Seq. IIIH Piston Hardware Task Force

Teleconference

Wednesday, March 5, 2017
09:00 – 11:00 EST

Agenda (Attachment #1)

1.) Attendance.

Addison Schweitzer, Charlie Leverette, Pat Lang, Chaudhry Ankit, Amol Savant, Ed Altman, George Szappanos, Jeff Betz, Bob Campbell, Rich Grundza, Karin Haumann, Matt Bowden, Robert Stockwell, Jason Bowden, Todd Dvorak, Jerry Brys, Doyle Boese

2.) Approve Minutes from Feb. 15, 2017 – Jason Bowden / Ed Altman-Approved

3.) Action Item Review

Action Item #1: OHT to confirm if the 60 each pistons offered by 2/27/17 will be BC4 pistons.- **Complete**

Jason Bowden confirmed the initial BC4 pistons have been delivered to OHT and the balance of the BC4 pistons have an estimated delivery by 3/10/17.

Action Item #2: OHT to review differences between production and special test rings supplied by OHT. – **Complete**

Jason Bowden confirmed the only design differences are gap.

Action Item #3: Labs to report if they changed how they measured blowby data between matrix and post-matrix. Labs will report findings to the task force. - **Complete**

With the exception of Lubrizol who still uses the fixed orifice, all other Seq. IIIH labs used the fixed orifice during the precision matrix and then switched to the JTec flow meter post precision matrix.

Action Item #4: Labs to confirm if honing results are different between matrix and post matrix and report summary to task force. -**Complete**

Stats Group will provide information to the Surveillance Panel for discussion.

Action Item #5: Labs to confirm calibration and cleaning procedure of JTec – Addison Schweitzer – **Complete**

Labs provided a summary to Addison **(Attachment #2).** Review determined that there were differences with how labs have the JTEC calibrated, but cleaning procedures were fairly similar. Labs typically do not see a change in calibration.

3/1/17 Action Item #1: Addison will develop a calibration procedure for the JTEC and have the Task Force review.

Action Item #6: Confirm how the JTEC data is being collected. Ankit will survey the labs to have them provide the raw data that is being collected along with each labs practices for measuring barometric pressure, JTEC flow, temp, etc.)-Ankit Chaudhry – **Ongoing**

Ankit is currently awaiting replies to his survey from the balance of the labs. Southwest Research presented data showing that the blowby flow stabilizes after 2 minutes sample time **(Attachment #3).**

Action Item #7: Todd Dvorak will review honing analysis he prepared for the November 2016 Panel meeting comparing the correlation pre and post matrix by lab vs. blowby and output results – Todd Dvorak **Ongoing**

Action Item #8: Stand review of blowby evacuation setup to confirm each stand meets the schematic shown in the procedure – All Labs – **Complete**

All labs confirmed they meet the schematic shown in the procedure. Amol commented that the procedure schematic shows the canister in the vertical position. The manufacturer recommends the canister be placed in the horizontal position.

Motion #1: Jason Bowden / Addison Schweitzer: Jason Bowden / Addison Schweitzer: Task Force recommend to the Surveillance Panel that the schematic (shown in figure A3.1) for the canister in the blowby circuit be modified to be shown in a horizontal line. – **Passed - Unanimous**

Action Item #9: Amol will survey the labs to determine how they are insulating the exhaust downpipes and how the exhaust systems are routed- Amol Savant- **Ongoing**

Action Item #8: Labs to provide results to the Task Force on prior 436 results in stand being used in Ring Gap DOE. Valvoline to report 438 results. – All Labs - **Ongoing**

Most data presented with the exception of an MRV results and Phos. Ret from a lab.

4.) Update on Initial Ring Gap DOE-

a. **Todd Dvorak will provided analysis of DOE results from Stats Group to help answer the following questions: (Attachment #4)**
   - Blowby change vs severity change, by lab
     - "Can we use blowby to predict severity and therefore target (limit) the initial value?"
     - If yes, what are the limits
     - If no, then what's impacting severity?
   - Blowby change vs ring gap
     - "Can we use the relationship to predict the required adjustment necessary for appropriate blowby?"
     - If yes, what is the relationship?
     - If no, what matrix needs run when new hardware is introduced?
   - PVIS change vs ring gap, by lab
     - "Did the ring gap reduce severity, and is it consistent among labs?"
     - If yes, can we implement?
     - If no, is there any plan B besides BC4?

Todd presented initial data review of the Ring Gap DOE. He commented that the data is limited by not knowing what the actual ring gaps were. The data presented compared the Ring Gap DOE and individual lab experiments with all chartable 436 and 438 ref runs. The data presented shows that the reduced ring gap did not show a significant difference between matrix, PM matrix and BC3 PM for Ln(PVIS), Ln(MRV), PHOS, average blowby. The Reduced Ring Gap showed higher blowby for initial and Hr. 6-21 than the normal ring gaps, the average BLWBY was not statistically different than the matrix.

Jason Bowden enquired to see if it was possible to compare only the data on the same oils and stands used in the Ring Gap DOE. Todd offered to look at this as well. Also, Todd requested that all labs report their actual ring gap measurements for both the Ring Gap DOE and the prior Ref Oil runs in the stand used for this experiment.

3/1/17 Action Item # 2: Labs to provide actual ring gaps to TMC for tests run in Task Force Ring Gap DOE and prior reference oil 436/438 runs on the stands used in in the DOE.

3/1/17 Action Item # 3: Jason Bowden to summarize Ring Gap DOE and prior Ref Oil results on each stand.

The Statisticians Group with continue analysis of the data utilizing the ring gap data and the prior reference oil results by individual stand.

5.) Introduction of BC4 Piston and Ring hardware

There was significant discussion with regards to how the BC4 pistons should be introduced. The conversation fell between two options: Option A- introduce batch code 4 pistons on a reference test using existing inventory of BC3 rings or Option B-Introduce BC4 pistons using BC4 pistons and BC4 rings. With limited inventory remaining of the BC3 rings at the CPD, but not knowing how much inventory remained at the lab level, the group decided on the following motion.

