D	A	0.72	0.22
D	E	0.68	0.37
D	G	0.61	0.36
D	B	0.51	0.64
B	A	0.21	0.95
B	E	0.17	0.99
G	A	0.11	0.99
B	G	0.10	1.00
G	E	0.07	1.00
E	A	0.04	1.00

Lab	WPD LS Mean
A	3.92
B	4.12
D	4.64
E	3.95
G	4.02

WPD Stand(lab) Difference

No significant stand(lab) difference



Lab/Stand1	Lab/Stand2	Difference	p-Value
[A]2	[A]1	0.39	0.27
[G]2	[G]1	0.05	0.88

Lab/Stand	WPD LS Mean
[A]1	3.72
[A]2	4.11
[G]1	4.00
[G]2	4.05

WPD Precision

Model: Oil, Lab, Stand(Lab)

Model RMSE

- s = 0.48
- IIIH Prove-out s=0.40
- IIIG Precision Matrix s=0.60
- IIIG recent data s=0.39-0.43

Repeatability

- s = 0.48
- r = 1.33

Reproducibility

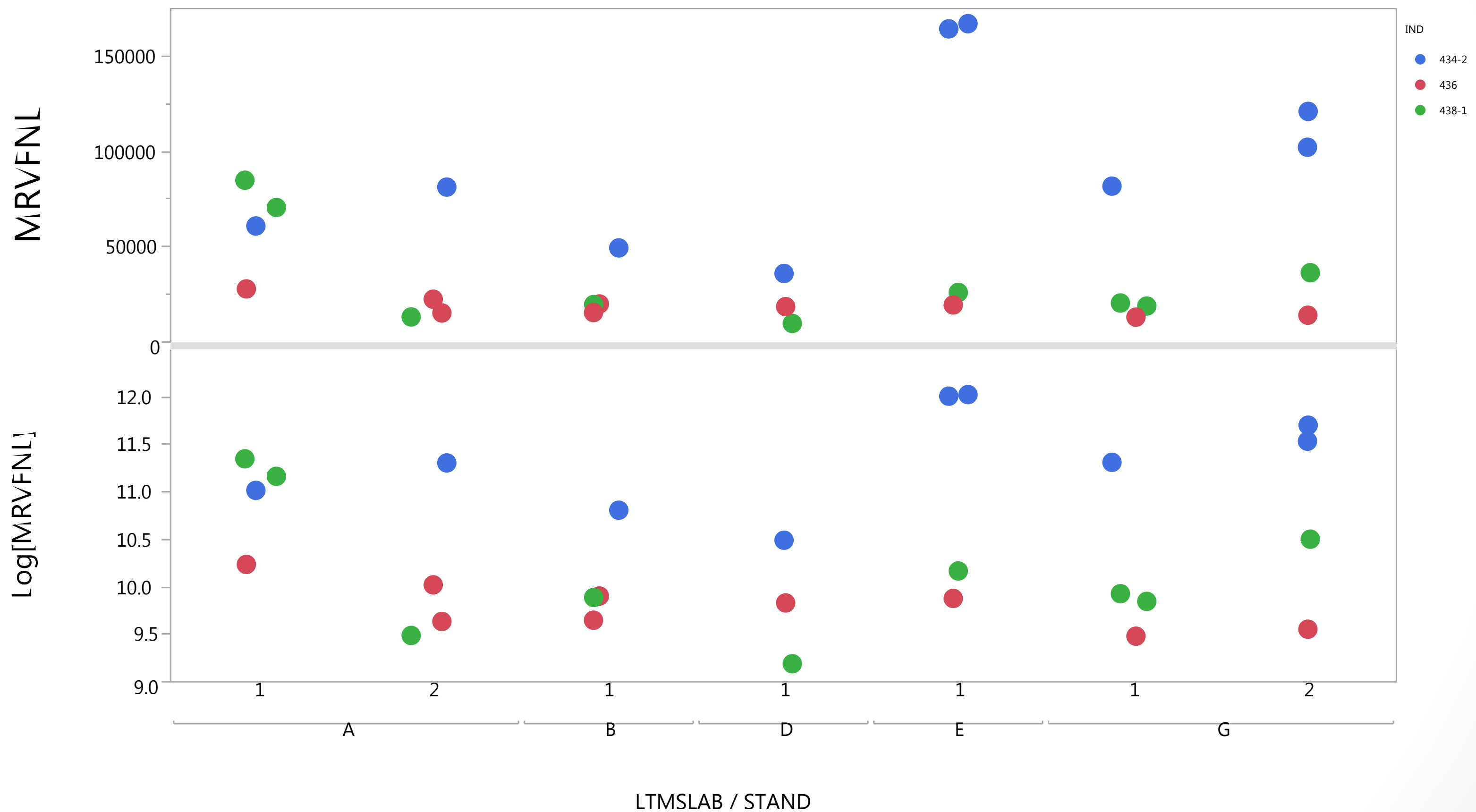
- s = 0.49
- R = 1.36

WPD Precision

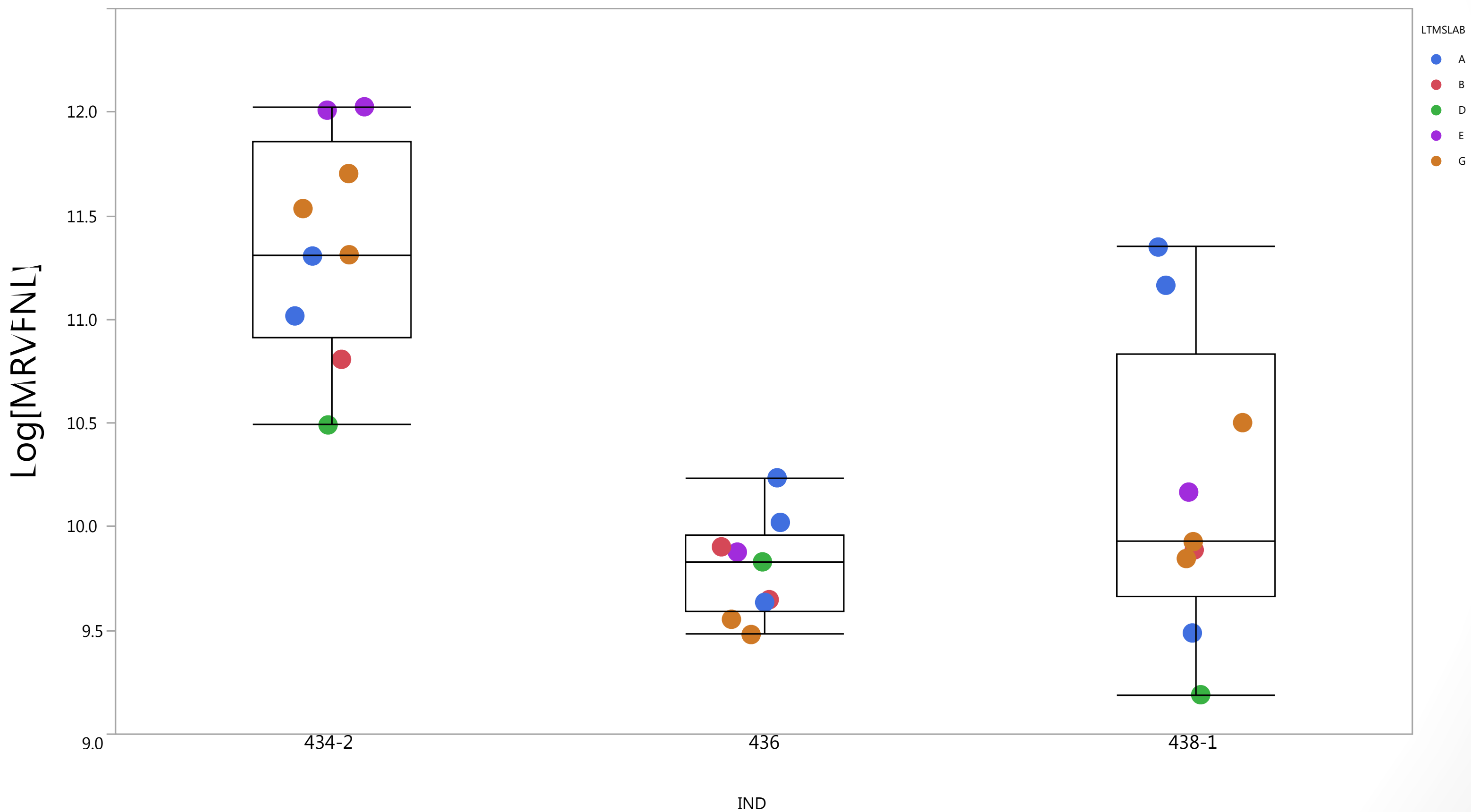
Based upon the Seq. III pooled standard deviations (s_r) and ASTM's repeatability (*r*) definition for the *maximum allowable difference between successive test results*, there is no significant difference between a WPD result[1] of 2.7 – *4.0* for the IIIH and 2.*3* – *4.0* for the IIIG.

