IIIH Task Force Conference Call February 27, 2015

Attendees:
Chrysler: Haiying Tang, Jeff Betz
Intertek: Adison Schweitzer, Charlie Leverett, Bill Buscher
Lubrizol: George Szappanos, Kevin OMalley, Michael Conrad
Afton: Ed Altman, Bob Campbell
SwRI: Karin Haumann, Sid Clark, Janet Buckingham, Pat Lang, Michael Lochte
Ashland: Amol Savant, Tim Caudill
Infineum: Mike McMillan, Andy Ritchie, Gordon Farnsworth, Doyle Boese
Shell: Scott Lindholm, Jeff Shu
Oronite: Kaustav Sinha, Joe Martinez
IMTS: Dave Passmore
OHT: Matt Bowden, Jason Bowden
TMC: Rich Grundza
Ford: Ron Romano
GM: Bruce Mathews, Andy Buczynsky

Karin opened the meeting with a review of the agenda. (See Attachment #1)

Agenda Action Item 1:
Janet provided an overview of the analysis she performed looking at the data from the past twelve months including PVIS and WPD for the Sequence IIIG as requested from the last meeting. This presentation includes all tests using Stellite Seat Heads in the IIIG.
(See Attachment #2)

Janet reviewed the PVIS and WPD Summary Slides (2 &3)
Note: there is a typo change on slide 3 as noted by Janet during her presentation and an asterisk and accompanying note at the bottom of the slide by the secretary during the writing of these minutes.

Janet then reviewed slides 4 through 9 going over the analysis for PVIS on both the IIIG and IIIH tests.

Janet fielded questions after slide 9 on the PVIS analysis for the IIIG and IIIH.

- Scott Lindholm asked if the data in slide #6 might indicate 434-2 might be different than 434-1.
    - Janet replied indicating 434-2 had a small data set and you need to look at each p value in the table and change the cut off to look for significant differences.
- Doyle Boese asked if Janet was taking multiple comparisons into account.
    - I believe Janet answered yes.

- Andy Buczynsky asked if Janet could tell how the variability on 434-1 compares between the IIIG and IIIH.
    - Janet replied the model did not look at variability of specific oils.
    - Janet indicated she could run an analysis on 434-1, but indicated there was a small sample size between the two tests.

Action Item: Janet will run an analysis on the variability of 434-1 between the IIIG and IIIH tests.

- Addison asked if Janet could send this presentation to martin Chadwick at Intertek.

Action Item: Janet will forward the data to Martin Chadwick at Intertek and the industry stats group.

Janet returned to her presentation picking up at slide 10 with a review of her model for the WPD analysis. After explaining the data set used for the analysis, Rich Grundza asked if her explanations were in the summary, Janet responded she did not have the full explanation in the presentation but would send a summary to the group later.

Action Item: Janet will send a summary of her data set models to the group in a separate email.

Janet went through slides 10 through 16 explaining the IIIG data fielding questions as she explained each slide. Rich Grundza asked if Janet had performed a Box Cox analysis on the data and Janet replied she had but it did not provide good information on what the transformation should be.

Janet next reviewed the data for the IIIH WPD from slide 17 through slide 19 again explaining each slide. After finishing with slide 19, Janet informed the group that everything after slide 19 was copy of last week's presentation and she included it so everyone would have all the data presented.

Janet next went back to the beginning slides and reviewed her summary of all the models and analysis for PVIS and WPD on both the IIIG and IIIH analyses.

After a lengthy explanation of Lab / Stand variables / Residuals / RMSE values and a summary that 434-1 < REO2 < REO3, Janet asked if there were any questions on the WPD Analyses.

Doyle Boese simply said "Good Job Janet".

Karin picked up the call reviewing the AOAP Action Items starting with the first item

1. *Hours to PVis data on the IIIG and comparison of variability between the IIIH and IIIG –*
    a. *Statistical analysis presented on the February 20 conference call showed a direct comparison of PVis on the two tests with regard to oil, lab and stand effects.*
    b. *WPD analysis is being conducted along repeating the previous analysis of PVis on the IIIG excluding all tests prior to February 2014 per GM's request.*

c. *Statisticians advised exploring hours to PVis as a pass/fail criterion after the matrix is complete to have a large enough data set to generate a model.*

Karin reviewed last week's analysis commenting on Today's additional data analysis presentation by Janet on the past 12 months of test activity in the Sequence IIIG covering both WPD and PVIS. Karin discussed hours to PVIS indicating the statisticians have suggested this would have to come out of the precision matrix as decided last week.

Karin asked if there were any additional questions from the first point on the AOAP motion, hearing none, Karin moved on to the second agenda item.

2. *Hardware availability – Task Force discussion on the February 16 conference call focused on the labs agreeing to reduce the size of the first reference period. There was a general consensus about the idea pending a full inventory of available hardware. There are 72 sets of hardware available.*

Andy Ritchie asked if the labs have agreed to shorten the first reference period. Karin indicated the lab agreement was the first step, however if this needs to be discussed at a higher level we could continue this discussion. Ed Altman explained our intent to use some of the reference oil 438 tests as part of the precision matrix runs. Ed reviewed the number of sets of hardware for the group; 72 sets of parts, 28 sets for precision matrix with 5 runs before the matrix. Karin commented the desire is to get approval for the 438 tests to be counted as part of the matrix so they don't have to be run twice. If everything goes according to plan there would be 35 tests available after the matrix for candidate testing. Plans are to have additional hardware available by the end of the precision matrix.

Bruce asked why the urgency to run the precision matrix as soon as possible. Karin commented the desire was to give Chrysler direction on the engine before model year change over. Jeff Betz explained the plans for storage and packaging indicating the engines are going to be available but getting someone to sign off on the run in June or July might be difficult. Jeff indicated the engines could still be run out as late as July or August but he needs to get internal agreement before June / July.

Bob Campbell explained the issues realized in the Heavy Duty group indicating if everything goes well, it would take 5 to 6 weeks to run the matrix with about 8 weeks to review the data. The group discussed timing and agreed we need to establish a timeline for the matrix program.

Action Item: Chrysler and the Development Group along with the critical part suppliers and the task force need to establish a timeline for running the precision matrix, analysis, and hardware availability.

The group continued discussion with Bob Campbell asking where is the depository for all the prove-out data. Rich Grundza commented the data is at the TMC however, labs are still sending in the data. Kevin OMalley questioned how long it would take for blending of the reference oils and Rich confirmed all oils were in-house and pre-positioned at the labs. Kevin, Bob, and Rich

continued discussion about review of the operational data and the importance of data reporting in the same format from all labs to make the review simpler.
The group continued discussion about timing and the challenges of running the precision matrix, performing the analysis, looking at controlled and non-controlled parameters, statistical variation and what happens if the variation from one lab is too far out. Rich Grundza offered up the possibility that part of the matrix could possibly need to be re-run.

At this time in the discussions, Kaustav Sinha suggested the group focus on the motion we are trying to resolve.

5 *Resolve thermocouple location issue –*

a. *The labs met in San Antonio this week, and went through each thermocouple location and placement requirements to ensure consistency between labs.*
b. *All tests run with the new thermocouple location have been run with a set point of 151 deg. A review of the oil temperature data by both Afton and SwRI statisticians has been done in an effort to confirm this change has not negatively affected the test.*

Karin explained the work done at SwRI over the past week with all the engineers from each laboratory meeting at SwRI to review all the thermocouple locations and insertion depths. Karin also explained the decision to locate the oil temperature control thermocouple 14 mm down from the top of the main oil gallery under the oil cooler. Karin explained the group had run five tests controlling the oil gallery temperature at 151°C using this new location. The group compared uncontrolled parameter temperatures, realizing there were questions about some of the sump temps and oil pump out temperatures that were lower than the control set point during test operation. Janet commented Karin had asked her to look at the tests to see if there was an effect on WPD and PVIS between these tests and Janet indicated she ran one model on the IIIH sump temperature data and could not find a significant outlier or a negative effect on the test. Ed Altman indicated Afton looked at the data and concluded it looked like 151°C was a good control point for the oil gallery set point.

At this time the conversations about sump temperatures, gallery temperatures, oil pump temperatures, and whether they were higher or lower got out of hand and Karin finally indicated the focus of the labs getting together this past week was to review and agree on measurement of the questionable temperatures and how to move forward.

The secretary indicated he had stopped trying to capture the context of the conversation.

Rich Grundza finally suggested everyone submit all their calibration data to the TMC and he will make it available on the website for everyone to review. Ed Altman, Karin, and Rich agreed everyone should calibrate their IIIH stand prior to running any reference oil 438 tests.

Action Item: Labs will calibrate their test stand prior to starting their reference oil 438 tests and forward the calibration data to Rich Grundza at the TMC.

The group discussed efforts in San Antonio with all five lab engineers to review thermocouple location and insertion depths for the IIIH. Discussions focused on using the thermocouple location in the main oil gallery below the oil cooler. Karin fielded questions about tests run using this new location and explained that although they were not exactly in the same position, in general they were in the same area and the data agreed. Karin also explained a fixture apparatus has been fabricated for locating, drilling, tapping, and installing the thermocouple fitting in the main oil gallery in the same exact position for every test.

Motion: Karin Haumann / Scott Lindholm

Karin made the motion that AOAP Action Item Number Five (see italicized text) has been resolved.

5 *Resolve thermocouple location issue –*

- *c. The labs met in San Antonio this week, and went through each thermocouple location and placement requirements to ensure consistency between labs.*
- *d. All tests run with the new thermocouple location have been run with a set point of 151 deg. A review of the oil temperature data by both Afton and SwRI statisticians has been done in an effort to confirm this change has not negatively affected the test.*

Discussion:
Bruce Matthews asked if the position for the main oil gallery had been resolved and nothing else needed to be discussed. Karin responded yes the positioning had been resolved.

Haiying Tang asked if Afton was in agreement with the new location as there had been some indication of concern expressed at the AOAP meeting by Afton. Bob Campbell responded with comment that Afton was alright with this decision.

Karin asked whether we needed to call the question individually or could we just ask if there were any negatives, Karin asked if there were any negatives and hearing none the motion was considered a unanimous pass.

Karin moved back to Agenda Item #2 for continued discussion.