Motion # 2: Jason Bowden / George Szappanos: Task Force recommends to the Seq. III Surveillance Panel that labs must run entire calibration period on same batch of critical parts the stand was referenced on. - **Motion passed with one waive.**

The group also discussed the fact that we will need to review the data once it is complete to determine if there has been any shift in severity of the test. Jason Bowden reminded the group that the intent of the Task Force should be to return the test to precision matrix severity levels. Charlie Leverett reminded the group that one reason a correction factor

could not be instituted for the prior batch was due to significant differences amongst the labs and stands. The group agreed that once reference data was available the Surveillance Panel would have to review.

Pat Lang also offered Southwest services in running a 20 hour screener test on the BC4 hardware. The group agreed.

3/1/17 Action Item #4: Southwest to run BC4 piston screener test.

3/1/17 Action Item #5: OHT to donate one engine set of BC4 pistons to Southwest.

6.) **Old Business** - None

7.) **New Business** - None

8.) **Motion and Action Item Review (Attachment #5)**

9.) **Next Meeting** – After Seq. III Surveillance Panel and when Stats Group and Open Actions have been completed for review.

10.) **Meeting adjourn – 11:30 am**

Attachment #1

Seq. IIIH Piston Hardware Task Force

Teleconference

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Agenda

1.) Attendance.

2.) **Action Item Review**

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Action Item #6: Confirm how the JTEC data is being collected. Ankit will survey the labs to have them provide the raw data that is being collected along with each labs practices for measuring barometric pressure, JTEC flow, temp, etc.)-Ankit Chaudhry

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3.) **Update on Initial Ring Gap DOE-** Group

a. **Todd Dvorak will provide analysis of DOE results**

- Blowby change vs severity change, by lab
  - "can we use blowby to predict severity and therefore target (limit) the initial value?"

        - If yes, what are the limits
        - if no, then what's impacting severity?
    - Blowby change vs ring gap
        - "can we use the relationship to predict the required adjustment necessary for appropriate blowby?"
        - If yes, what is the relationship?
        - If no, what matrix needs run when new hardware is introduced?
    - PVIS change vs ring gap, by lab
        - "did the ring gap reduce severity, and is it consistent among labs?"
        - **If yes, can we implement?**
        - if no, is there any plan B besides BC4?

4.) Introduction of BC4 Piston and Ring hardware

a. Introduce material on a reference test or a donated test?

b. SwRI presentation on BC2/BC3 Piston screen test-Ankit Chaudhry

5.) **Old Business**

6.) **New Business**

7.) **Motion and Action Item Review**

8.) **Meeting adjourn**

Attachment #2

Intertek

Setup and Maintenance of the J-Tec Model Model VF563AA Blowby Flow Meter

Cleaning Procedure:

A4.3 Cleaning and Maintenance

A4.3.1 To ensure the inside of the flow tube and strut remain in a clean condition, carry out the following cleaning procedure prior to every test start.

A4.3.1.1 Gently brush the strut and the inside of the tube with a soft brush or cotton swab. A solvent cleaner, such as a brake parts cleaner that degreases and leaves no residue, may be used to loosen deposits. Ensure the solvent is compatible with aluminum, fluorelastomers, and PTFE.

A4.3.1.2 DO NOT use wire brushes or use high-pressure liquids which may cause damage to the transducers.

Cleaning is performed at IAR using a no residue solvent cleaner pre and post test on every test. Reinforced tygon hoses are changed prior to each test per procedure.

Calibration Procedure

10.4.9 As a minimum, calibrate the following quantities prior to every reference test sequence, unless the required six-month calibration was completed within 60 days prior to to reference tests start: engine speed, dynamometer torque, engine coolant flow, engine coolant out thermcouple, main oil galley thermocouple.

J-Tec calibration was performed by J-Tec during test development and precision matrix (NIST traceable). Since the precision matrix, IAR has developed a calibration cart using filtered shop air and a MicroMotion as a system fourth order polynomial calibration.

Afton

Cleaning Procedure:

Afton replaces all hoses, after each test. We don't have a cleaning schedule, we monitor after each test and spray out with mineral spirits if it's dirty then air dry.

Calibration Procedure

All J-Tec flowmeters at our lab are sent out for a calibration check yearly.

Lubrizol

Does not use JTEC

Cleaning Procedure:

N/A

Calibration Procedure

N/A

Southwest

Cleaning Procedure:

Hoses are changes every test.

JTEC filter is drained every test and changed if it appears to be dirty.

Calibration Procedure

We send out J-TECs for a calibration check after every reference period.