Note 1: A WPD of 4.0 was arbitrarily selected in the calculations as the upper pass/fail limit.

MRV Viscosity



LnMRV



Log[MRVFNL]
12.0
11.5
11.0
10.5
10.0
9.5
9.0
434-2
436
438-1
IND
LTMSLAB
A
B
D
E
G

LnMRV ANOVA

Summary of Fit

RSquare	0.824911
RSquare Adj	0.747094
Root Mean Square Error	0.426958
Mean of Response	10.44152
Observations (or Sum Wgts)	27

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	15.459373	1.93242	10.6006
Error	18	3.281277	0.18229	**Prob > F**
C. Total	26	18.740650		<.0001*

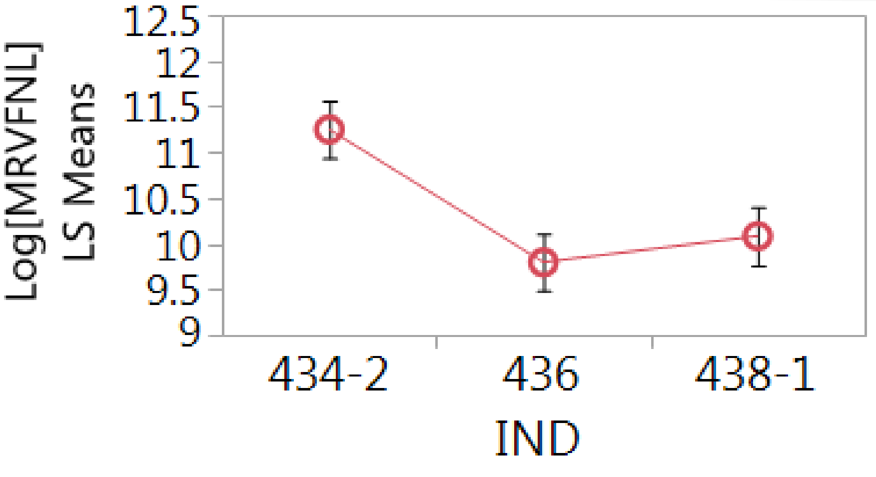
Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
IND	2	2	10.072512	27.6272	<.0001*
LTMSLAB	4	4	2.138079	2.9322	0.0498*
LTMSAPP[LTMSLAB]	2	2	1.427663	3.9158	0.0387*

LnMRV Oil Discrimination

436 is significantly lower than 434-2

438-1 is significantly lower than 434-2

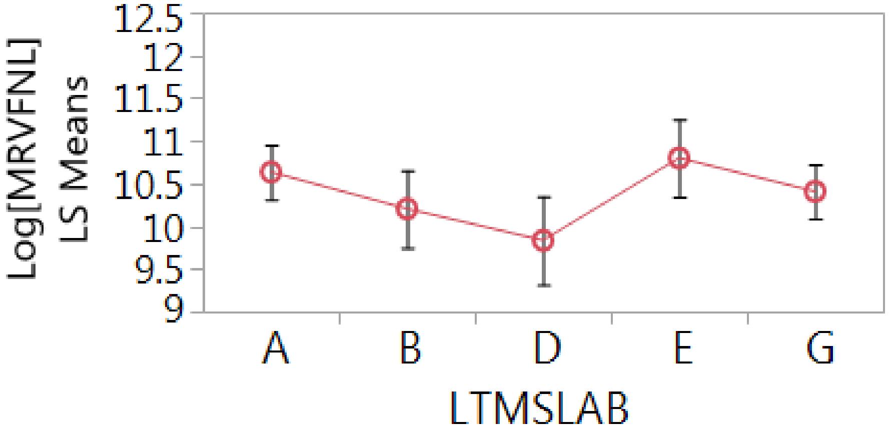


Oil1	Oil2	Difference	p-Value
434-2	436	1.4529	0.00
434-2	438-1	1.1673	0.00
438-1	436	0.2856	0.37

Oil	LnMRV LS Mean	MRV LS Mean
434-2	11.2520	77034
436	9.7991	18018
438-1	10.0847	23973

LnMRV Lab Difference

No significant lab difference

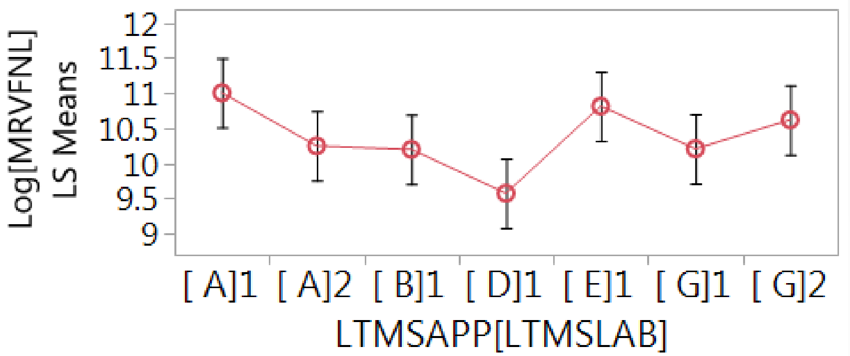


Lab1	Lab2	Difference	p-Value
E	D	0.9643	0.06
A	D	0.7990	0.08
E	B	0.5949	0.33
G	D	0.5729	0.31
A	B	0.4295	0.5
E	G	0.3915	0.58
B	D	0.3695	0.79
A	G	0.2261	0.83
G	B	0.2034	0.94
E	A	0.1653	0.97

Lab	LnMRV LS Mean	MRV LS Mean
A	10.6364	41623
B	10.2069	27089
D	9.8374	18721
E	10.8018	49109
G	10.4103	33200

LnMRV Stand(Lab) Difference

Stand A2 is significantly lower than Stand A1



Lab/Stand1	Lab/Stand2	Difference	p-Value
[A]1	[A]2	0.7578	0.02
[G]2	[G]1	0.3899	0.22