2 *Hardware availability – Task Force discussion on the February 16 conference call focused on the labs agreeing to reduce the size of the first reference period. There was a general consensus about the idea pending a full inventory of available hardware. There are 72 sets of hardware available.*

Discussion on this subject involved many comments focused on shorter reference period testing and the fact that a new batch of pistons and rings would be introduced into the data with a small N=size of candidate tests to base any shift in performance against. Andy Ritchie

commented he felt there would not be enough matrix batch material hardware to complete a full candidate test program before the introduction of newer batch materials. Bob Campbell expressed concern about any shift in performance and the fact that the industry would have to deal with that shift for the life of the category.

Rich Grundza reminded everyone that historically, we have accomplished running batch changes in materials in the Sequence III test since introduction and only time we made special documentation of changes have been when there has been a known change to the test procedure, hardware material specifications, or supplier changes.

Discussion continued focused on the understanding the matrix would not start until after approval from the AOAP at the March 19 meeting and when the Matrix would actually start.

Ed Altman asked OHT when the materials might actually be available and Jason replied the piston rings were expected around mid-April with the pistons possibly earlier.

Karin reminded the current focus was to allow the 438 runs to be part of the matrix and start the actual matrix the third week of March.

Michael Conrad suggested Karin work with the group to put together a timeline to back calculate when the Matrix might have to start in order to meet Chrysler's concerns. Karin agreed to work with Scott and Chrysler to construct a timeline that could be reviewed during the next call.

Karin moved conversation to AOAP Agenda Action Item number three for discussion.

3 *Additional testing on 434-2 to resolve inter lab variability –*
   a. *Statistical analysis of IIIH variability conducted with and without data from the "severe" lab shows the variability of the test does not decrease by excluding the lab.*
   b. *Labs are working together to identify any potential lab differences.*

The group discussed the need to run additional testing on Reference Oil 434-2. Karin asked Ron Romano to comment as this was part of his action item from the AOAP Motion. Ron commented he doesn't think running additional tests on 434-2 are needed as Janet's review showed that if it is different, which it looks like it will be, it really doesn't mean there are lab variables. Ron Romano concluded he is OK with the proposed resolution for AOAP Action Item number three as tests on 434-2 will be part of the precision matrix.

Motion: Scott Lindholm / Ron Romano

Based on the SwRI analysis of the IIIG and IIIH, no additional testing on 434-2 prior to the matrix as requested in AOAP Action Item #3 is required as it will be addressed in the precision matrix.

Discussion;
The group discussed Janet's analysis with comment from Bruce Matthews, Andy Buczynsky, Ron Romano, Scott Lindholm, Bob Campbell, and Andy Ritchie. Comments focused on not having actual 434-1 to use for investigations, consuming matrix hardware on 434-2 runs to look into variability of 434-1 tests.

Karin summarized everyone's comments saying the intent is to go back to the AOAP saying no further testing on 434-2 is needed as variability on this item is being addressed statistically and operationally at the labs. Both Scott and Ron agreed as motioner and seconder of the original motion.

Karin asked if there was any further discussion, hearing none she asked if there were any objections to the motion.

Hearing none, the motion passed unanimously.

Karin next opened discussion on Reference Oil 438 testing addressing AOAP Action Item number four.

4 *Two tests on oil 438 at each participating lab –*
a. Hardware constraints preclude 2 tests per lab prior to starting the matrix.
b. A minimum of 3 tests on 438 will be run prior to the next AOAP meeting to evaluate the data.

Discussion:
Another lengthy discussion ensued about who would run the 438 tests and whether we needed two runs at each lab, could they be considered part of the precision matrix, could we actually wait for the large batch hardware, etc. Ron Romano agreed 3 tests on Reference Oil 438 would be acceptable if they all produced lower WPD results than the other oils.

Final resolution on this topic resulted in another motion:

Motion: Scott Lindholm / Ron Romano

AOAP Action Item to run additional testing on Reference Oil 438 will be addressed by running three tests; one each at three volunteering labs and the data will determine whether additional testing is needed.

Discussion focused on the same comments as mentioned above with additional comment from Bob Campbell recommending the labs look at available data to determine whether they need to address any additional parameters prior to running the 438 tests.

Karin followed the same format asking if there were any objections to the motion.

Hearing none, the motion passed unanimously.
The group discussed tabling AOAP Action Items #1 and #2 until the next meeting.

Mike McMillan asked where the minutes form the task force conference calls could be found. Sid commented the minutes are posted on the TMC website and he would forward a link to everyone on the call. Mike suggested we forward that link to everyone upon posting each set of minutes.

Bruce Matthews asked if GM could be provided Sequence IIIG Test Results on REO2 and the response was the supplier had supplied a range of data not the actual test results.

Karin agreed to ask the supplier if they would be willing to share the actual data.

Bob Campbell asked how the group should handle earlier test results on Reference Oil 435.

Ron Romano fielded the comment indicating the NOAK Volatility of REO435 was above 15% and the therefore would preclude it from passing GF-6 requirements. Andy Ritchie commented he felt that was the same for Reference Oil 438.

Karin indicated we would save these discussions for the next meeting and adjourned the call at 1:24PM

Action Items:

1) Janet will run an analysis on the variability of 434-1 between the IIIG and IIIH tests.
2) Janet will forward the data to Martin Chadwick at Intertek and the industry stats group.
3) Janet will send a summary of her data set models to the group in a separate email.
4) Chrysler and the Development Group along with the critical part suppliers and the task force need to establish a timeline for running the precision matrix, analysis, and hardware availability.
5) Labs will calibrate their test stand prior to starting their reference oil 438 tests and forward the calibration data to Rich Grundza at the TMC.
6) Sid will send a link to the TMC Chrysler IIIH Task Force Minutes to the group.

This is a compilation from notes recorded during the call, with comments from member participants during the Draft Review. Certain subjects may not necessarily be in exact order; however, they are believed to represent an accurate account of the call. If anyone feels changes or additional content may be necessary, please contact Sid Clark @ 586-873-1255 or Sidney.Clark@swri.org

Thanks, Sid

Sequence IIIH Task Force
February 27, 2015
10:00 pm CST
Call-in Number: 866-588-1857
Conference Number: 8186490

AOAP Motion Action Items:

Here is a summary of where the task force is on the AOAP action items

1. Hours to PVis data on the IIIG and comparison of variability between the IIIH and IIIG –
    a. Statistical analysis presented on the February 20 conference call showed a direct comparison of PVis on the two tests with regard to oil, lab and stand effects.
    b. WPD analysis is being conducted along repeating the previous analysis of PVis on the IIIG excluding all tests prior to February 2014 per GM's request.
    c. Statisticians advised exploring hours to PVis as a pass/fail criterion after the matrix is complete to have a large enough data set to generate a model.
2. Hardware availability – Task Force discussion on the February 16 conference call focused on the labs agreeing to reduce the size of the first reference period. There was a general consensus about the idea pending a full inventory of available hardware. There are 72 sets of hardware available.
3. Additional testing on 434-2 to resolve inter lab variability –
    a. Statistical analysis of IIIH variability conducted with and without data from the "severe" lab shows the variability of the test does not decrease by excluding the lab.
    b. Labs are working together to identify any potential lab differences.
4. Two tests on oil 438 at each participating lab –
    a. Hardware constraints preclude 2 tests per lab prior to starting the matrix.
    b. A minimum of 3 tests on 438 will be run prior to the next AOAP meeting to evaluate the data.
5. Resolve thermocouple location issue –
    a. The labs met in San Antonio this week, and went through each thermocouple location and placement requirements to ensure consistency between labs.
    b. All tests run with the new thermocouple location have been run with a set point of 151 deg. A review of the oil temperature data by both Afton and SwRI statisticians has been done in an effort to confirm this change has not negatively affected the test.

Next Meeting

TBD

PVIS and WPD Analyses for IIIG and IIIH

Janet Buckingham, SwRI

2/27/15

PVIS Summary

- All models included Oil, Lab and Stand(Lab)
- Used 5% level of significance

IIIG			IIIH		
Model	Oil Discrimination	RMSE	Model	Oil Discrimination	RMSE
#1 (n=154) All data Original cylinder heads	438 < (435,435-2,434-1)	0.53	#1 (n=18) All Data Final hardware	REO3 < REO2 < 434-1	0.44
#2 (n=150) Removed 4 outliers Original cylinder heads	438 < (435,435-2,434-1) 434-1 < 435-2	0.40	#2 (n=17) Removed LZ Oil 434-1 with PVIS=754.7 Final Hardware	REO3 < REO2 < 434-1	0.40
#3 (n=150) Removed 4 outliers Combined 435 oils Original cylinder heads	438 < 434-1 < 435	0.40	#3 (n=13) Removed all LZ results Final hardware	(REO2,REO3) < 434-1 Note: only 1 test at REO3	0.44
#4 (n=75) Last 75 ref tests Original cylinder heads	438 < (435-2,434-1)	0.63			
#5 (n=74) Last 75 ref tests Removed 1 outlier Lab B with PVIS=2403 Original cylinder heads	438 < (435-2, 434-1)	0.55			
#6 (n=23) 2/24/14 - 2/18/15 All Stellite Seats	438 < 434-1	0.50			

WPD Summary

- All models included Oil, Lab and Stand(Lab)
- Used 5% level of significance

IIIG			IIIH		
Model	Oil Discrimination	RMSE	Model	Oil Discrimination	RMSE
#1 (n=154) Combined 435 oils Original cylinder heads	438 < 435 < 434-1	0.43	#1 (n=18) All Data	434-1 < REO2 < REO3	0.28
#2* (n=151) Removed 3 outliers Combined 435 oils Original cylinder heads	438 < 435 < 434-1	0.38			
#3 (n=23) 2/24/14 - 2/18/15 All Stellite Seats	438 < 434-2	0.49			

* Model #2 , typo was changed from #1 to #2 by the secretary before PDF was generated for the minutes.