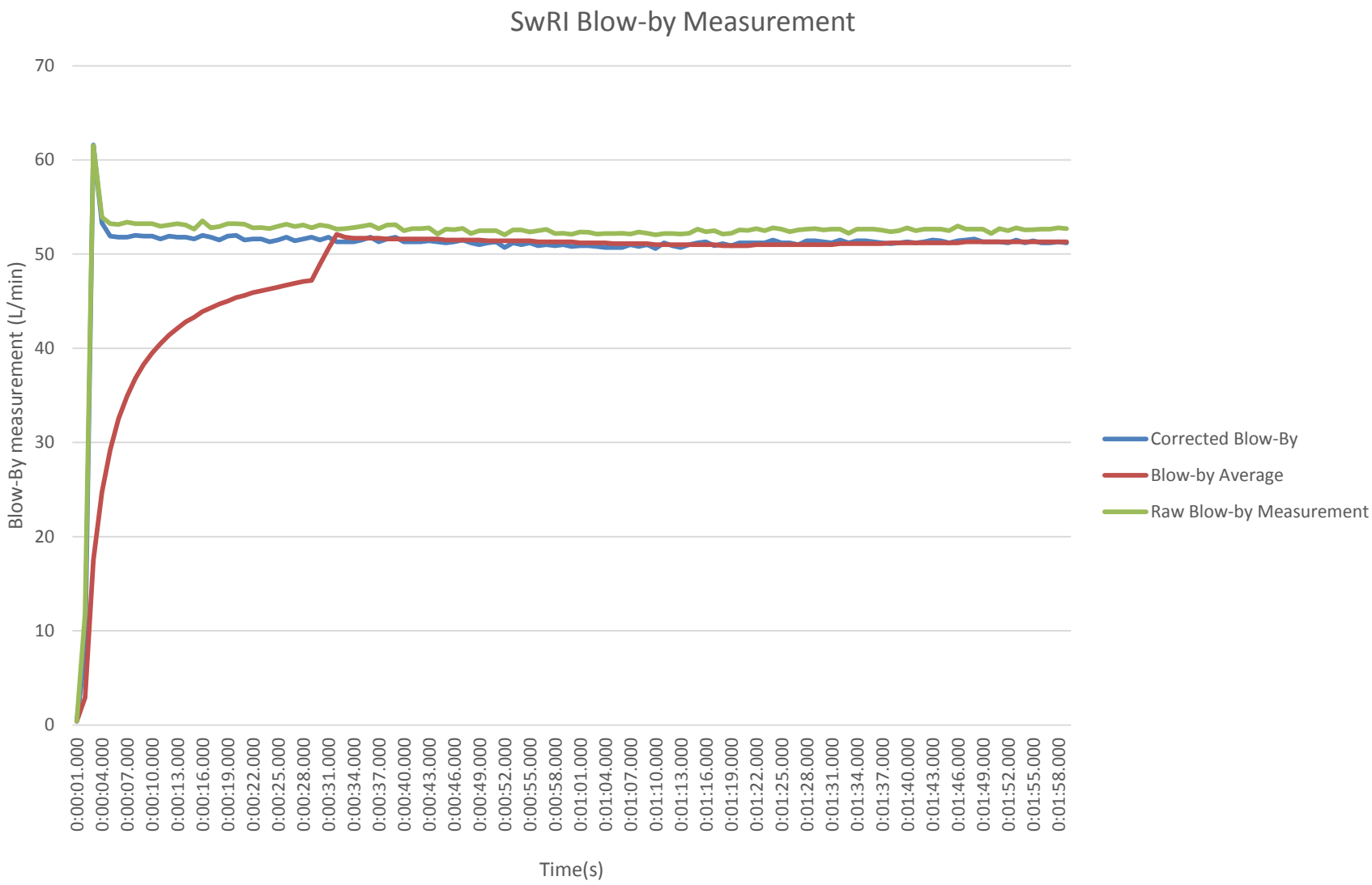
Attachment #3

Blow-by Comparison Data Acquisition

SOUTHWEST RESEARCH INSTITUTE®

Ankit Chaudhry

Project Engineer



For Additional Information

Ankit Chaudhry
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Visit us on the world wide web at:

http://www.swri.edu/4org/d08/d08home.htm

Attachment #4

IIIH Analysis

Statistics Group

Date: March 1, 2017

Statistics Group

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

IIIH Data Analysis

- Executive Summary
  - BlowbyHr6-21 average for WPD factor is significant
  - Emphasis in analysis focused on the contrast between ***matrix batch 2 pistons with normal ring gaps*** (M-2-Normal) vs. ***post matrix batch 3 pistons with reduced ring gaps*** (PM-3-Reduced)
  - The following table summarizes whether or not the contrast was statistically significant:

Parameter for Contrast (M-2-Normal) vs. (PM-3-Reduced)	Significant Difference between contrast (*p* value < 0.05)	Direction of Difference
Ln(PVIS)	No	
WPD	No	
LN(MRV)	No	
Phos	No	
BlowbyHr1	Yes	PM-3-Reduced > M-2-Normal
BlowbyHr6-21	Yes	PM-3-Reduced > M-2-Normal
BlowbyAvg	No	

Blowby to Predict Severity (WPD & TPVIS)

IIIH Data Analysis

- Analysis of LnPVIS data with Blow-by factors in model
  - Blowby Hr1 and Hr6-21 factors are not significant

Response LnPVIS

Whole Model

RefOil | LTMSLAB | LTMSAPP[LTMSLAB] | BLWBH001 | BlowByHr6-21_Avg

Actual by Predicted Plot

Summary of Fit

RSquare	0.515578
RSquare Adj	0.360198
Root Mean Square Error	0.713668
Mean of Response	4.015159
Observations (or Sum Wgts)	71

Analysis of Variance

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	2.5074962	0.571226	4.39	<.0001*	.
RefOil[RO434-2]	0.4257031	0.127411	3.34	0.0015*	1.4975779
RefOil[RO436]	-0.734507	0.13824	-5.31	<.0001*	1.7629656
LTMSLAB[A]	-0.184032	0.188232	-0.98	0.3327	2.3867938
LTMSLAB[B]	0.2112476	0.198363	1.06	0.2917	2.3851209
LTMSLAB[D]	0.1412125	0.188907	0.75	0.4581	1.9618393
LTMSLAB[E]	0.1928937	0.27555	0.70	0.4870	2.6623738
LTMSLAB[A]:LTMSAPP[1]	0.342615	0.26314	1.30	0.1985	1.4016312
LTMSLAB[A]:LTMSAPP[2]	0.379589	0.274553	1.38	0.1726	1.4049511
LTMSLAB[A]:LTMSAPP[3]	-0.258838	0.416116	-0.62	0.5366	1.3598677
LTMSLAB[B]:LTMSAPP[3A]	0.3224887	0.401526	0.80	0.4255	2.4610246
LTMSLAB[B]:LTMSAPP[1]	-0.299361	0.264939	-1.13	0.2636	2.0497616
LTMSLAB[D]:LTMSAPP[1]	-0.297013	0.269461	-1.10	0.2753	1.2649687
LTMSLAB[D]:LTMSAPP[2]	-0.174012	0.284189	-0.61	0.5429	1.2596242
LTMSLAB[G]:LTMSAPP[1]	-0.122811	0.339763	-0.36	0.7192	1.3599089
LTMSLAB[G]:LTMSAPP[2]	0.1685252	0.26847	0.63	0.5329	1.5068212
BLWBH001	0.0095916	0.020105	0.48	0.6353	6.3479852
BlowByHr6-21_Avg	0.0226495	0.030955	0.73	0.4676	6.8470454

IIIH Data Analysis

- Analysis of WPD data with Blowby factors in model
  - Blowby Hr6-21 factor is significant