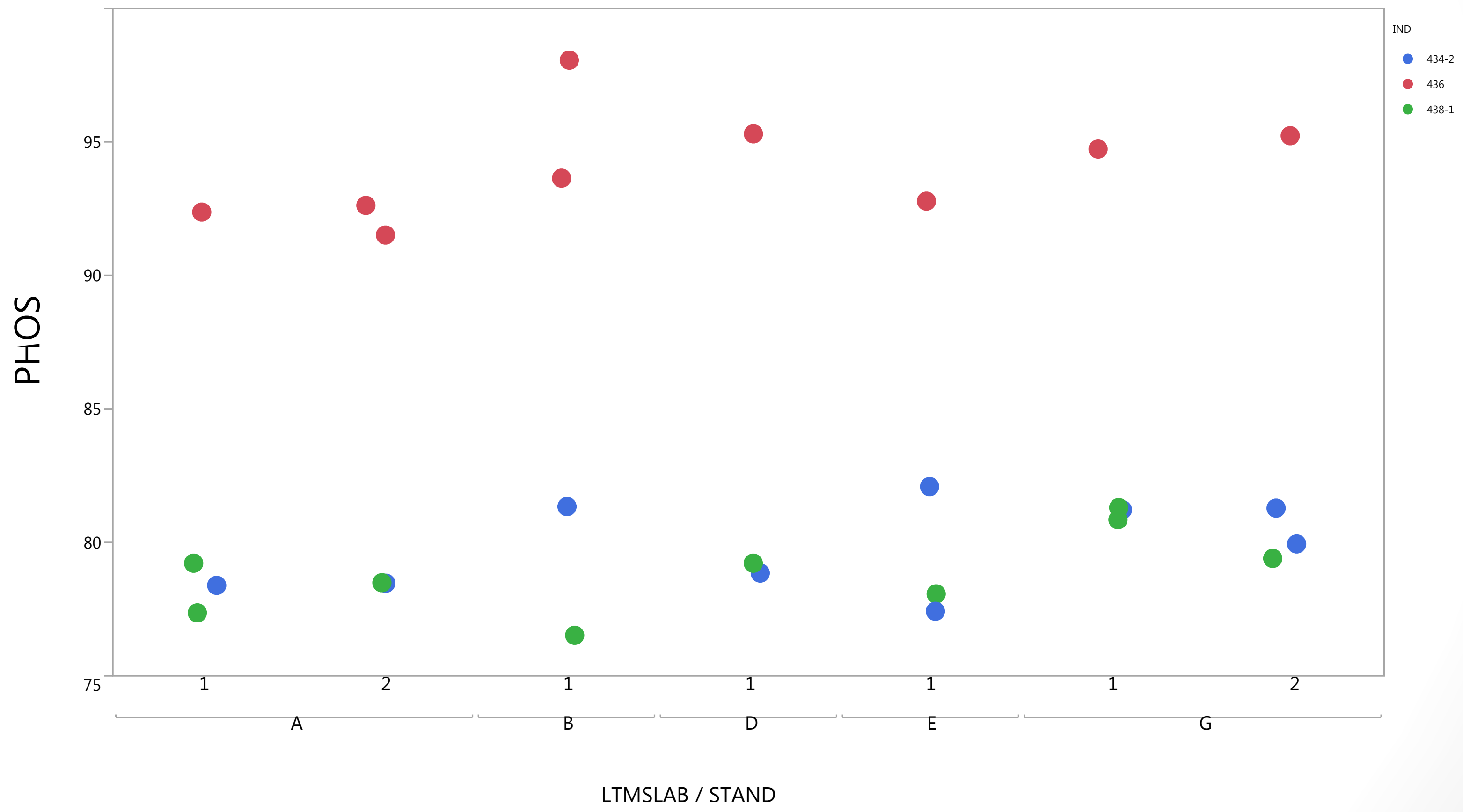
Lab/Stand	LnMRV LS Mean	MRV LS Mean
[A]1	11.0153	60797
[A]2	10.2576	28498
[G]1	10.2153	27318
[G]2	10.6053	40348

LnMRV Precision

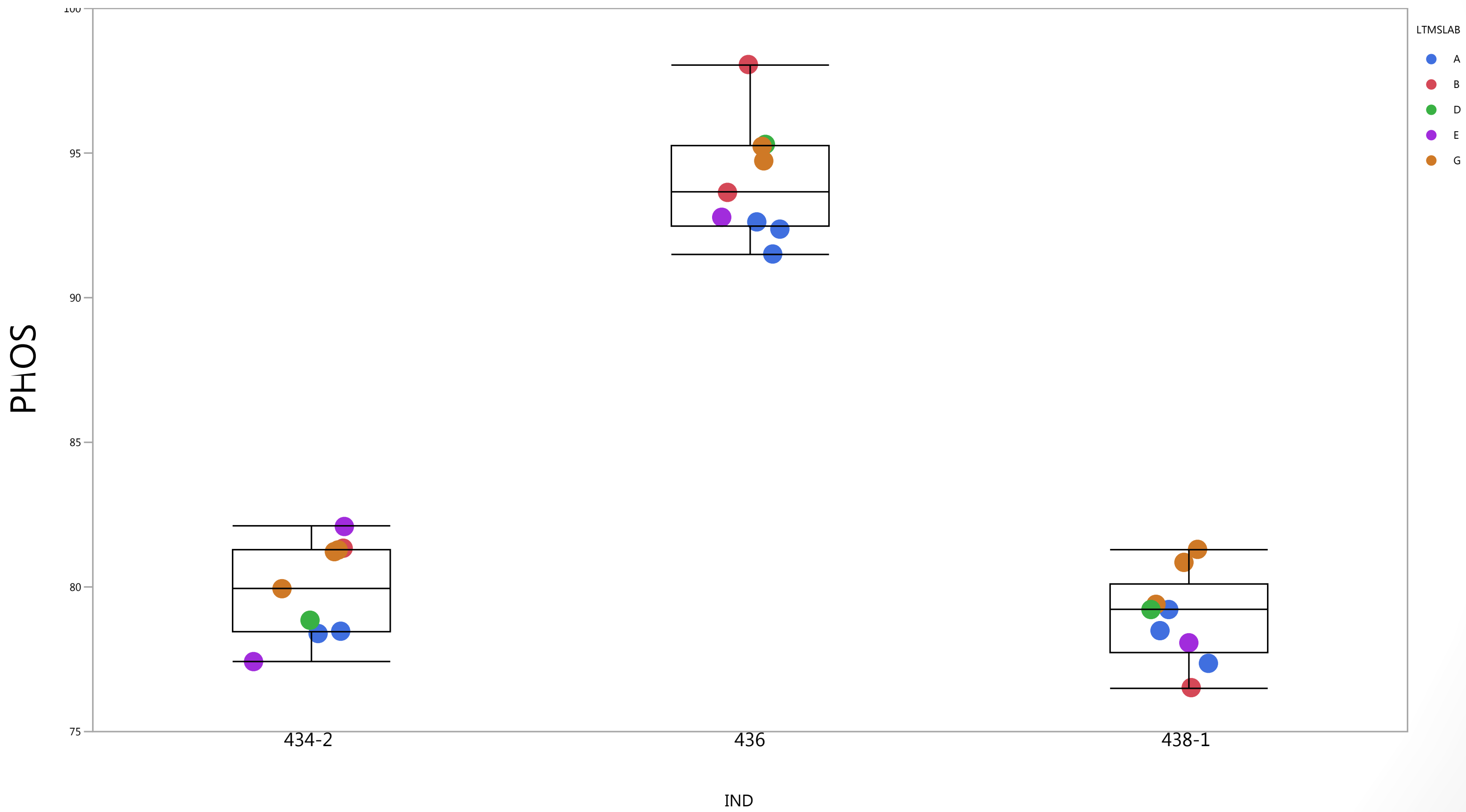
Model: Oil, Lab, Stand(Lab)

Model RMSE	Repeatability	Reproducibility
• s = 0.4270 • No IIIGA s	• s = 0.4270 • r = 1.1836	• s = 0.5332 • R = 1.4780

Phosphorus Retention



PHOS



PHOS ANOVA

Summary of Fit

RSquare	0.96727
RSquare Adj	0.952723
Root Mean Square Error	1.572013
Mean of Response	84.28407
Observations (or Sum Wgts)	27

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	1314.5782	164.322	66.4942
Error	18	44.4821	2.471	Prob > F
C. Total	26	1359.0603		<.0001*

Effect Tests

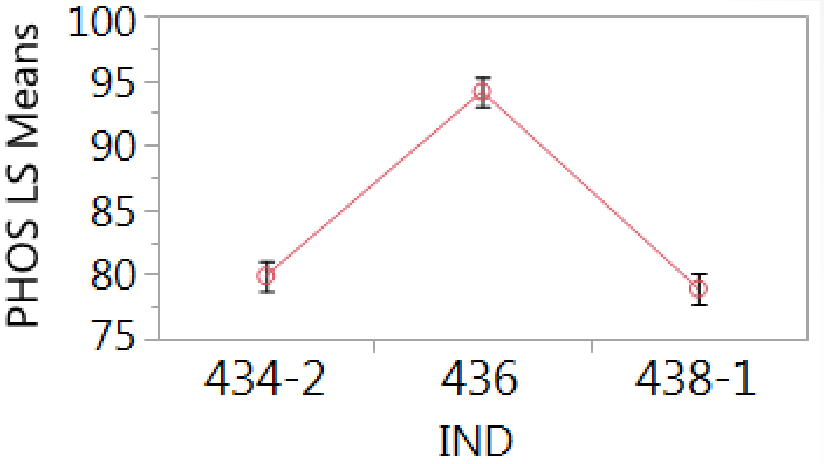
Source	DF	Sum of Squares	F Ratio	Prob > F
IND	2	1235.8765	250.0533	<.0001*
LTMSLAB	4	27.5381	2.7859	0.0581
LTMSAPP[LTMSLAB]	2	1.5231	0.3082	0.7386