Seq IIIG PVIS Analysis

- LTMS Reference data
  - n=23 tests
  - Chartable tests only
  - Test dates: 2/24/2014 – 2/18/2015
  - Tests in this year-ling period were with Stellite seats
- Used LN(PVIS) transformation in model

Model #6: IIIG LN(PVIS)

n=23 tests 2/24/14 – 2/18/15

Summary of Fit

RSquare	0.78561
RSquare Adj	0.410428
Root Mean Square Error	0.495463
Mean of Response	5.076853
Observations (or Sum Wgts)	23

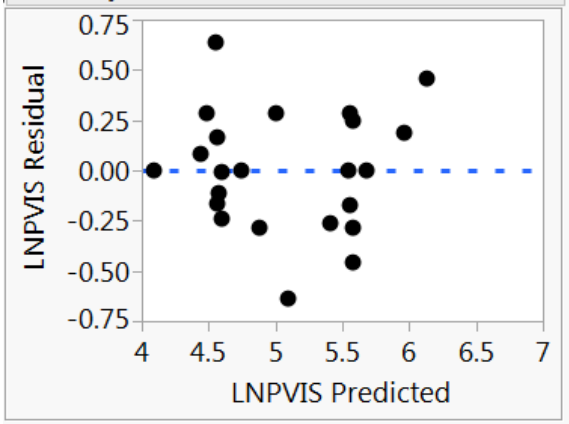
Analysis of Variance

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
IND	3	3	3.0060293	4.0818	0.0496*
LTMSLAB	4	4	0.7737554	0.7880	0.5642
LTMSAPP[LTMSLAB]	7	7	2.8193350	1.6407	0.2511

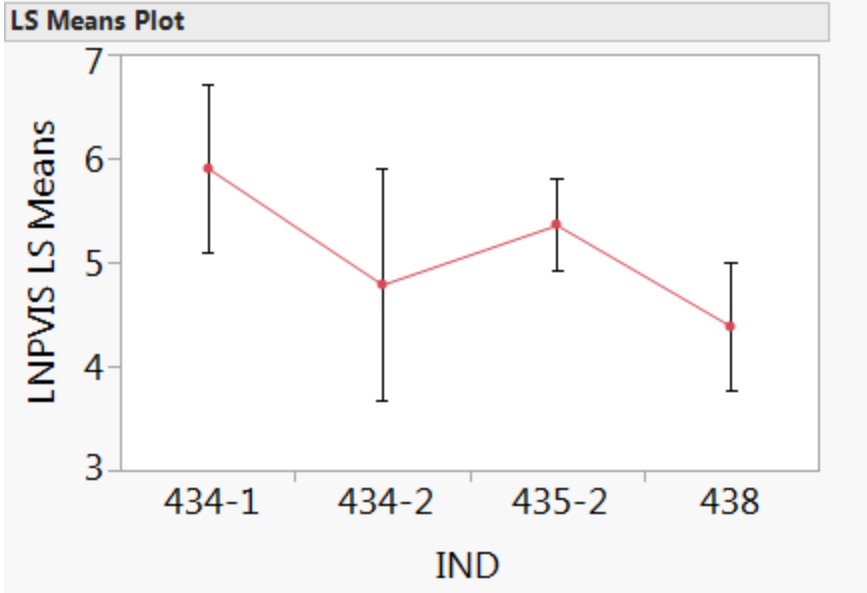
Residual by Predicted Plot



- Model includes:
  - Oil
  - Lab
  - Stand(Lab)
- Oil Discrimination
  - 438 < 434-1
- No significant lab differences
- No significant stand differences
- RMSE = 0.50
- IIIG target s = 0.2919

Model #6: IIIG LN(PVIS)

Oil Discrimination – 2/24/14 – 2/18/15



Oil	IIIG Target	IIIG #6 LS Means
438	4.57	4.39
434-1	4.73	5.91
434-2	4.73	4.79
435-2	5.18	5.36
s	0.2919	0.50

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
434-1	438	1.523268	0.4682399	0.02380	3.022733	0.0466*
434-1	434-2	1.120717	0.6347383	-0.91193	3.153368	0.3542
435-2	438	0.976073	0.3353136	-0.09772	2.049862	0.0754
435-2	434-2	0.573522	0.5230605	-1.10150	2.248541	0.7014
434-1	435-2	0.547195	0.3895991	-0.70044	1.794826	0.5305
434-2	438	0.402551	0.5230605	-1.27247	2.077571	0.8659

Note: 95% confidence intervals on LSMeans are not used for

Seq IIIH PVIS Analysis

- Prove-Out Matrix data
  - n=13 tests
  - Removed 5 tests performed at LZ
  - Test oils:
    - 434-1 (n=4)
    - REO2 (n=8)
    - REO3 (n=1) ← note only one test at SwRI
  - All tests on final hardware
- Used LN(PVIS) transformation in the models

Model #3: IIIH LN(PVIS)

Final hardware - Removed all LZ tests (n=13 with 1 test on REO3)

Summary of Fit

RSquare	0.825029
RSquare Adj	0.650057
Root Mean Square Error	0.439283
Mean of Response	4.218591
Observations (or Sum Wgts)	13

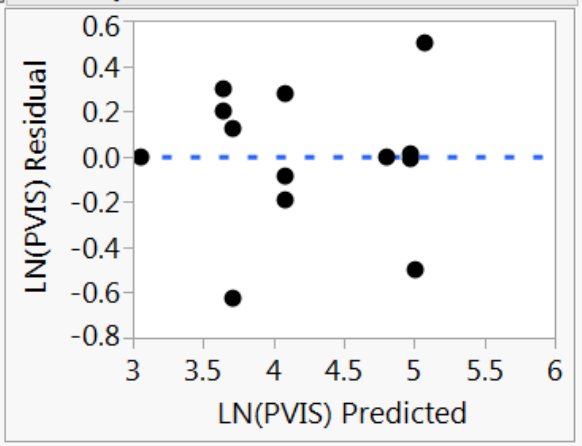
Analysis of Variance

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Oil	2	2	3.3016965	8.5550	0.0175*
Lab	2	2	0.4030970	1.0445	0.4081
Stand[Lab]	2	2	1.0035148	2.6002	0.1537

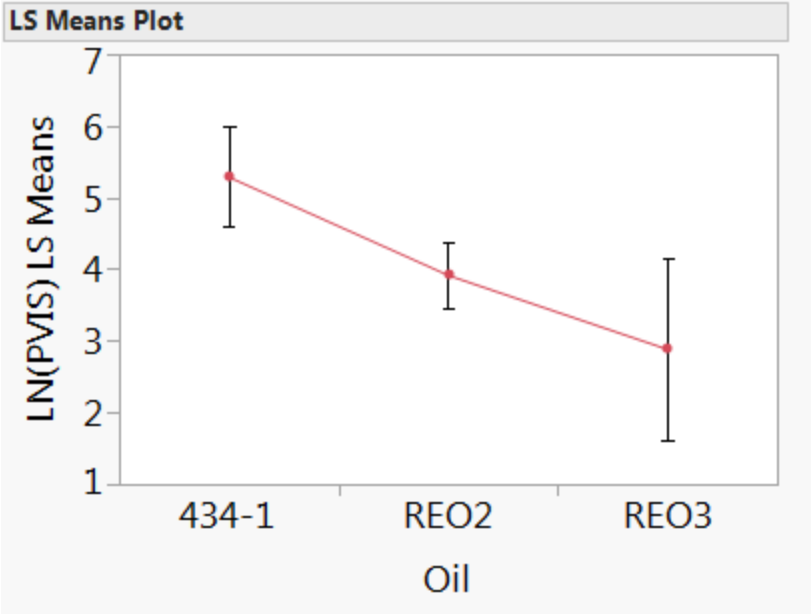
Residual by Predicted Plot



- Model includes:
  - Oil
  - Lab
  - Stand(Lab)
- Oil Discrimination
  - (REO3,REO2) < 434-1
- No significant lab differences
- No significant stand differences
- RMSE = 0.44
- IIIG target s = 0.2919

Model #3: IIIH LN(PVIS)

Oil Discrimination (removed all LZ tests)



Oil	IIIG #2 LS Means	IIIH #3 LS Means
434-1	5.01	5.29
REO2		3.92
REO3		2.89
s	0.40	0.44

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
434-1	REO3	2.402616	0.6340497	0.457257	4.347975	0.0212*
434-1	REO2	1.369734	0.3804298	0.202519	2.536950	0.0264*
REO2	REO3	1.032881	0.5072398	-0.523406	2.589169	0.1843

Note: 95% confidence intervals on LSMeans are not used for

Seq IIIG WPD Analysis

- LTMS Reference data
  - n=154 tests
  - Chartable tests only
  - Test dates: 1/6/2009 – 2/2/2014
  - All tests with original cylinder heads

Model #1: IIIG WPD

Original cylinder heads – all data, combined 435 oils

Summary of Fit

RSquare	0.54308
RSquare Adj	0.47437
Root Mean Square Error	0.424757
Mean of Response	3.436753
Observations (or Sum Wgts)	154

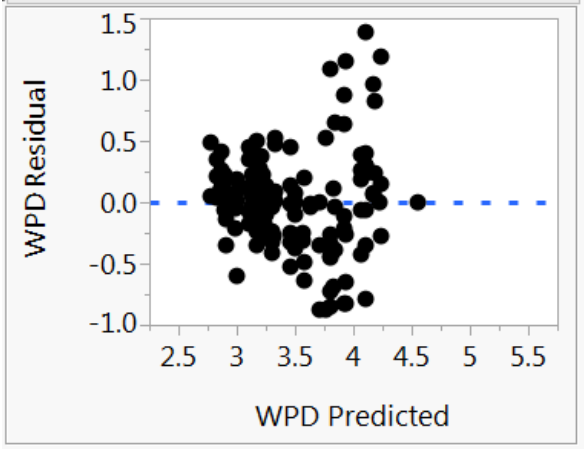
Analysis of Variance

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
INDx	2	2	21.455144	59.4593	<.0001*
LTMSLAB	5	5	0.781514	0.8663	0.5057
STAND[LTMSLAB]	13	13	3.186848	1.3587	0.1878

Residual by Predicted Plot

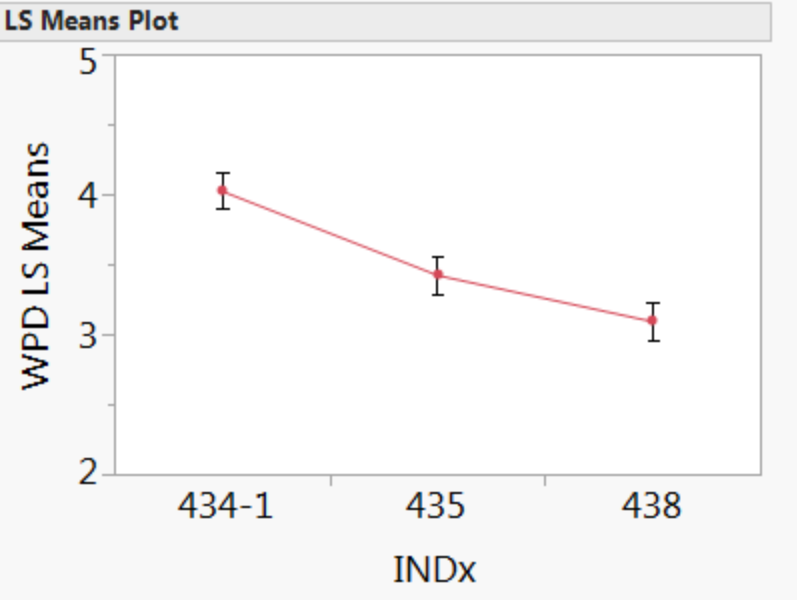


- Model includes:
  - Oil
  - Lab
  - Stand(Lab)
- Oil Discrimination
  - 438 < 435 < 434-1
- No significant lab differences
- Significant stand differences
- RMSE = 0.42
- IIIG target s = 0.60

Note: Different transformations on WPD were analyzed, but the oil discriminations were similar.