Least Squares Fit
Response LnPVIS
Response WPD
Whole Model
Actual by Predicted Plot
Summary of Fit
Analysis of Variance
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	5.508098	0.370825	14.85	<.0001*	.
RefOil[RO434-2]	0.1144226	0.082712	1.38	0.1723	1.4975779
RefOil[RO436]	0.6709577	0.089742	7.48	<.0001*	1.7629656
LTMSLAB[A]	0.0629767	0.122196	0.52	0.6084	2.3867938
LTMSLAB[B]	-0.191761	0.128772	-1.49	0.1424	2.3851209
LTMSLAB[D]	0.0414029	0.122634	0.34	0.7370	1.9618393
LTMSLAB[E]	-0.163423	0.17888	-0.91	0.3651	2.6623738
LTMSLAB[A]:LTMSAPP[1]	-0.052496	0.170824	-0.31	0.7598	1.4016312
LTMSLAB[A]:LTMSAPP[2]	-0.171442	0.178233	-0.96	0.3405	1.4049511
LTMSLAB[A]:LTMSAPP[3]	0.3298606	0.270132	1.22	0.2274	1.3598677
LTMSLAB[B]:LTMSAPP[3A]	-0.279568	0.260661	-1.07	0.2883	2.4610246
LTMSLAB[B]:LTMSAPP[1]	0.1044572	0.171991	0.61	0.5462	2.0497616
LTMSLAB[D]:LTMSAPP[1]	0.3359526	0.174927	1.92	0.0602	1.2649687
LTMSLAB[D]:LTMSAPP[2]	-0.136747	0.184488	-0.74	0.4618	1.2596242
LTMSLAB[G]:LTMSAPP[1]	-0.101812	0.220565	-0.46	0.6463	1.3599089
LTMSLAB[G]:LTMSAPP[2]	0.1465907	0.174284	0.84	0.4041	1.5068212
BLWBH001	0.0139718	0.013052	1.07	0.2893	6.3479852
BlowByHr6-21_Avg	-0.052433	0.020095	-2.61	0.0118*	6.8470454

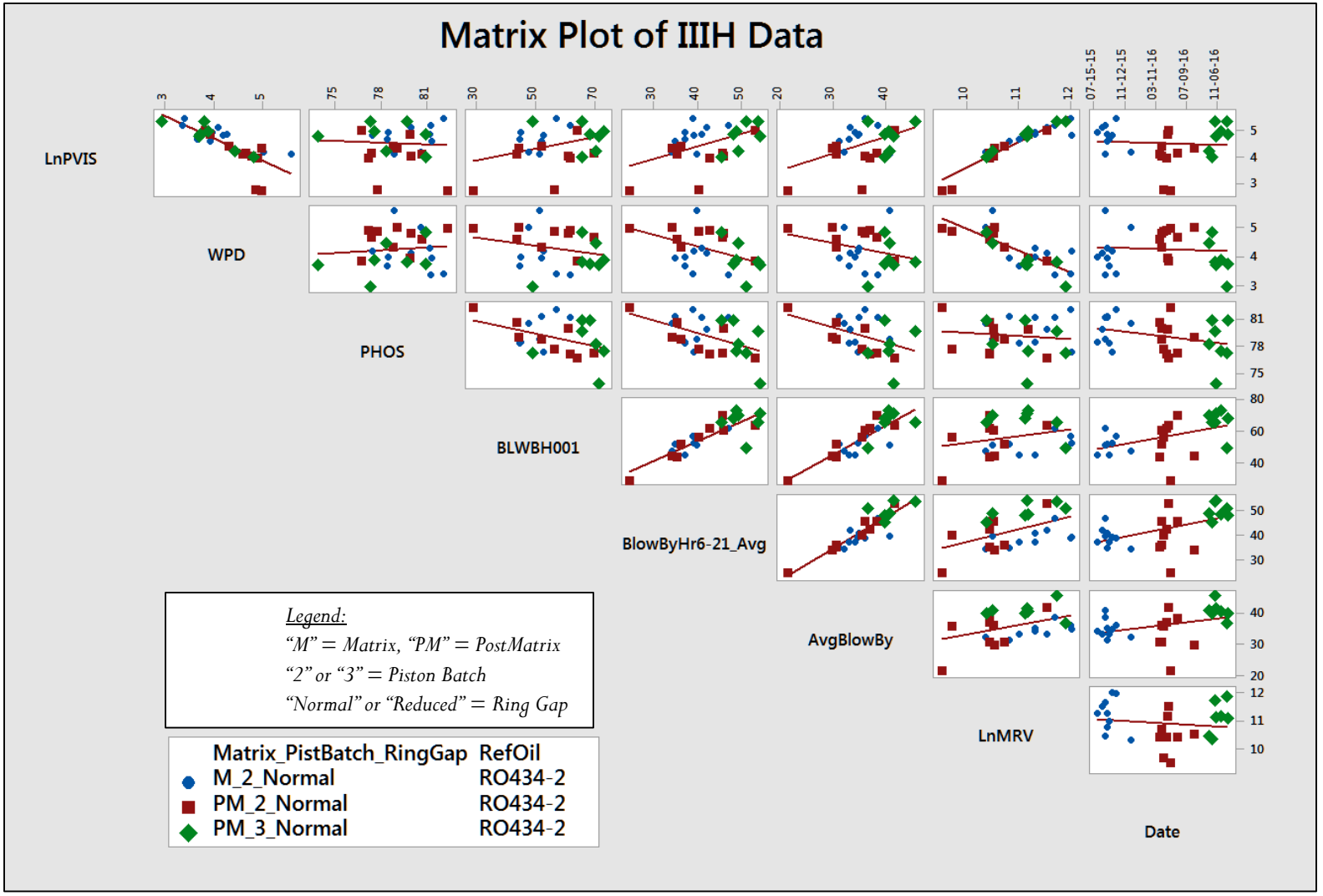
Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
RefOil	2	2	17.739257	41.3228	<.0001*
LTMSLAB	4	4	1.294030	1.5072	0.2133
LTMSAPP[LTMSLAB]	9	9	1.549291	0.8020	0.6161
BLWBH001	1	1	0.245967	1.1459	0.2893
BlowByHr6-21_Avg	1	1	1.461269	6.8079	0.0118*