Preliminary

PHOS Oil Discrimination

436 is significantly higher than 438-1

436 is significantly higher than 434-2

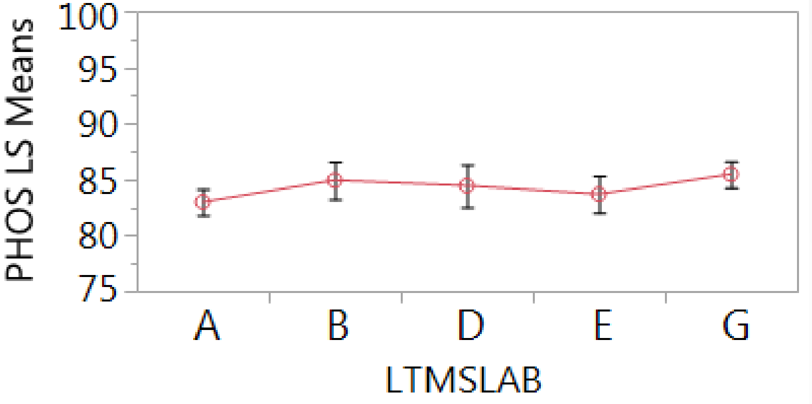


Oil1	Oil2	Difference	p-Value
436	438-1	15.24	0.00
436	434-2	14.25	0.00
434-2	438-1	0.99	0.42

Oil	PHOS LS Mean
434-2	79.89
436	94.14
438-1	78.90

PHOS Lab Difference

Lab A is significantly lower than Lab G

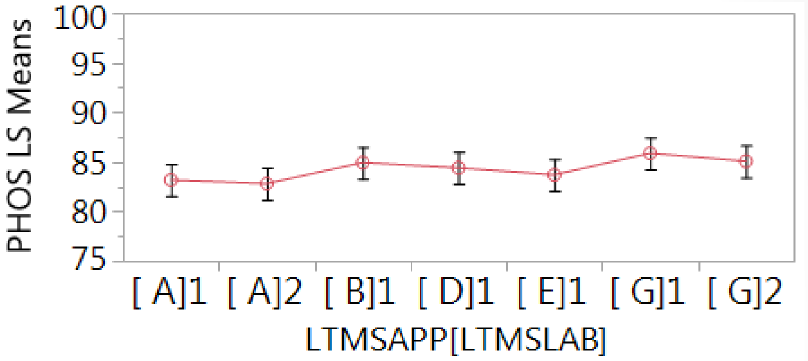


Lab1	Lab2	Difference	p-Value
G	A	2.47	0.04
B	A	1.93	0.31
G	E	1.78	0.38
D	A	1.46	0.66
B	E	1.24	0.81
G	D	1.02	0.87
D	E	0.76	0.97
E	A	0.69	0.95
G	B	0.54	0.98
B	D	0.48	0.99

Lab	PHOS LS Mean
A	83.00
B	84.93
D	84.46
E	83.70
G	85.47

PHOS Stand(Lab) Difference

No significant stand(lab) difference



Lab/Stand1	Lab/Stand2	Difference	p-Value
[G]1	[G]2	0.81	0.48
[A]1	[A]2	0.37	0.75

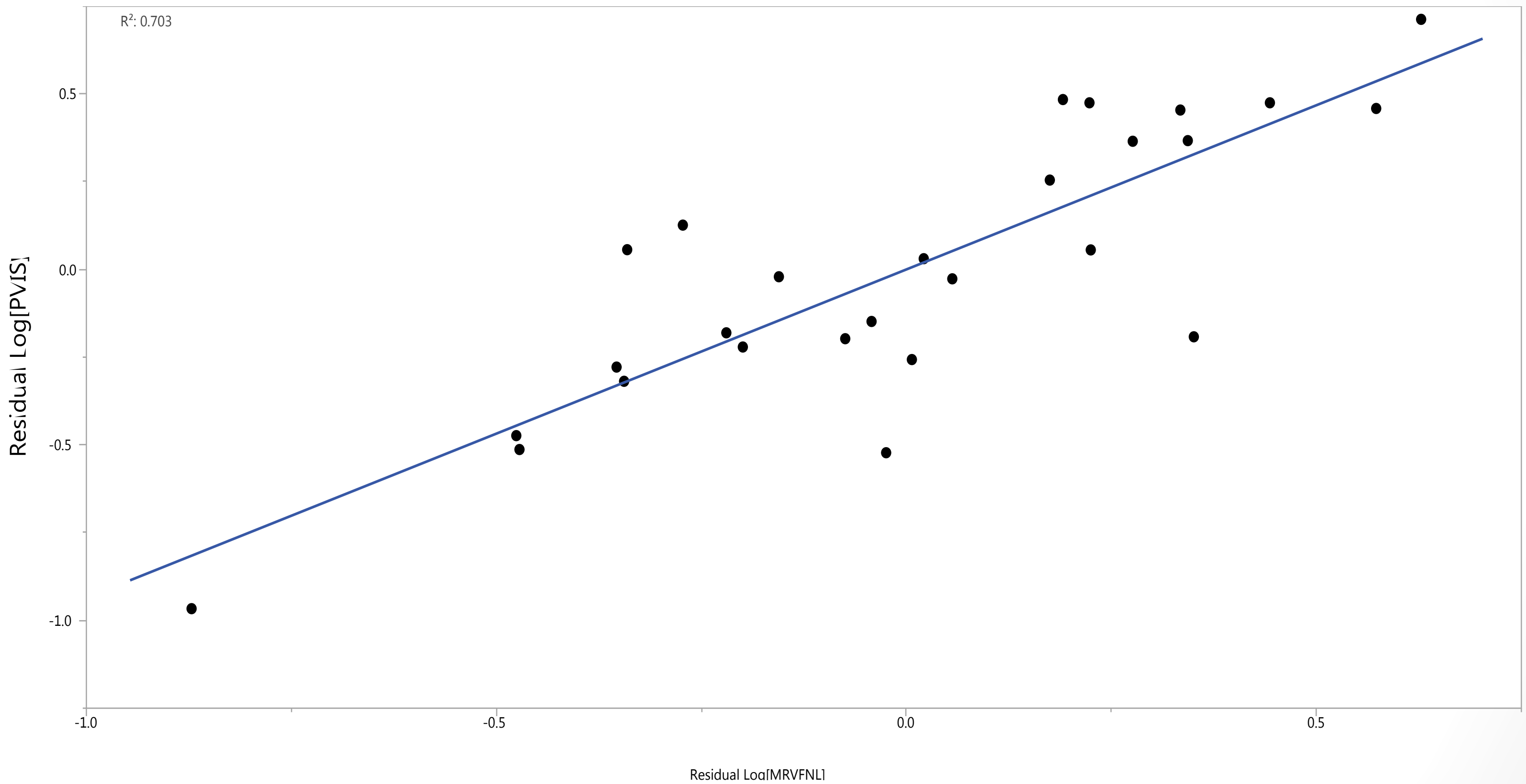
Lab/Stand	PHOS LS Mean
[A]1	83.19
[A]2	82.82
[G]1	85.88
[G]2	85.07

PHOS Precision

Model: Oil, Lab, Stand (Lab)

Model RMSE	Repeatability	Reproducibility
• s = 1.57 • IIIGB s=2.33	• s = 1.57 • r = 4.35	• s = 1.75 • R = 4.85

Correlation



PVIS and MRV are correlated

LTMS

ANOVA Factor	P-value			
	LnPVIS	WPD	LnMRV	PHOS
IND	0.00	0.00	0.00	0.00
LTMSLAB	0.07	0.29	0.05	0.05
LTMSAPP[LTMSLAB]	0.01	0.53	0.04	0.74

Looks like a Stand-based LTMS is appropriate for Sequence IIIH based on the Stand(Lab) factor being significant but a more detailed analysis of LTMS is needed to confirm this.