Model #1: IIIG WPD

Oil Discrimination – all data, combined 435 oils



Oil	IIIG Target	IIIG #1 LS Means
434-1	4.80	4.03
435	3.59	3.43
438	3.20	3.10
s	0.60	0.42

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
434-1	438	0.9306171	0.0861838	0.7263377	1.134897	<.0001*
434-1	435	0.6002000	0.0882435	0.3910386	0.809361	<.0001*
435	438	0.3304171	0.0864955	0.1253990	0.535435	0.0006*

Note: 95% confidence intervals on LSMeans are not used for

Model #2: IIIG WPD

Original cylinder heads – deleted 3 outliers on 434-1, combined 435 oils

Summary of Fit

RSquare	0.55338
RSquare Adj	0.484669
Root Mean Square Error	0.377378
Mean of Response	3.399139
Observations (or Sum Wgts)	151

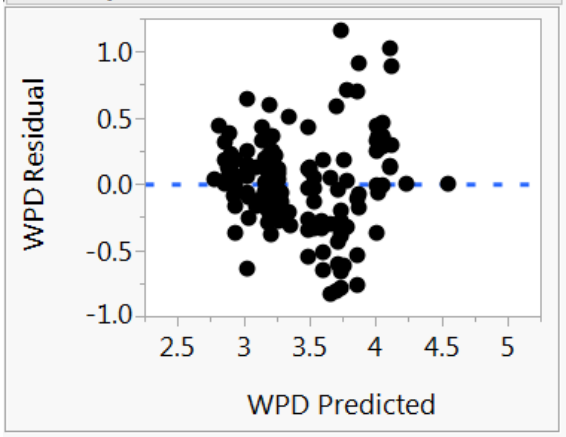
Analysis of Variance

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
INDx	2	2	16.648883	58.4523	<.0001*
LTMSLAB	5	5	0.367201	0.5157	0.7640
STAND[LTMSLAB]	13	13	3.167897	1.7111	0.0657

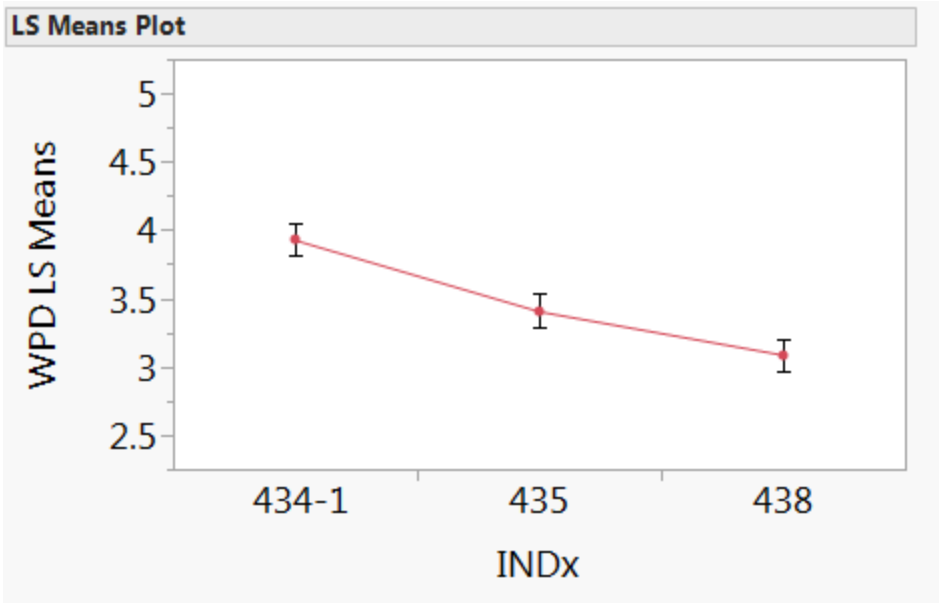
Residual by Predicted Plot



- Model includes:
  - Oil
  - Lab
  - Stand(Lab)
- Oil Discrimination
  - 438 < 435 < 434-1
- No significant lab differences
- Significant stand differences
- RMSE = 0.38
- IIIG target s = 0.60

Model #2: IIIG WPD

Oil Discrimination – deleted 3 outliers on 434-1, combined 435 oils



Oil	IIIG Target	IIIG #2 LS Means
434-1	4.80	3.93
435	3.59	3.41
438	3.20	3.09
s	0.60	0.38

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
434-1	438	0.8393043	0.0780255	0.6543142	1.024294	<.0001*
434-1	435	0.5205907	0.0794640	0.3321901	0.708991	<.0001*
435	438	0.3187136	0.0769755	0.1362130	0.501214	0.0002*

Note: 95% confidence intervals on LSMeans are not used for

Model #3: IIIG WPD

n=23 tests 2/24/14 – 2/18/15

Summary of Fit

RSquare	0.829519
RSquare Adj	0.531177
Root Mean Square Error	0.487068
Mean of Response	3.470435
Observations (or Sum Wgts)	23

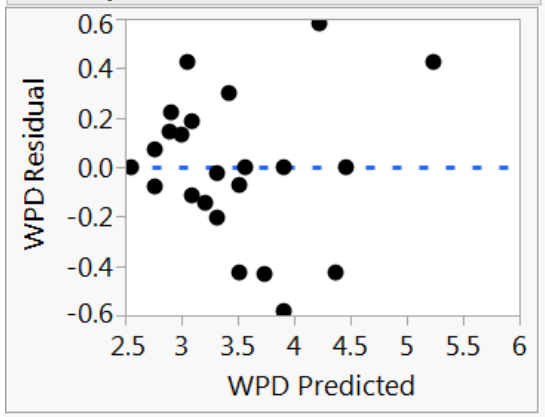
Analysis of Variance

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
IND	3	3	2.9628680	4.1631	0.0474*
LTMSLAB	4	4	2.3939860	2.5228	0.1236
LTMSAPP[LTMSLAB]	7	7	0.5448470	0.3281	0.9201

Residual by Predicted Plot

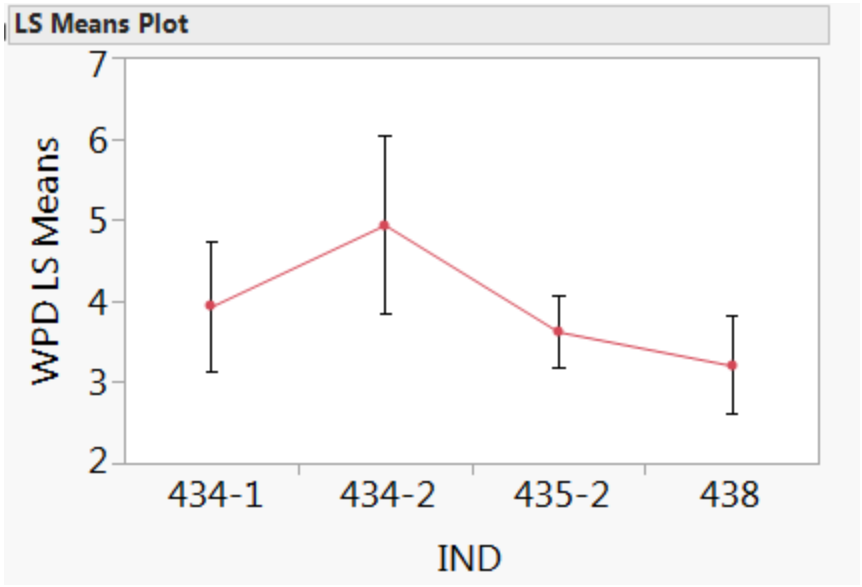


- Model includes:
  - Oil
  - Lab
  - Stand(Lab)
- Oil Discrimination
  - 438 < 434-2
- No significant lab differences
- No significant stand differences
- RMSE = 0.49
- IIIG target s = 0.60

Note: Different transformations on WPD were analyzed, but the oil discriminations were similar.