Matrix Plots of Data for Analysis

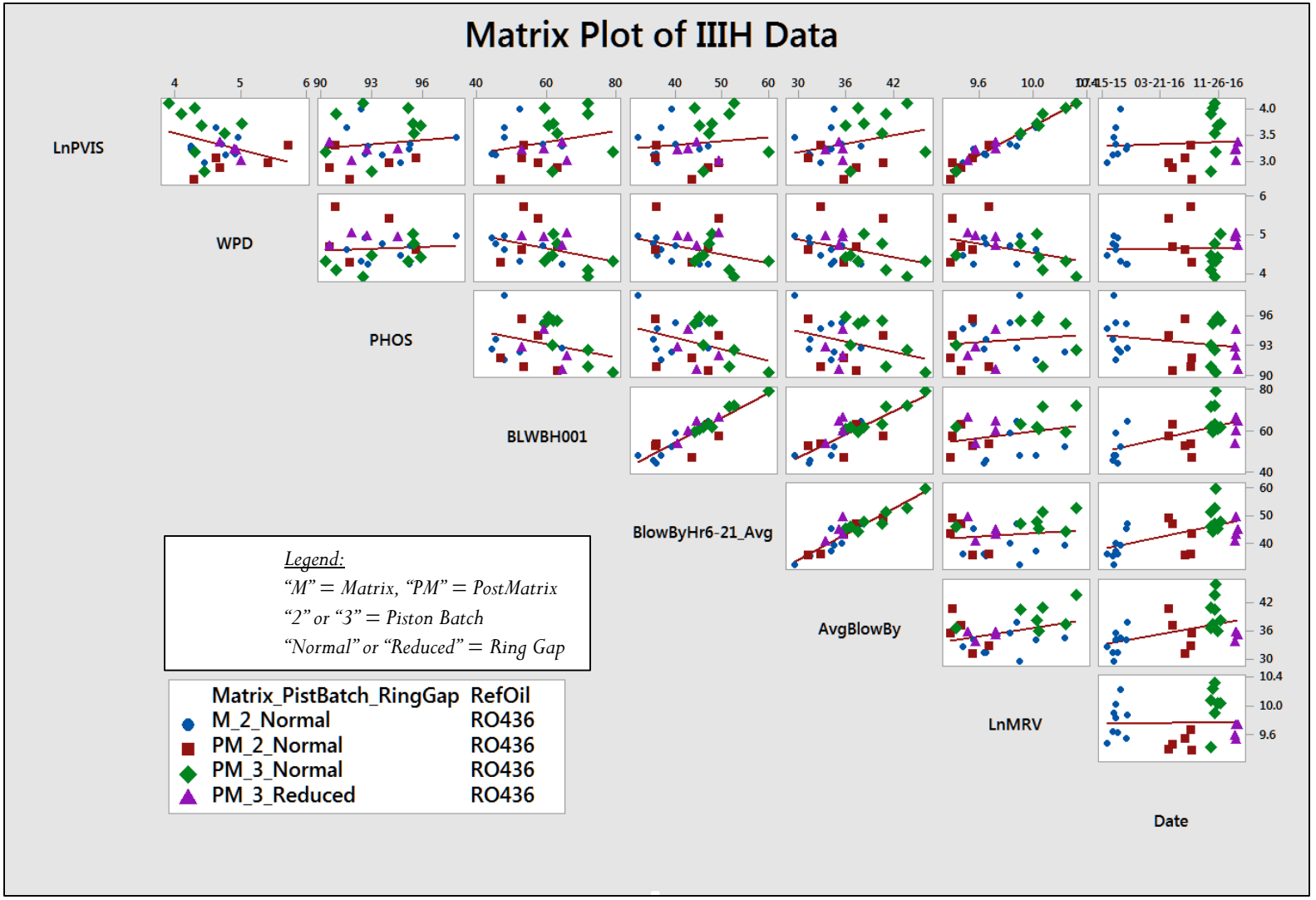
IIIH Data Analysis

- Matrix plot of available RO434-2 data:



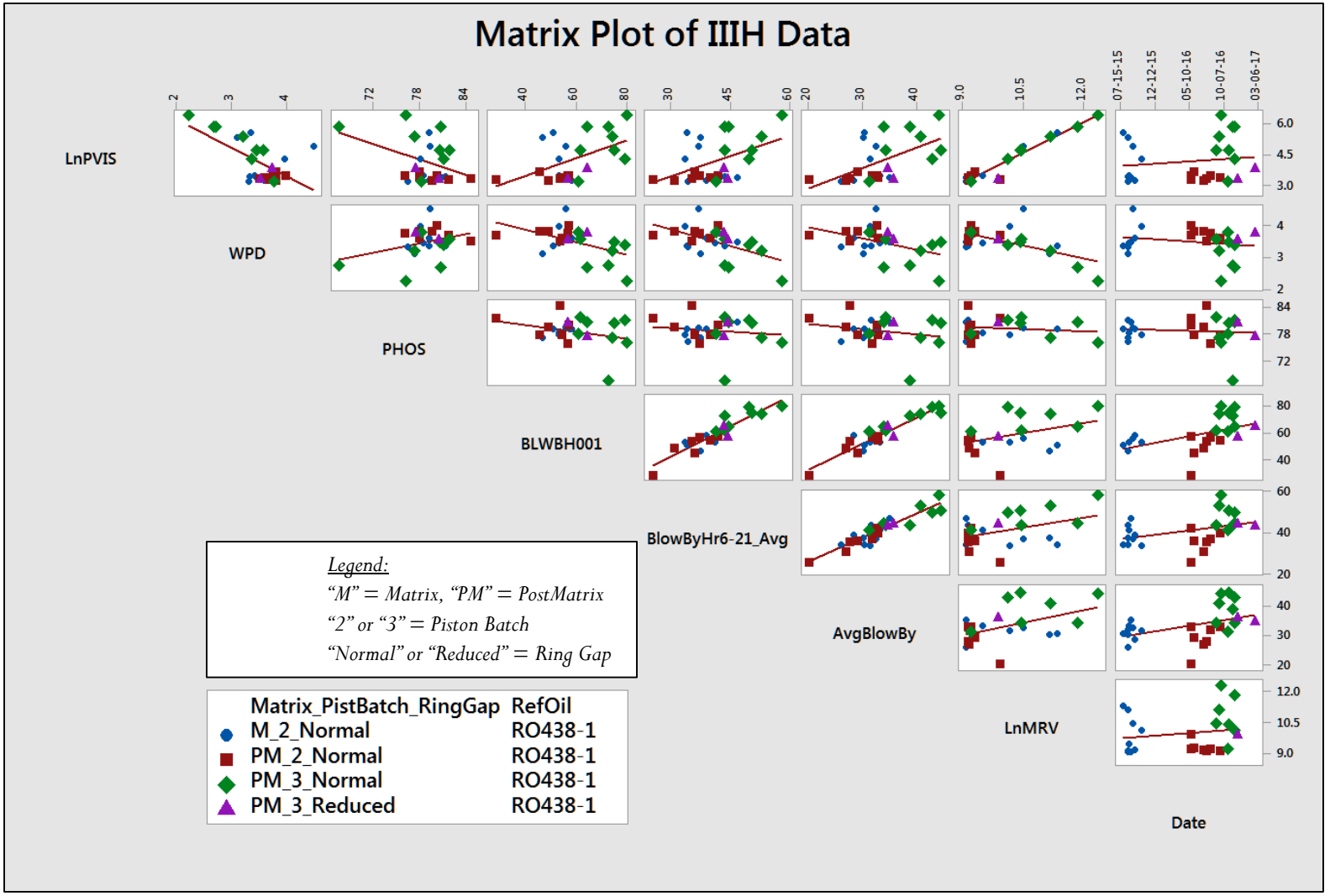
IIIH Data Analysis

- Matrix plot of available RO436 data:



IIIH Data Analysis

- Matrix plot of available RO438-1 data:



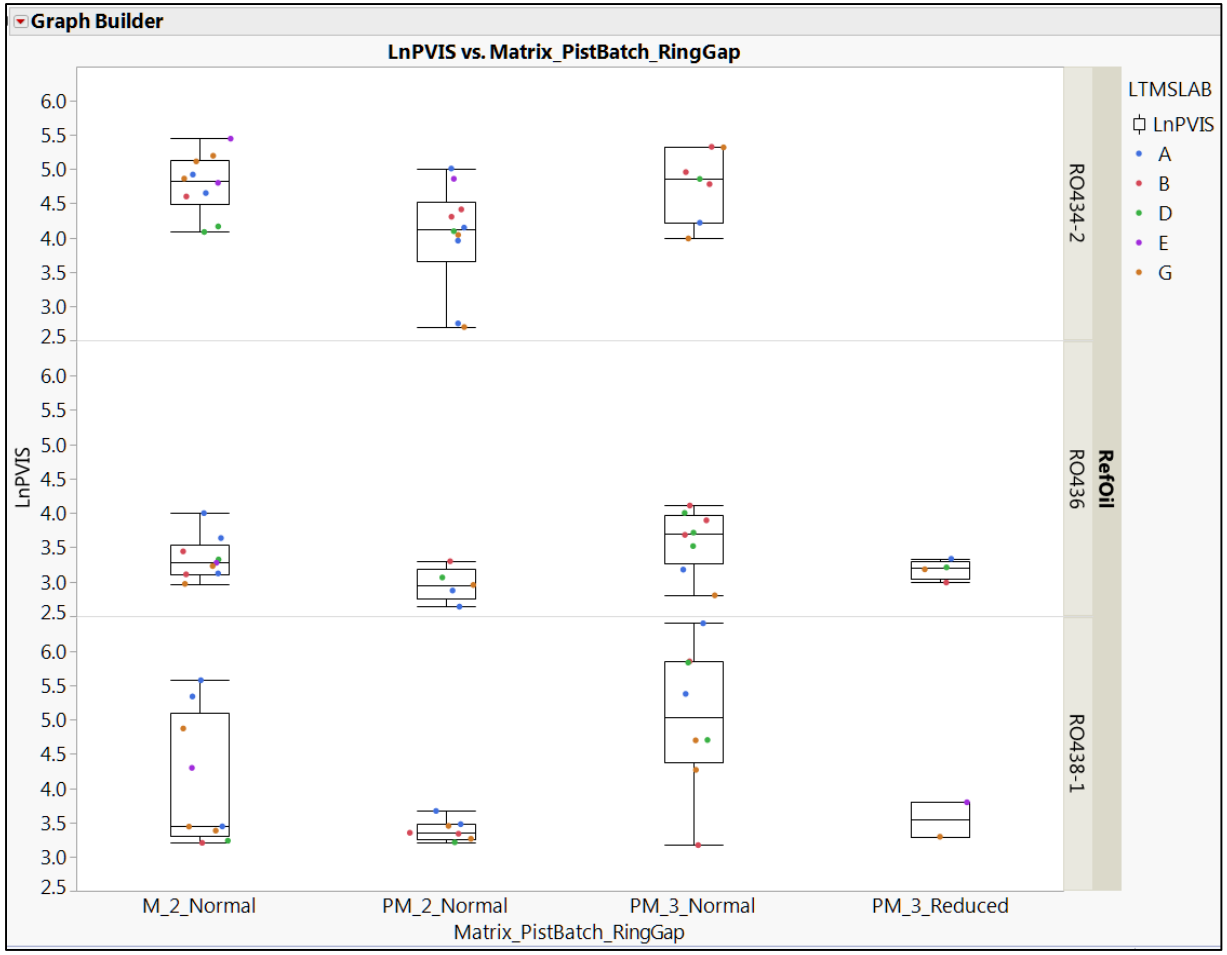
PVIS Parameter Data Analysis

IIIH Data Analysis

- Available PVIS data for analysis:
  - Matrix_PistBatch2_NormalRingGaps n=28
  - PostMatrix_PistBatch2_NormalRingGaps n=22
  - PostMatrix_PistBatch3_NormalRingGaps n=23
  - PostMatrix_PistBatch3_ReducedRingGaps n=6

IIIH Data Analysis

- Plot of raw IIIH Test result data for LnPVIS parameter



Legend:

"M" = Matrix, "PM" = PostMatrix

"2" or "3" = Piston Batch

"Normal" or "Reduced" = Ring Gap

IIIH Data Analysis

- Analysis of IIIH Test Result Data for LnPVIS parameter:
  - PM_BC3_Normal >PM_BC2_Normal, PM_3_Reduced *(pvalue ~ 0.10)*
  - No statistical difference between M_BC2_Normal and PM_BC3_Reduced

Response LnPVIS

Whole Model

Effect Summary

Actual by Predicted Plot

Summary of Fit

RSquare	0.623267
RSquare Adj	0.510247
Root Mean Square Error	0.621198
Mean of Response	4.001811
Observations (or Sum Wgts)	79