Reference Oil Targets

PERCENT VISCOSITY INCREASE Unit of Measure: LN(PVIS)					
IIIH			IIIG		
Reference Oil	LSMean	Standard Deviation	Reference Oil	Mean	Standard Deviation
434-2	4.7292	0.3943	434	4.7269	0.3859
436	3.3308	0.3138			
438-1	3.9773	0.9558	438	4.5706	0.1768

WEIGHTED PISTON DEPOSITS Unit of Measure: Merits					
IIIH			IIIG		
Reference Oil	LSMean	Standard Deviation	Reference Oil	Mean	Standard Deviation
434-2	4.12	0.67	434	4.80	0.96
436	4.62	0.28			
438-1	3.65	0.43	438	3.20	0.33

Reference Oil Targets

MRV VISCOSITY

Unit of Measure: LN(MRV)

IIIH			IIIGA		
Reference Oil	LSMean	Standard Deviation	Reference Oil	Mean	Standard Deviation
434-2	11.2520	0.52391	434	10.7881	0.45550
436	9.7991	0.24233			
438-1	10.0847	0.72094	438	9.8277	0.16646

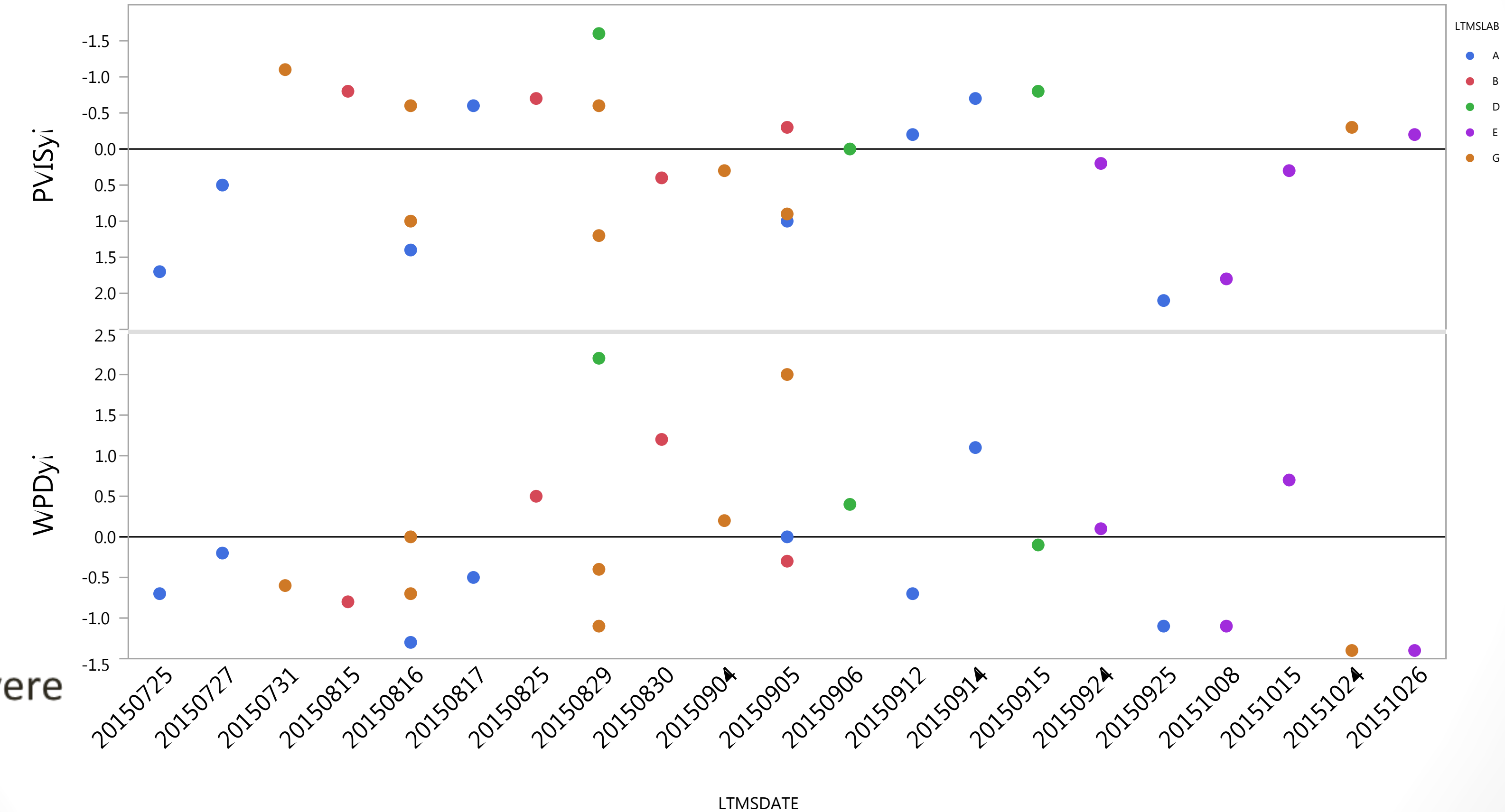
PHOSPHORUS RETENTION

Unit of Measure: Percent

IIIH			IIIGB		
Reference Oil	LSMean	Standard Deviation	Reference Oil	Mean	Standard Deviation
434-2	79.89	1.66	434	76.00	2.02
436	94.14	2.02			
438-1	78.90	1.54	438	78.20	2.56