Model #3: IIIG WPD

Oil Discrimination – n=23 tests 2/24/14 – 2/18/15



Oil	IIIG Target	IIIG #3 LS Means
434-2	4.80	4.94
434-1	4.80	3.94
435-2	3.59	3.62
438	3.20	3.21
s	0.60	0.49

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
434-2	438	1.732824	0.5141980	0.086185	3.379463	0.0395*
434-2	435-2	1.317176	0.5141980	-0.329463	2.963815	0.1233
434-2	434-1	1.005305	0.6239836	-0.992905	3.003516	0.4246
434-1	438	0.727519	0.4603063	-0.746540	2.201578	0.4395
435-2	438	0.415649	0.3296322	-0.639947	1.471244	0.6095
434-1	435-2	0.311870	0.3829980	-0.914621	1.538362	0.8462

Note: 95% confidence intervals on LSMeans are not used for

Model #1: IIIH WPD

Final hardware – all data

Summary of Fit

RSquare	0.94828
RSquare Adj	0.912077
Root Mean Square Error	0.27846
Mean of Response	4.812778
Observations (or Sum Wgts)	18

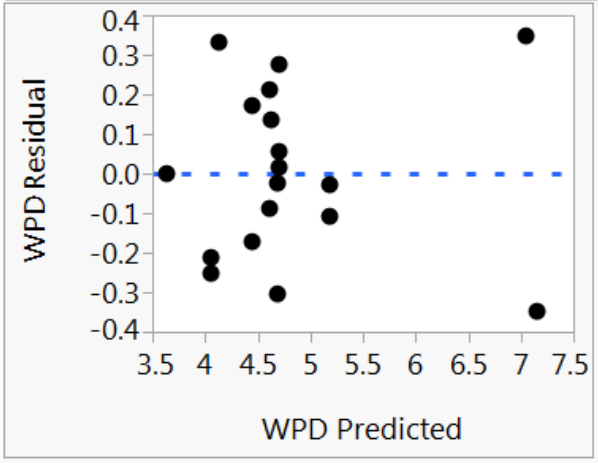
Analysis of Variance

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Oil	2	2	11.119888	71.7043	<.0001*
Lab	3	3	0.369178	1.5870	0.2535
Stand[Lab]	2	2	1.758127	11.3369	0.0027*

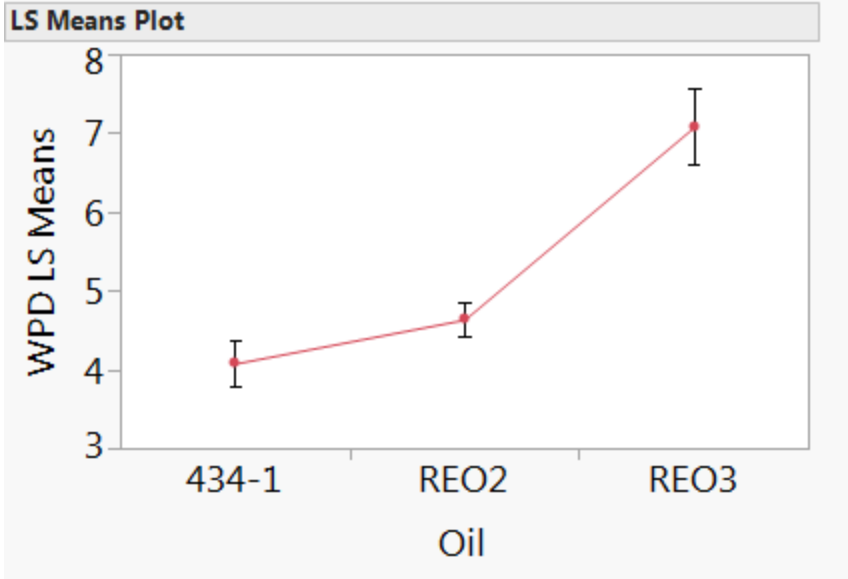
Residual by Predicted Plot



- Model includes:
  - Oil
  - Lab
  - Stand(Lab)
- Oil Discrimination
  - 434-1 < REO2 < REO3
- No significant lab differences
- Significant stand differences
- RMSE = 0.28
- IIIG target s = 0.60

Model #1: IIIH WPD

Oil Discrimination (all data)



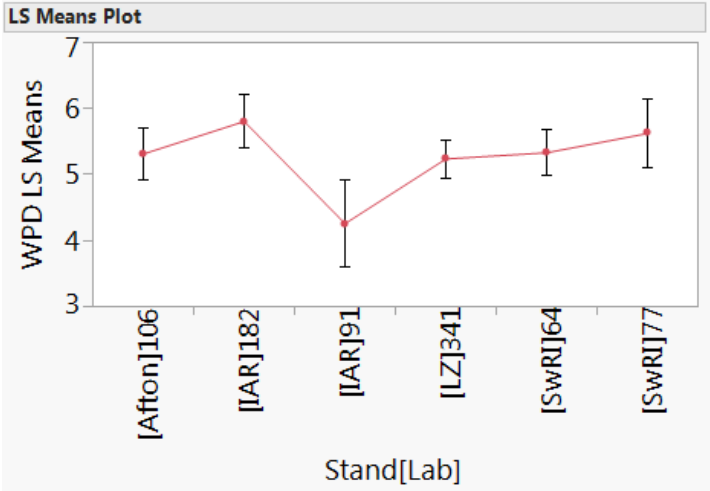
Oil	IIIG #2 LS Means	IIIH #1 LS Means
434-1	3.93	4.08
REO2	3.41	4.64
REO3	3.09	7.08
s	0.38	0.28

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
REO3	434-1	2.998850	0.2599809	2.286168	3.711532	<.0001*
REO3	REO2	2.443009	0.2283653	1.816994	3.069023	<.0001*
REO2	434-1	0.555841	0.1786281	0.066170	1.045511	0.0272*

Note: 95% confidence intervals on LSMeans are not used for

Model #1: IIIH WPD

Stand Effect (all data)



IAR Stand 91 only ran one test (Oil REO2). This test produced the lowest WPD among all the oils.

SwRI Stand 77 ran two tests for oil 434-1.

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
[IAR]182	[IAR]91	1.548614	0.3270043	0.412823	2.684404	0.0076*
[SwRI]77	[IAR]91	1.365841	0.3849907	0.028645	2.703037	0.0446*
[SwRI]64	[IAR]91	1.074248	0.3165190	-0.025124	2.173620	0.0564
[Afton]106	[IAR]91	1.055280	0.3270043	-0.080511	2.191071	0.0727
[LZ]341	[IAR]91	0.979735	0.3186796	-0.127142	2.086611	0.0915
[IAR]182	[LZ]341	0.568879	0.2092893	-0.158050	1.295808	0.1548
[IAR]182	[Afton]106	0.493333	0.2273615	-0.296366	1.283033	0.3281
[IAR]182	[SwRI]64	0.474366	0.2250866	-0.307432	1.256164	0.3548
[SwRI]77	[LZ]341	0.386106	0.2566605	-0.505358	1.277570	0.6696
[SwRI]77	[Afton]106	0.310560	0.2807096	-0.664434	1.285555	0.8682
[SwRI]77	[SwRI]64	0.291593	0.2986724	-0.745792	1.328978	0.9155
[IAR]182	[SwRI]77	0.182773	0.2807096	-0.792222	1.157767	0.9837
[SwRI]64	[LZ]341	0.094513	0.1994974	-0.598405	0.787432	0.9961
[Afton]106	[LZ]341	0.075546	0.2092893	-0.651383	0.802475	0.9989
[SwRI]64	[Afton]106	0.018968	0.2250866	-0.762830	0.800765	1.0000

Note: 95% confidence intervals on LSMeans are not used for

Appendix – PVIS Models

Model #1: IIIG LN(PVIS)

Original cylinder heads - all data

Summary of Fit

RSquare	0.398466
RSquare Adj	0.297445
Root Mean Square Error	0.526619
Mean of Response	5.032369
Observations (or Sum Wgts)	154

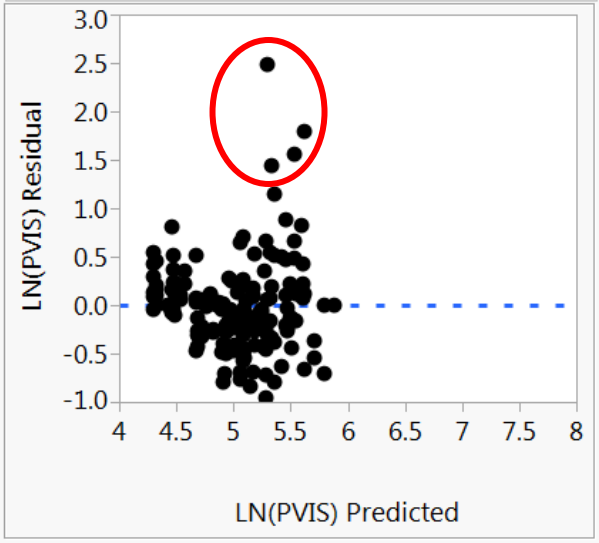
Analysis of Variance

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
IND	4	4	14.021368	12.6397	<.0001*
LTMSLAB	5	5	2.129974	1.5361	0.1829
STAND[LTMSLAB]	13	13	5.263485	1.4599	0.1411

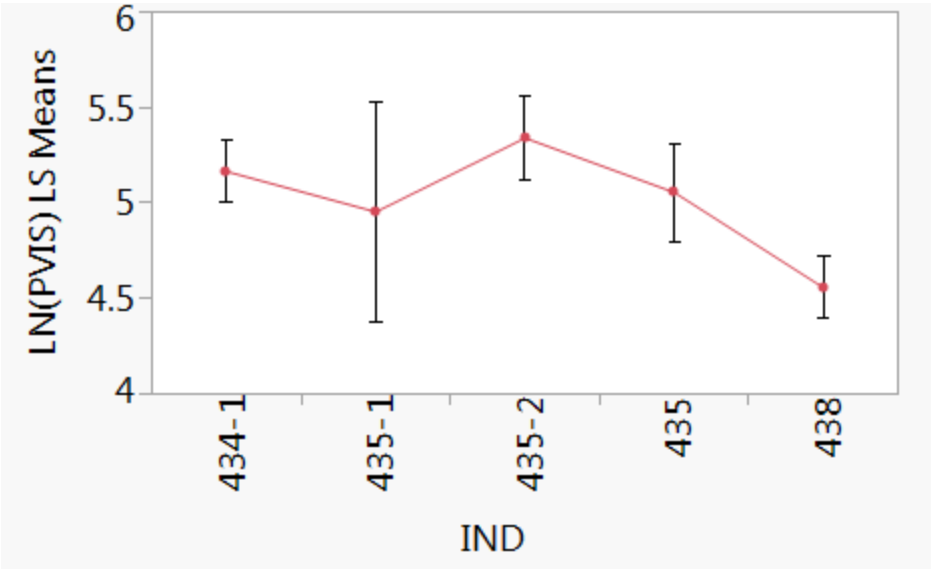
Residual by Predicted Plot



- Model includes:
  - Oil
  - Lab
  - Stand(Lab)
- Oil Discrimination
  - 438 < (435, 435-2, 434-1)
- No significant lab differences
- No significant stand differences
- RMSE = 0.53
- IIIG target s = 0.2919

Model #1: IIIG LN(PVIS)

Oil Discrimination (Original cylinder heads – all data)



Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
435-2	438	0.7843112	0.1280988	0.429972	1.138651	<.0001*
434-1	438	0.6087097	0.1068566	0.313129	0.904290	<.0001*
435	438	0.4992472	0.1432095	0.103109	0.895385	0.0059*
435-1	438	0.3970138	0.2960911	-0.422016	1.216044	0.6663
435-2	435-1	0.3872974	0.3041925	-0.454142	1.228737	0.7081
435-2	435	0.2850640	0.1592783	-0.155522	0.725650	0.3839
434-1	435-1	0.2116959	0.2977747	-0.611991	1.035383	0.9537
435-2	434-1	0.1756015	0.1299462	-0.183848	0.535051	0.6597
434-1	435	0.1094625	0.1444786	-0.290186	0.509111	0.9421
435	435-1	0.1022335	0.3118901	-0.760499	0.964966	0.9975

Oil	IIIG Target	IIIG #1 LS Means
438	4.57	4.56
434-1	4.73	5.17
435	5.18	5.06
435-1	5.18	4.95
435-2	5.18	5.34
s	0.2919	0.53

Note: 95% confidence intervals on LSMeans are not used for

Model #2: IIIG LN(PVIS)

Original cylinder heads - removed 4 434-1 outliers

Summary of Fit

RSquare	0.49613
RSquare Adj	0.408846
Root Mean Square Error	0.395367
Mean of Response	4.972889
Observations (or Sum Wgts)	150

Analysis of Variance

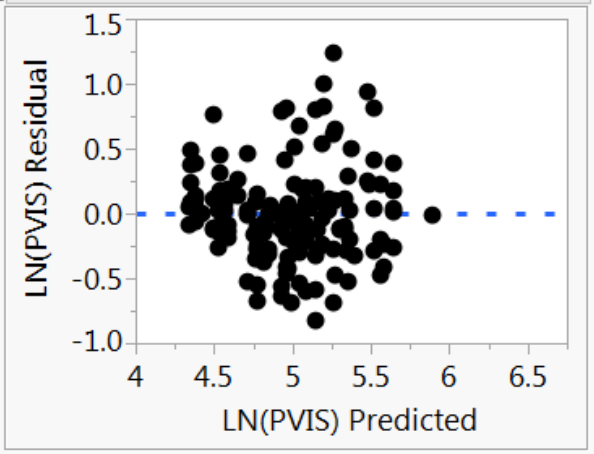
Lack Of Fit

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
IND	4	4	12.123414	19.3894	<.0001*
LTMSLAB	5	5	1.757809	2.2491	0.0534
STAND[LTMSLAB]	13	13	3.375937	1.6613	0.0772

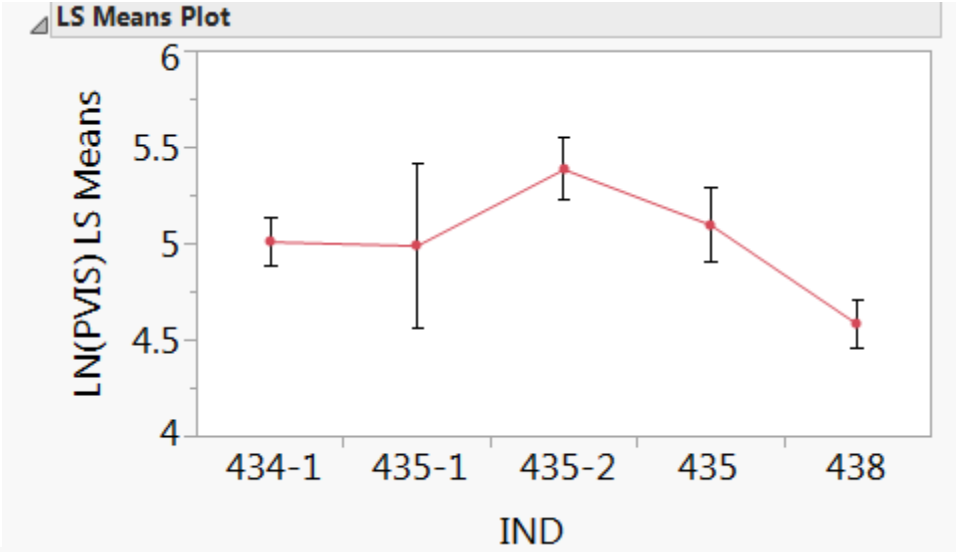
Residual by Predicted Plot



- Model includes:
  - Oil
  - Lab
  - Stand(Lab)
- Oil Discrimination
  - 438 < (435, 435-2, 434-1)
  - 434-1 < 435-2
- No significant lab differences
- No significant stand differences
- RMSE = 0.40
- IIIG target s = 0.2919

Model #2: IIIG LN(PVIS)

Oil Discrimination – removed 4 434-1 outliers



Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
435-2	438	0.8044034	0.0962675	0.537996	1.070810	<.0001*
435	438	0.5155944	0.1076736	0.217623	0.813566	<.0001*
434-1	438	0.4277852	0.0822802	0.200086	0.655484	<.0001*
435-1	438	0.4073312	0.2224366	-0.208231	1.022894	0.3603
435-2	435-1	0.3970722	0.2285084	-0.235293	1.029437	0.4148
435-2	434-1	0.3766183	0.0995436	0.101145	0.652091	0.0022*
435-2	435	0.2888090	0.1196741	-0.042373	0.619991	0.1184
435	435-1	0.1082632	0.2341999	-0.539853	0.756379	0.9905
435	434-1	0.0878093	0.1101840	-0.217110	0.392728	0.9311
434-1	435-1	0.0204540	0.2243921	-0.600520	0.641428	1.0000

Oil	IIIG Target	IIIG #2 LS Means
438	4.57	4.58
434-1	4.73	5.01
435	5.18	5.10
435-1	5.18	4.99
435-2	5.18	5.39
s	0.2919	0.40

Note: 95% confidence intervals on LSMeans are not used for

Model #3: IIIG LN(PVIS)

Original cyl heads - removed 4 434-1 outliers; combined 435 oils

Summary of Fit

RSquare	0.466816
RSquare Adj	0.384152
Root Mean Square Error	0.40354
Mean of Response	4.972889
Observations (or Sum Wgts)	150

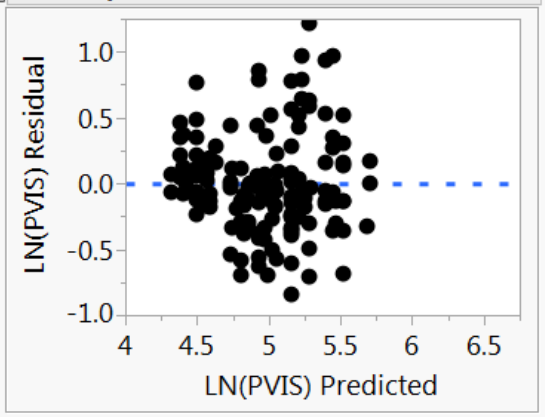
Analysis of Variance

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
INDx	2	2	10.968473	33.6778	<.0001*
LTMSLAB	5	5	1.726853	2.1209	0.0670
STAND[LTMSLAB]	13	13	3.534633	1.6697	0.0750

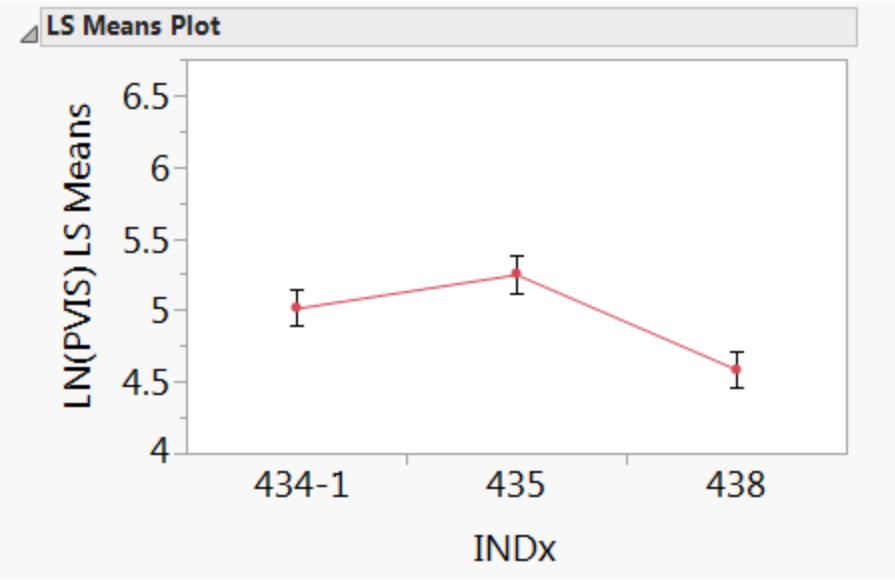
Residual by Predicted Plot



- Model includes:
  - Oil
  - Lab
  - Stand(Lab)
- Oil Discrimination
  - 438 < 434-1 < 435
- No significant lab differences
- No significant stand differences
- RMSE = 0.40
- IIIG target s = 0.2919

Model #3: IIIG LN(PVIS)

Oil Discrimination - removed 4 434-1 outliers; combined 435 oils



Oil	IIIG Target	IIIG #3 LS Means
438	4.57	4.59
434-1	4.73	5.02
435	5.18	5.25
s	0.2919	0.40

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
435	438	0.6635319	0.0823015	0.4683864	0.8586775	<.0001*
434-1	438	0.4279799	0.0839779	0.2288595	0.6271003	<.0001*
435	434-1	0.2355520	0.0861403	0.0313042	0.4397998	0.0194*

Note: 95% confidence intervals on LSMeans are not used for

Model #4: IIIG LN(PVIS)

Original cyl heads - last 75 reference tests: 1/24/11 - 2/2/14)

Summary of Fit

RSquare	0.473839
RSquare Adj	0.304716
Root Mean Square Error	0.627319
Mean of Response	5.174737
Observations (or Sum Wgts)	75