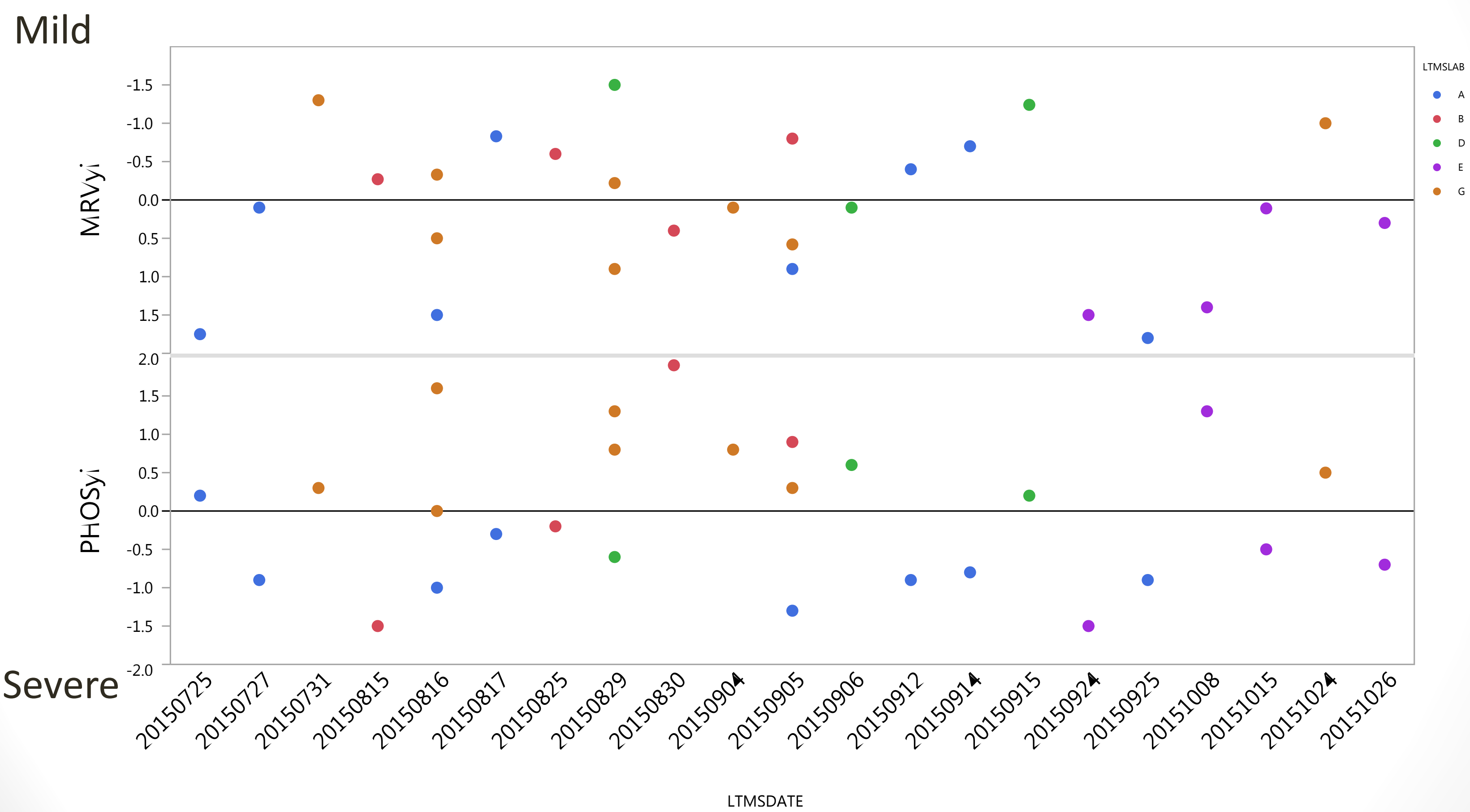
Industry Yi

Mild



Severe

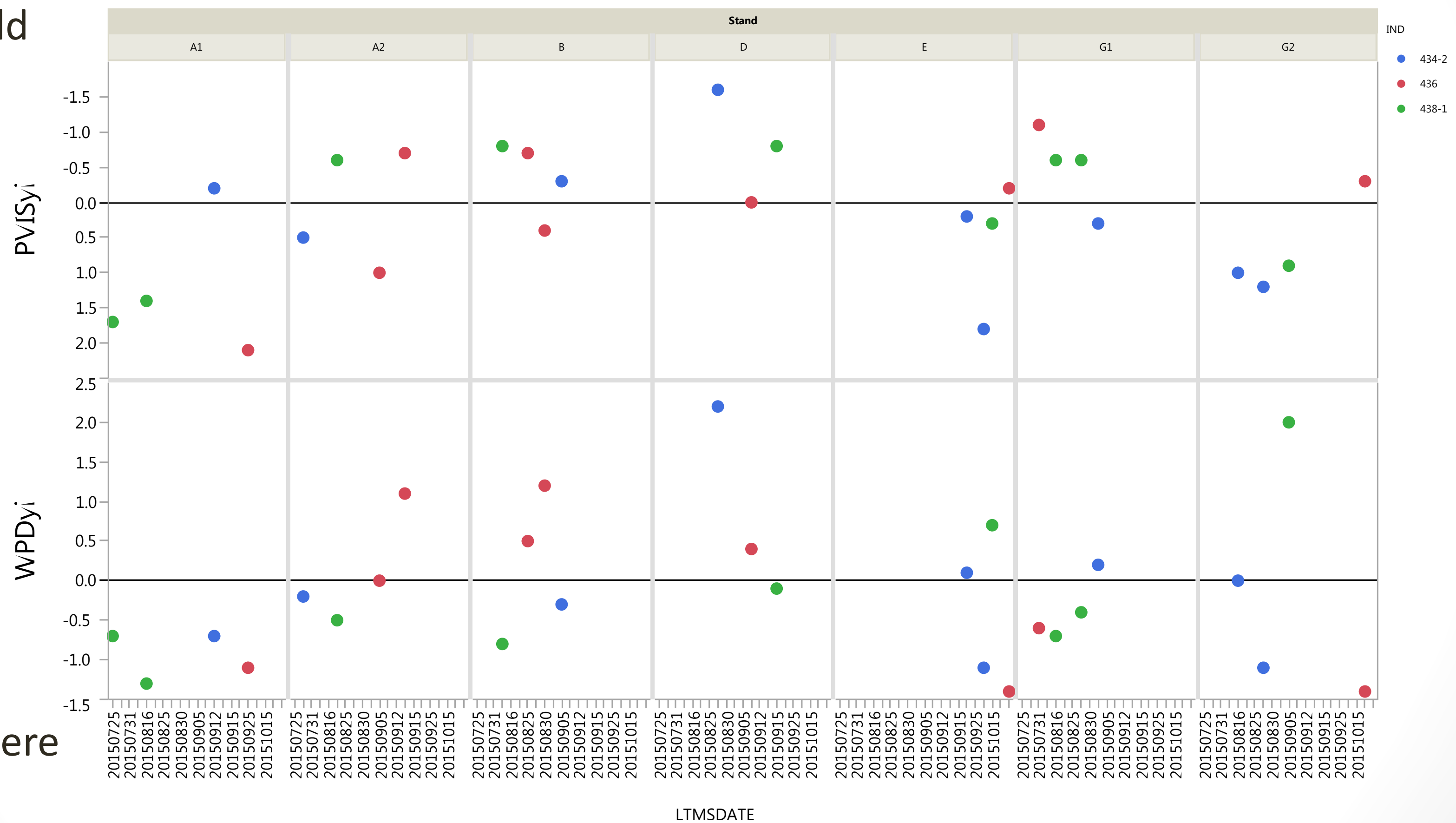
Industry Yi



Mild
Severe
MRVyi
PHOSyi
LTMSLAB
A
B
D
E
G
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
-2.0
20150725
20150727
20150731
20150815
20150816
20150817
20150825
20150829
20150830
20150904
20150905
20150906
20150912
20150914
20150915
20150924
20150925
20151008
20151015
20151024
20151026
LTMSDATE