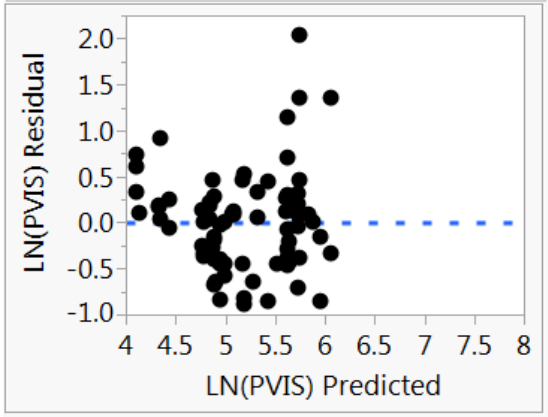
Analysis of Variance

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
IND	2	2	8.6240571	10.9573	<.0001*
LTMSLAB	5	5	3.8533779	1.9584	0.0991
STAND[LTMSLAB]	11	11	4.7799723	1.1042	0.3753

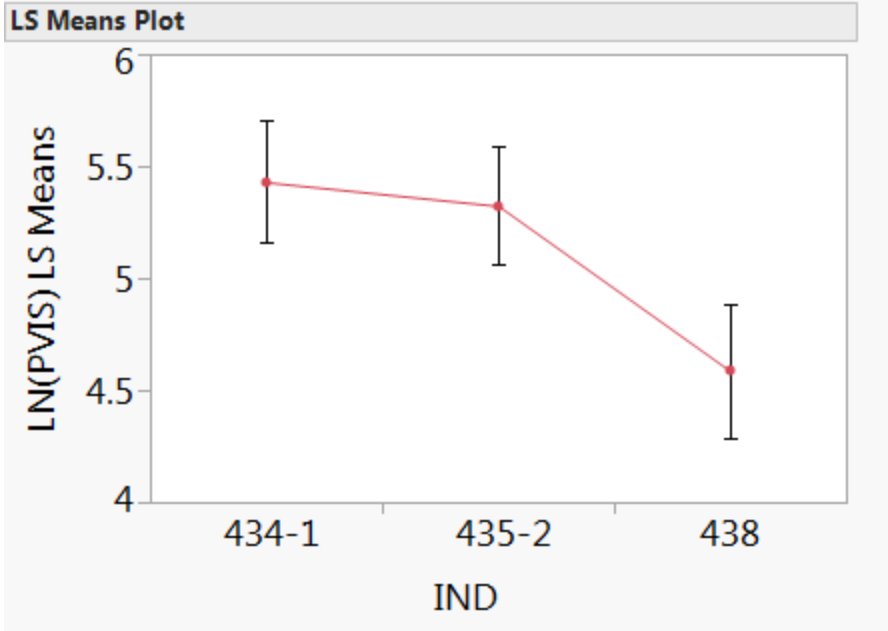
Residual by Predicted Plot



- Model includes:
  - Oil
  - Lab
  - Stand(Lab)
- Oil Discrimination
  - 438 < (435-2, 434-1)
- No significant lab differences
- No significant stand differences
- RMSE = 0.63
- IIIG target s = 0.2919

Model #4: IIIG LN(PVIS)

Oil Discrimination - last 75 reference tests: 1/24/11 - 2/2/14



Oil	IIIG Target	IIIG #4 LS Means
438	4.57	4.59
434-1	4.73	5.43
435-2	5.18	5.32
s	0.2919	0.63

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
434-1	438	0.8440431	0.1938007	0.377455	1.310632	0.0002*
435-2	438	0.7377256	0.1922442	0.274884	1.200567	0.0009*
434-1	435-2	0.1063176	0.1825899	-0.333280	0.545915	0.8301

Note: 95% confidence intervals on LSMeans are not used for

Model #5: IIIG LN(PVIS)

Original cyl heads - last 75 ref tests; deleted 1 434-1 outlier with PVIS=2403

Summary of Fit

RSquare	0.518776
RSquare Adj	0.361285
Root Mean Square Error	0.553234
Mean of Response	5.13947
Observations (or Sum Wgts)	74

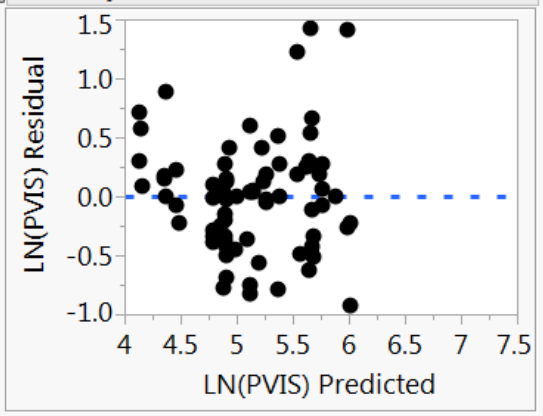
Analysis of Variance

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
IND	2	2	7.8221160	12.7784	<.0001*
LTMSLAB	5	5	3.8489341	2.5151	0.0403*
STAND[LTMSLAB]	11	11	3.7222484	1.1056	0.3747

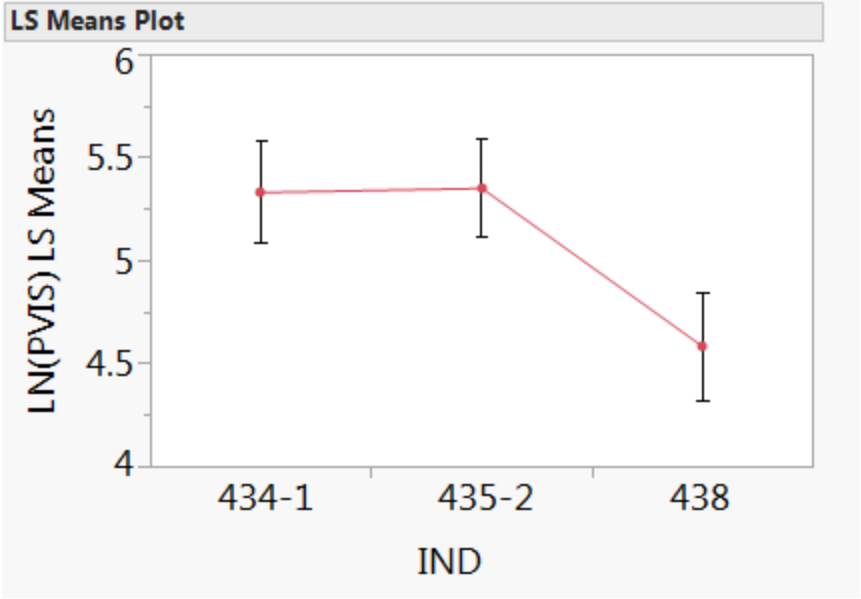
Residual by Predicted Plot



- Model includes:
  - Oil
  - Lab
  - Stand(Lab)
- Oil Discrimination
  - 438 < (435-2, 434-1)
- Significant lab differences
- No significant stand differences
- RMSE = 0.55
- IIIG target s = 0.2919

Model #5: IIIG LN(PVIS)

Oil Discrimination - last 75 ref tests; deleted 1 434-1 outlier with PVIS=2403



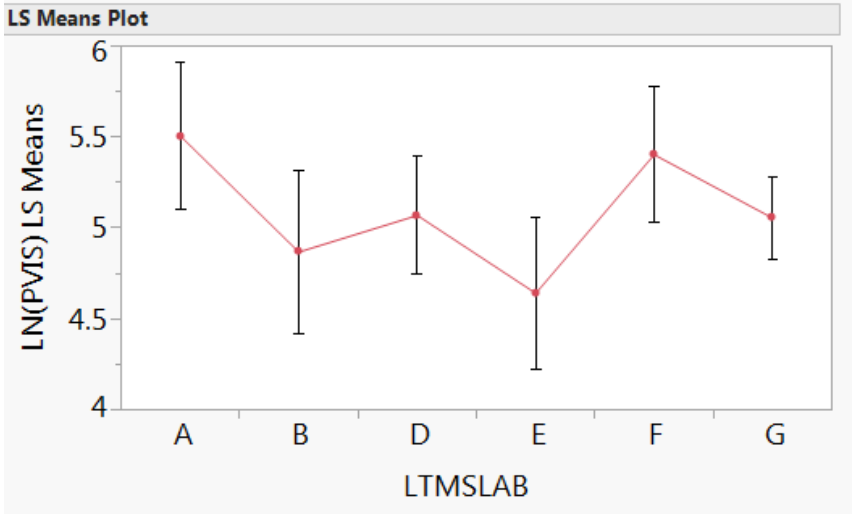
Oil	IIIG Target	IIIG #5 LS Means
438	4.57	4.58
434-1	4.73	5.33
435-2	5.18	5.35
s	0.2919	0.55

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
435-2	438	0.7684859	0.1697046	0.359709	1.177263	<.0001*
434-1	438	0.7486201	0.1724728	0.333175	1.164065	0.0002*
435-2	434-1	0.0198658	0.1639084	-0.374949	0.414681	0.9919

Note: 95% confidence intervals on LSMeans are not used for

Model #5: IIIG LN(PVIS)

Lab Differences - last 75 ref tests; deleted 1 434-1 outlier with PVIS=2403



Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
A	E	0.8646079	0.2912847	0.004579	1.724637	0.0481*
F	E	0.7621181	0.2805104	-0.066100	1.590336	0.0881
A	B	0.6379539	0.3014589	-0.252115	1.528023	0.2944
F	B	0.5354640	0.2911381	-0.324132	1.395060	0.4499
A	G	0.4513354	0.2308764	-0.230336	1.133007	0.3810
A	D	0.4367934	0.2569980	-0.322003	1.195590	0.5379
D	E	0.4278145	0.2635400	-0.350298	1.205926	0.5870
G	E	0.4132725	0.2382989	-0.290314	1.116859	0.5158
F	G	0.3488456	0.2170821	-0.292098	0.989789	0.5976
F	D	0.3343036	0.2452245	-0.389731	1.058338	0.7483
B	E	0.2266540	0.3051560	-0.674331	1.127639	0.9756
D	B	0.2011605	0.2740201	-0.607894	1.010215	0.9768
G	B	0.1866185	0.2505344	-0.553094	0.926331	0.9753
A	F	0.1024898	0.2719013	-0.700309	0.905289	0.9990
D	G	0.0145420	0.1968424	-0.566643	0.595727	1.0000

Model #1: IIIH LN(PVIS)

Final hardware - All data

Summary of Fit

RSquare	0.880982
RSquare Adj	0.797669
Root Mean Square Error	0.440073
Mean of Response	4.379123
Observations (or Sum Wgts)	18

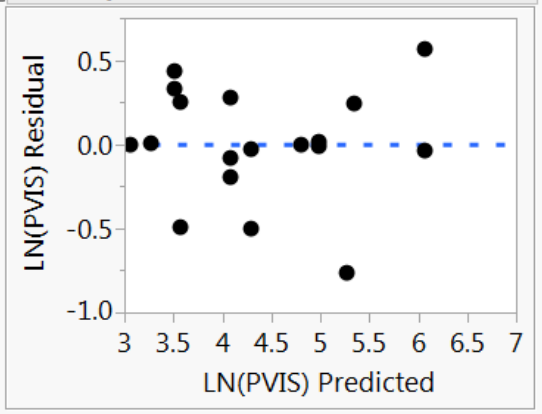
Analysis of Variance

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Oil	2	2	10.971507	28.3261	<.0001*
Lab	3	3	1.582469	2.7237	0.1003
Stand[Lab]	2	2	1.710976	4.4174	0.0422*

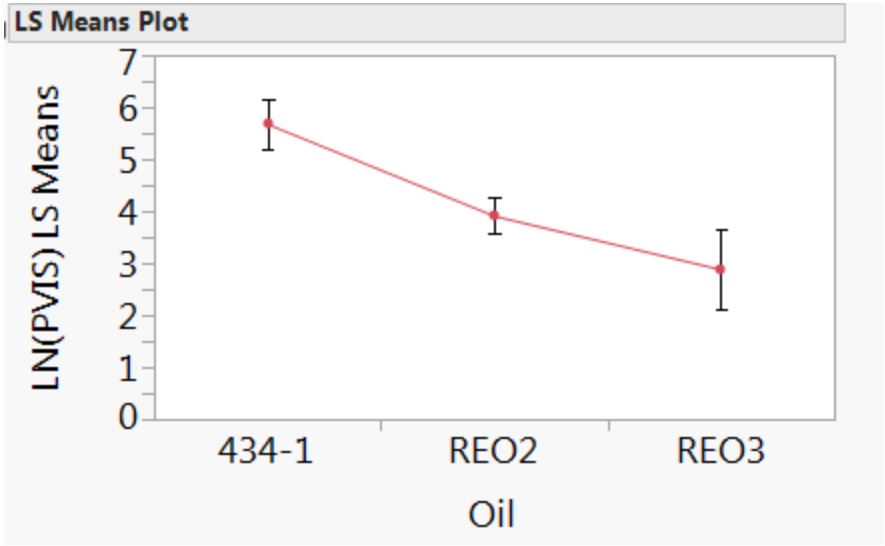
Residual by Predicted Plot



- Model includes:
  - Oil
  - Lab
  - Stand(Lab)
- Oil Discrimination
  - REO3 < REO2 < 434-1
- No significant lab differences
- No significant stand differences
- RMSE = 0.44
- IIIG target s = 0.2919

Model #1: IIIH LN(PVIS)

Oil Discrimination (all data)



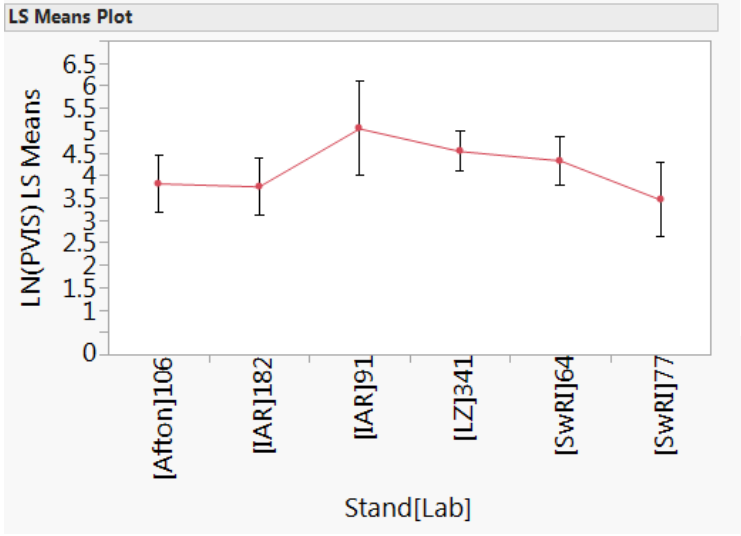
Oil	IIIG #2 LS Means	IIIH #1 LS Means
434-1	5.01	5.68
REO2		3.92
REO3		2.89
s	0.40	0.44

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
434-1	REO3	2.791519	0.4108695	1.665208	3.917829	0.0001*
434-1	REO2	1.764392	0.2823009	0.990525	2.538260	0.0003*
REO2	REO3	1.027126	0.3609047	0.037783	2.016469	0.0421*

Note: 95% confidence intervals on LSMeans are not used for

Model #1: IIIH LN(PVIS)

Stand Effect (all data)



Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
[IAR]91	[SwRI]77	1.586730	0.6084328	-0.52655	3.700012	0.1814
[IAR]91	[IAR]182	1.294772	0.5167922	-0.50021	3.089757	0.2096
[IAR]91	[Afton]106	1.226463	0.5167922	-0.56852	3.021448	0.2513
[LZ]341	[SwRI]77	1.082167	0.4056219	-0.32669	2.491022	0.1665
[SwRI]64	[SwRI]77	0.871437	0.4720168	-0.76803	2.510902	0.4813
[LZ]341	[IAR]182	0.790209	0.3307574	-0.35862	1.939035	0.2460
[LZ]341	[Afton]106	0.721900	0.3307574	-0.42693	1.870727	0.3229
[IAR]91	[SwRI]64	0.715293	0.5002213	-1.02214	2.452722	0.7107
[SwRI]64	[IAR]182	0.579479	0.3557230	-0.65606	1.815019	0.5998
[SwRI]64	[Afton]106	0.511170	0.3557230	-0.72437	1.746710	0.7068
[IAR]91	[LZ]341	0.504563	0.5036358	-1.24473	2.253851	0.9071
[Afton]106	[SwRI]77	0.360267	0.4436288	-1.18060	1.901132	0.9587
[IAR]182	[SwRI]77	0.291958	0.4436288	-1.24891	1.832823	0.9829
[LZ]341	[SwRI]64	0.210730	0.3152824	-0.88435	1.305807	0.9817
[Afton]106	[IAR]182	0.068309	0.3593183	-1.17972	1.316336	1.0000

Note: 95% confidence intervals on LSMeans are not used for

Model #2: IIIH LN(PVIS)

Final hardware - Removed LZ Oil 434-1 with PVIS=754.7

Summary of Fit

RSquare	0.867774
RSquare Adj	0.764932
Root Mean Square Error	0.400632
Mean of Response	4.246935
Observations (or Sum Wgts)	17

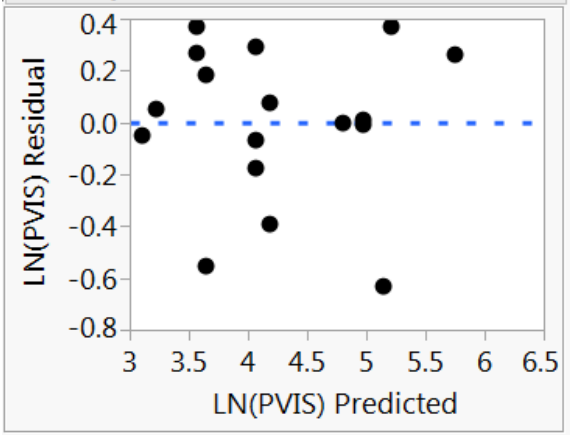
Analysis of Variance

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Oil	2	2	7.2783219	22.6731	0.0003*
Lab	3	3	0.8393312	1.7431	0.2277
Stand[Lab]	2	2	1.3109424	4.0838	0.0547

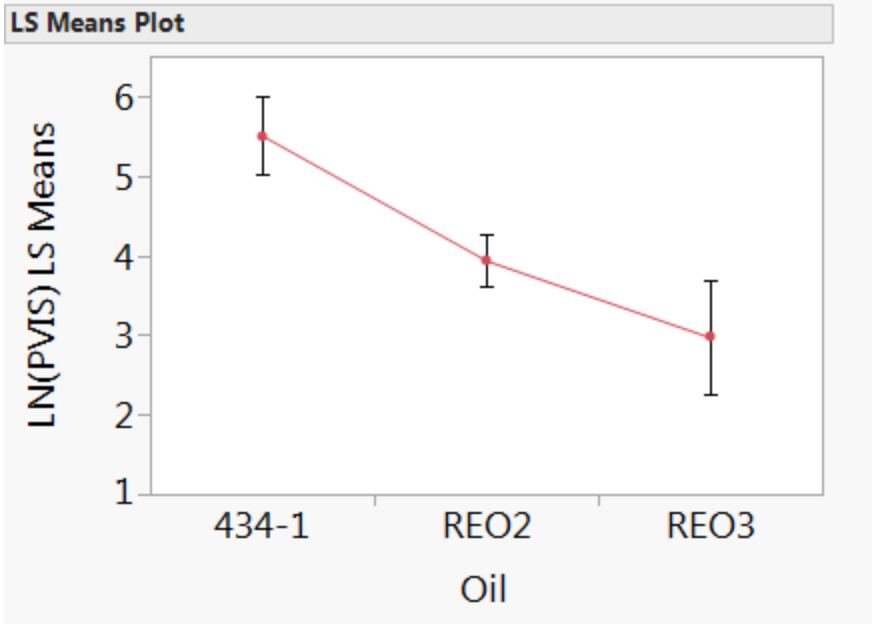
Residual by Predicted Plot



- Model includes:
  - Oil
  - Lab
  - Stand(Lab)
- Oil Discrimination
  - REO3 < REO2 < 434-1
- No significant lab differences
- No significant stand differences
- RMSE = 0.40
- IIIG target s = 0.2919

Model #2: IIIH LN(PVIS)

Oil Discrimination (removed LZ Oil 434-1 with PVIS=754.7)



Oil	IIIG #2 LS Means	IIIH #2 LS Means
434-1	5.01	5.51
REO2		3.94
REO3		2.97
s	0.40	0.40

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
434-1	REO3	2.533658	0.4019922	1.411292	3.656024	0.0004*
434-1	REO2	1.568111	0.2803839	0.785276	2.350945	0.0009*
REO2	REO3	0.965548	0.3304356	0.042968	1.888127	0.0408*

Note: 95% confidence intervals on LSMeans are not used for