Stand Yi

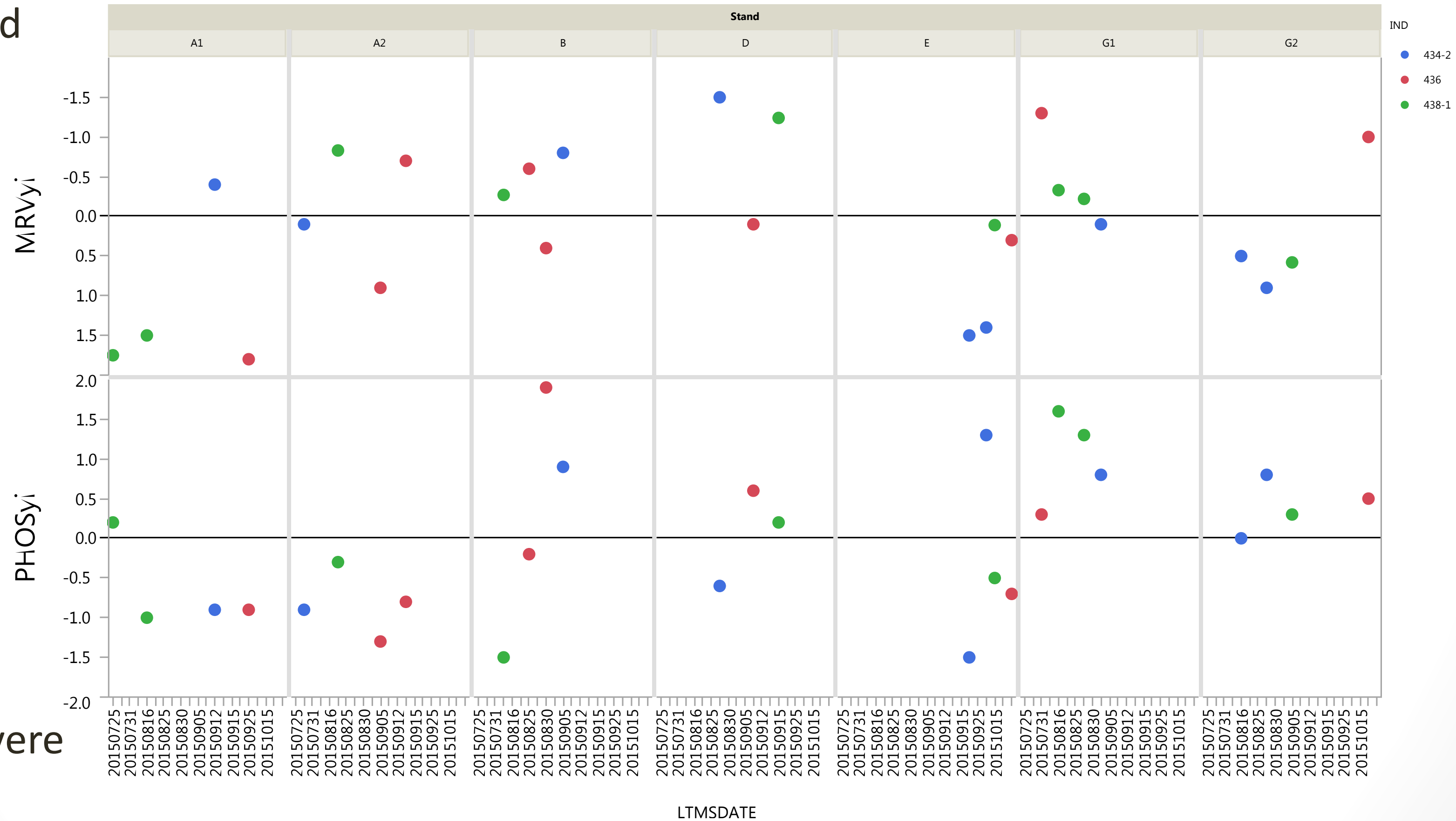
Mild



Severe

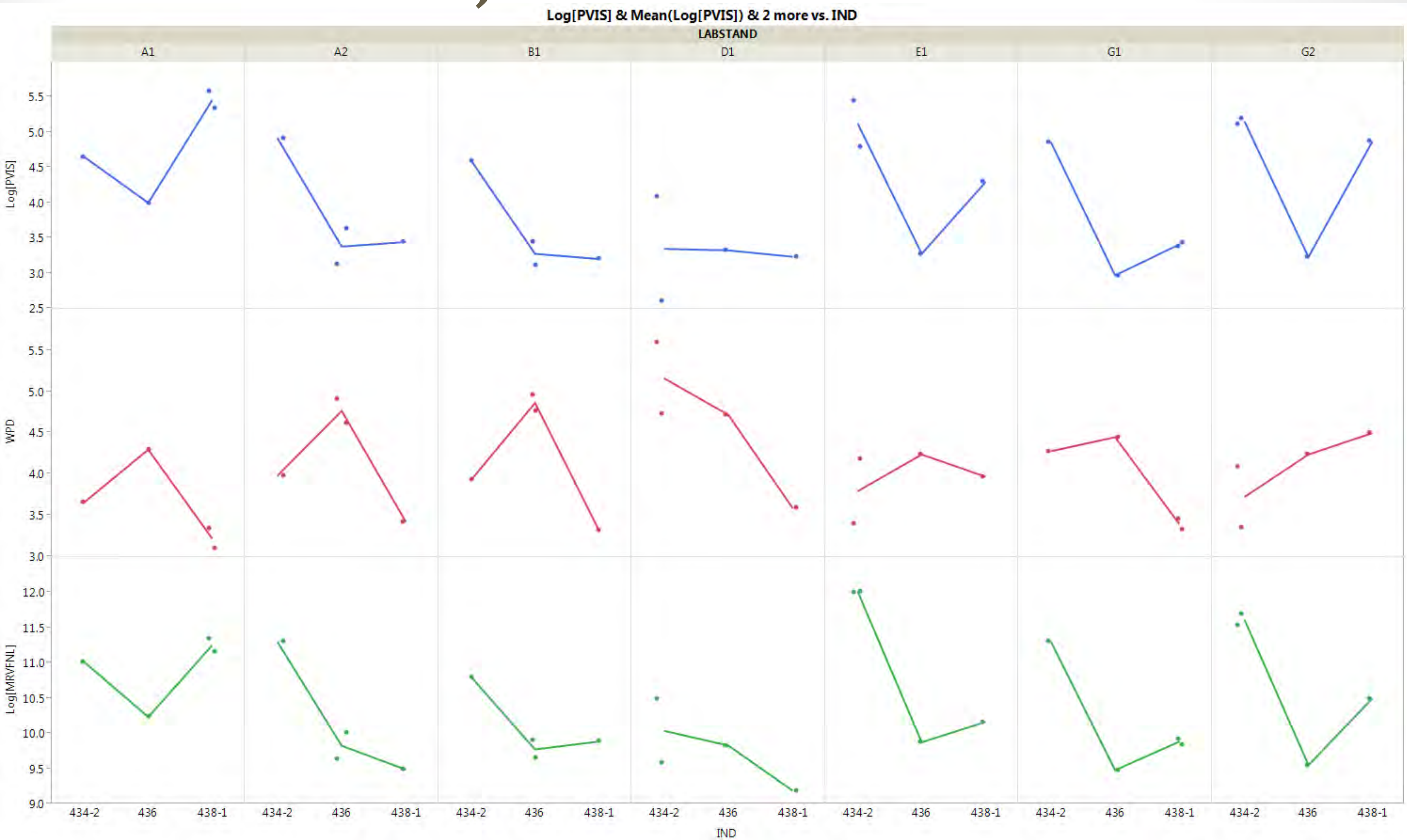
Stand Yi

Mild



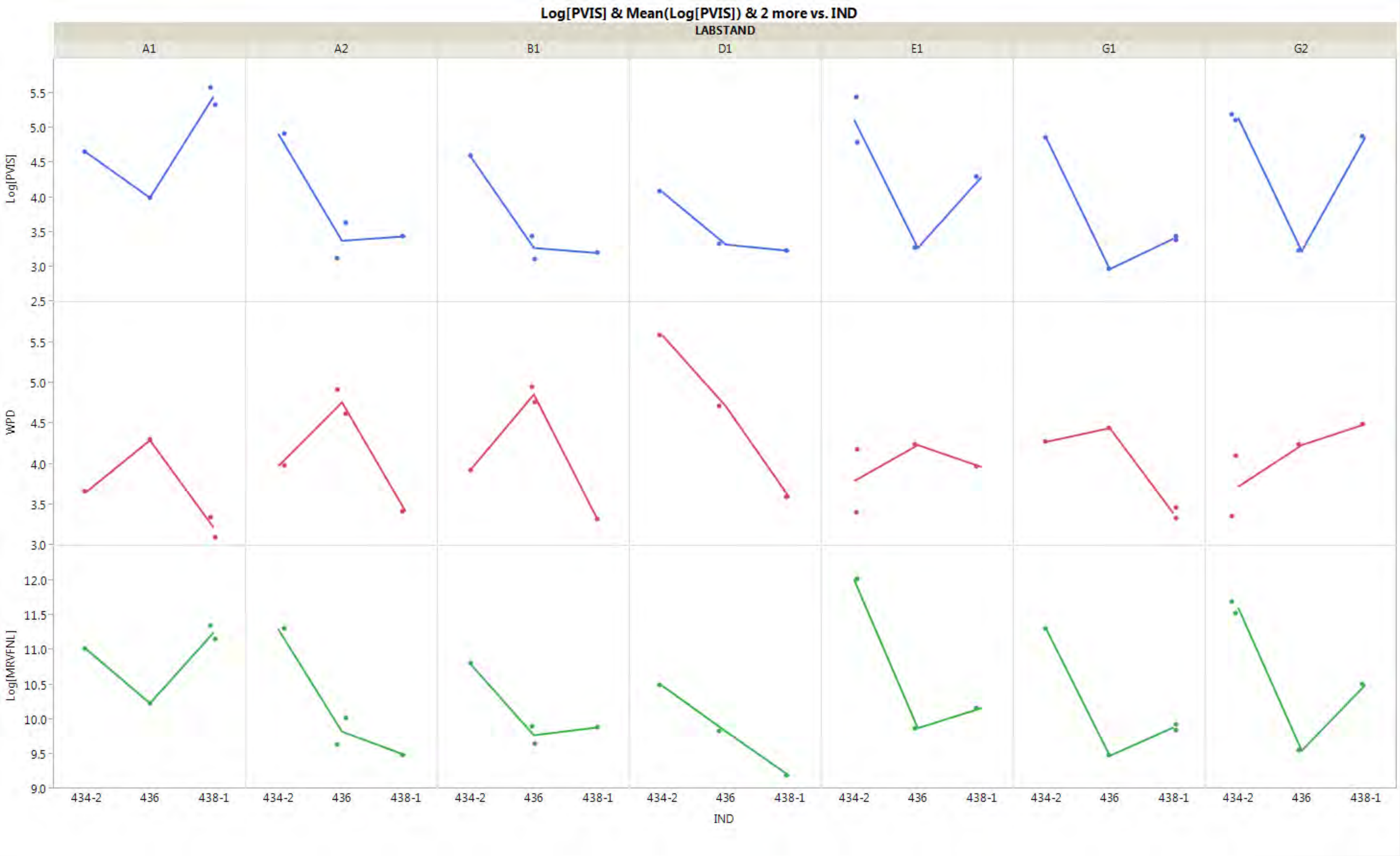
Severe

Concern 1, n=28



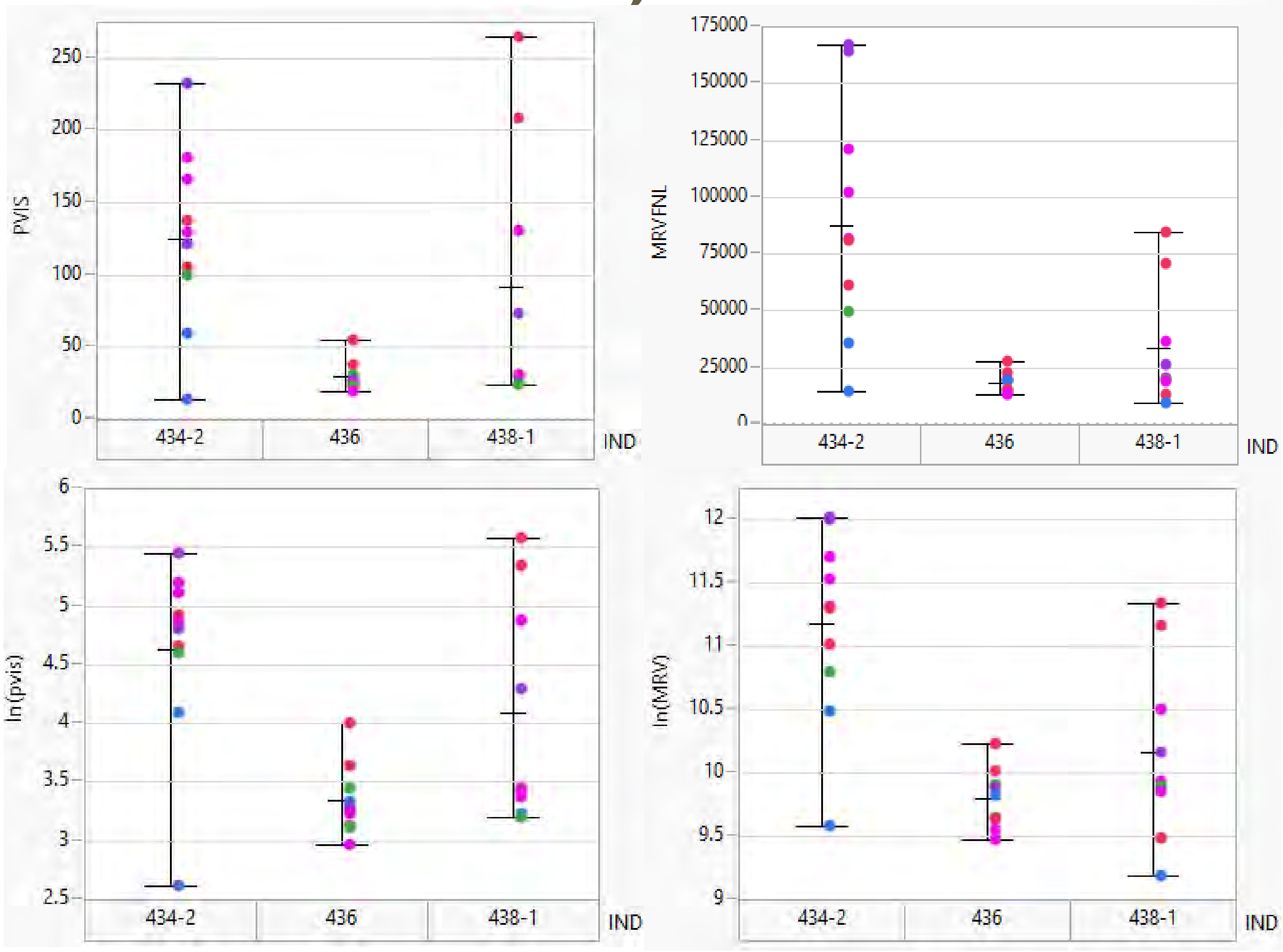
Stands do not discriminate the same way

Concern 1, n=27



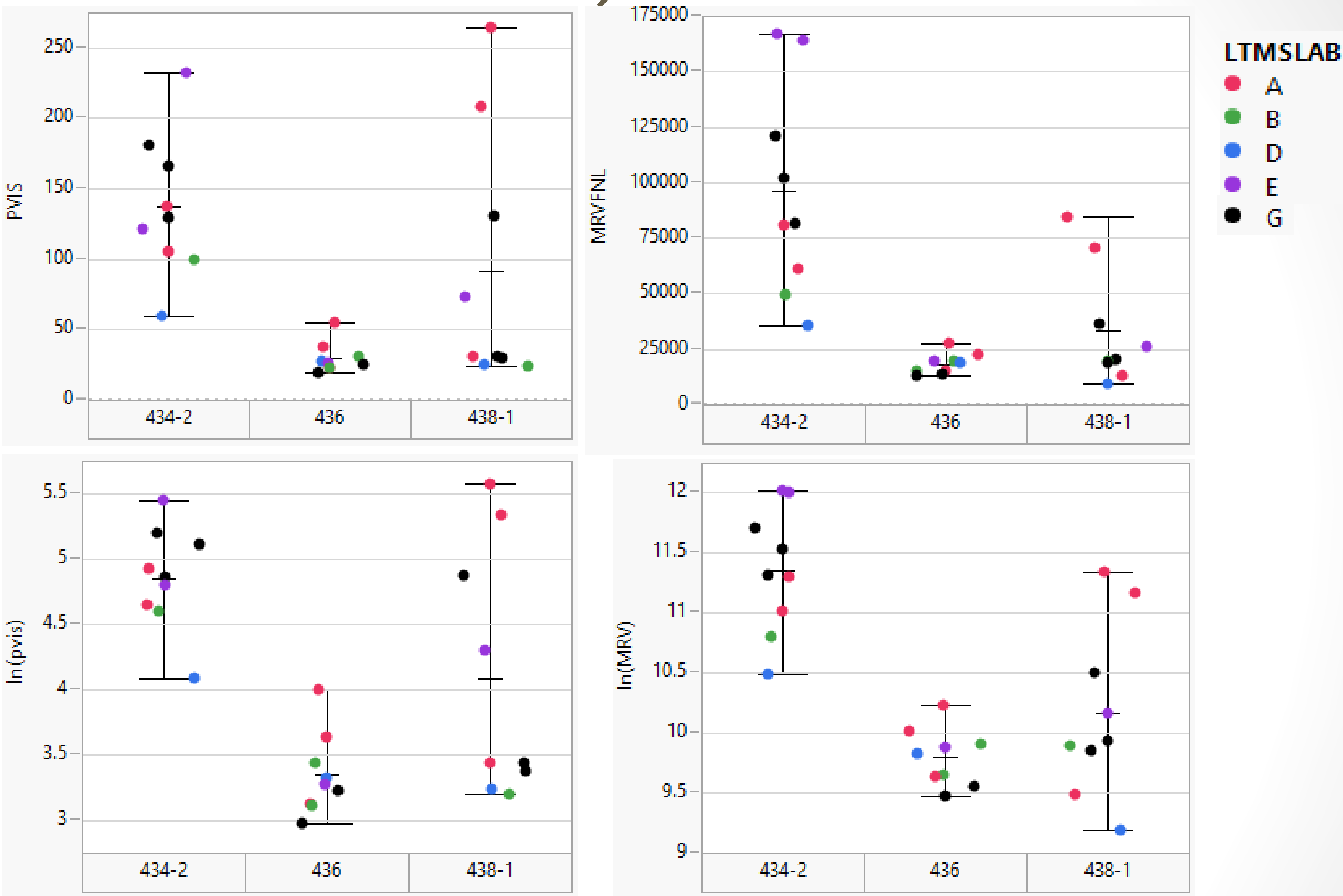
Stands do not discriminate the same way

PVIS Concern 2, n=28



If 434-2 is meant to be a failing oil, then will PVIS and/or MRV be adequate parameters to ensure failing oils won't pass and passing oils won't fail?
Is the test severe enough for PVIS to consistently reflect that 434-2 "breaks"?

PVIS Concern 2, n=27



If 434-2 is meant to be a failing oil, then will PVIS and/or MRV be adequate parameters to ensure failing oils won't pass and passing oils won't fail?
Is the test severe enough for PVIS to consistently reflect that 434-2 "breaks"?