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	18	38.304610	2.12803	5.5147
Error	60	23.153213	0.38589	Prob > F
C. Total	78	61.457823		<.0001*

Lack Of Fit

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
RefOil	2	2	16.679971	21.6125	<.0001*
LTMSLAB	4	4	2.377834	1.5405	0.2020
LTMSAPP[LTMSLAB]	9	9	4.084667	1.1761	0.3267
Matrix_PistBatch_RingGap	3	3	10.234055	8.8403	<.0001*

RefOil | LTMSLAB | LTMSAPP[LTMSLAB]

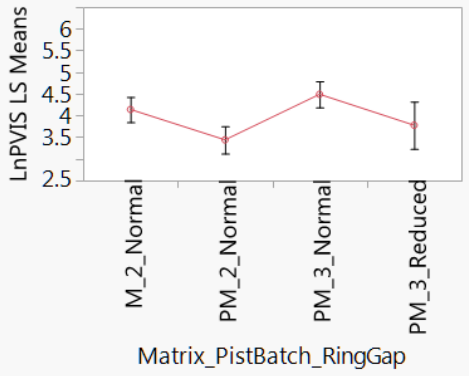
Matrix_PistBatch_RingGap

Leverage Plot

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
M_2_Normal	4.1415539	0.14532407	4.09901
PM_2_Normal	3.4409095	0.15707673	3.58455
PM_3_Normal	4.4917682	0.15111622	4.46538
PM_3_Reduced	3.7787844	0.27337187	3.30119

LS Means Plot



LSMeans Differences Tukey HSD

Legend:
"M" = Matrix, "PM" = PostMatrix
"2" or "3" = Piston Batch
"Normal" or "Reduced" = Ring Gap

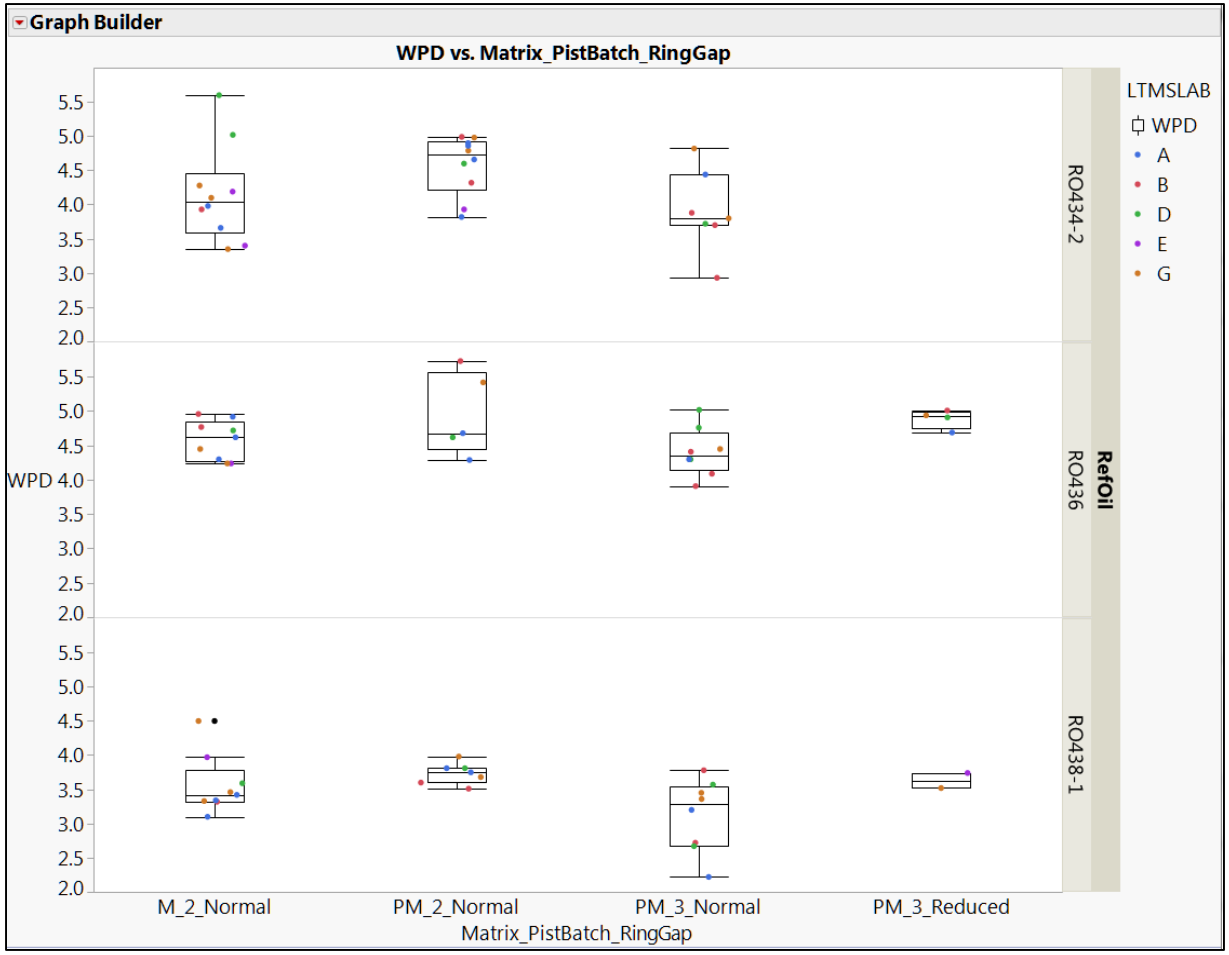
WPD Parameter Data Analysis

IIIH Data Analysis

- Available WPD data for analysis:
  - Matrix_PistBatch2_NormalRingGaps n=28
  - PostMatrix_PistBatch2_NormalRingGaps n=22
  - PostMatrix_PistBatch3_NormalRingGaps n=23
  - PostMatrix_PistBatch3_ReducedRingGaps n=6

IIIH Data Analysis

- Plot of raw IIIH Test result data for WPD parameter



Legend:

"M" = Matrix, "PM" = PostMatrix

"2" or "3" = Piston batch

"Normal" or "Reduced" = Ring Gap

IIIH Data Analysis Review

- Analysis of IIIH Test Result Data for WPD parameter:
  - PM_BC2_Normal >PM_BC3_Normal, PM_BC2_Normal >M_BC2_Normal
  - No statistical difference between M_BC2_Normal and PM_BC3_Reduced

Response WPD

Whole Model

Effect Summary

Actual by Predicted Plot

Summary of Fit

RSquare	0.690785
RSquare Adj	0.59802
Root Mean Square Error	0.442538
Mean of Response	4.124051
Observations (or Sum Wgts)	79

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	18	26.250314	1.45835	7.4467
Error	60	11.750389	0.19584	Prob > F
C. Total	78	38.000704		<.0001*

Lack Of Fit

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
RefOil	2	2	16.729304	42.7117	<.0001*
LTMSLAB	4	4	1.451014	1.8523	0.1307
LTMSAPP[LTMSLAB]	9	9	1.745114	0.9901	0.4578
Matrix_PistBatch_RingGap	3	3	3.819162	6.5005	0.0007*

RefOil | LTMSLAB | LTMSAPP[LTMSLAB]

Matrix_PistBatch_RingGap

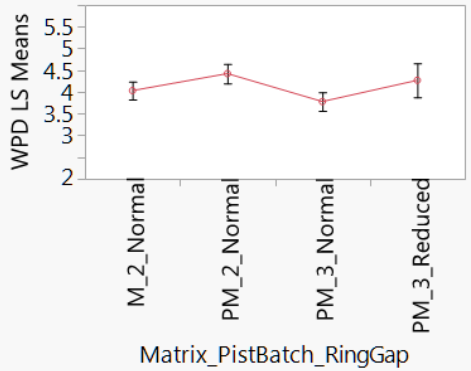
Leverage Plot

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
M_2_Normal	4.0340551	0.10352806	4.09857
PM_2_Normal	4.4246941	0.11190058	4.39682
PM_3_Normal	3.7814134	0.10765435	3.80435
PM_3_Reduced	4.2710898	0.19474859	4.46833

LSMeans Differences Tukey HSD

LS Means Plot



Legend:
"M" = Matrix, "PM" = PostMatrix
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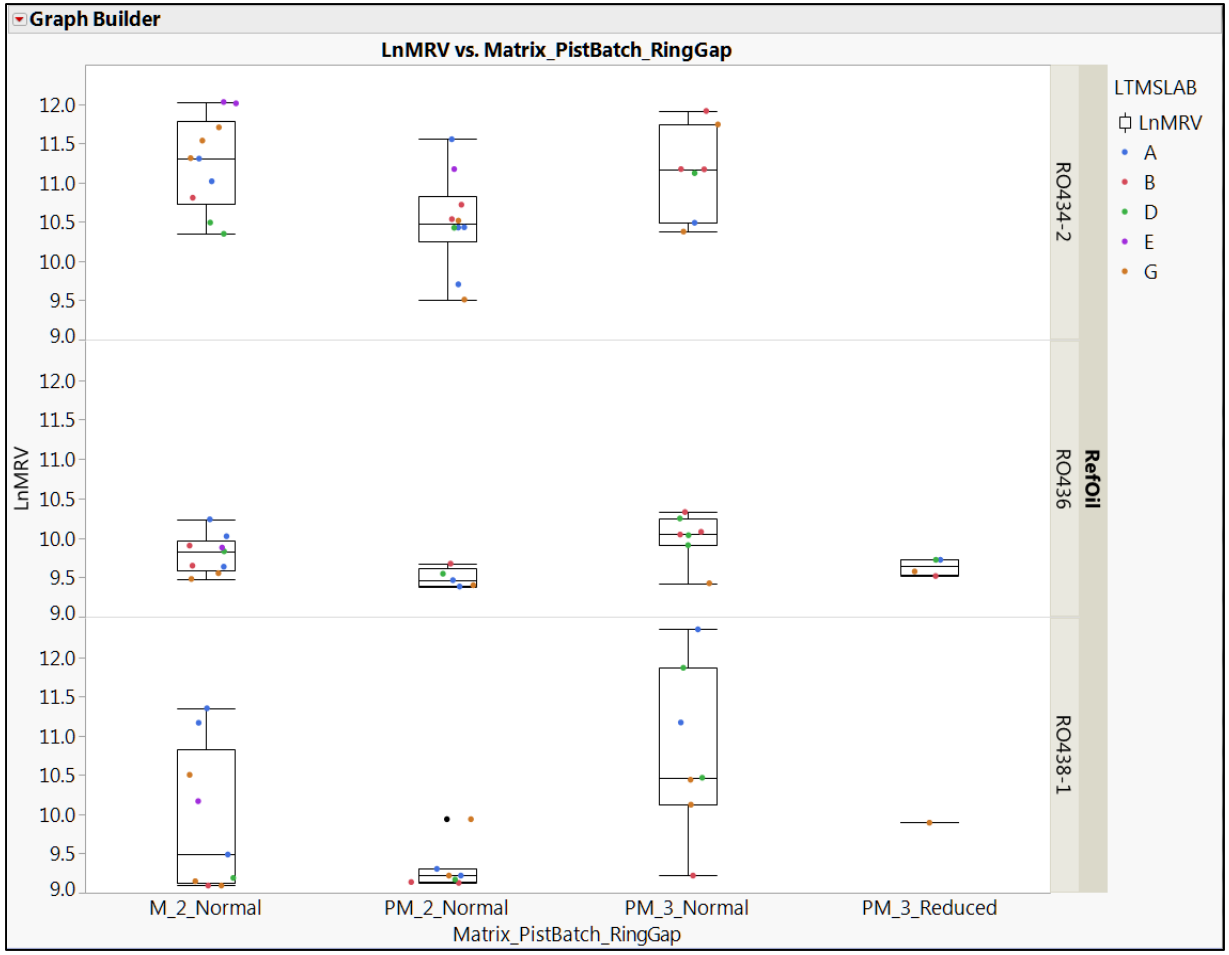
MRV Parameter Data Analysis

IIIH Data Analysis

- Available MRV data for analysis:
  - Matrix_PistBatch2_NormalRingGaps n=28
  - PostMatrix_PistBatch2_NormalRingGaps n=22
  - PostMatrix_PistBatch3_NormalRingGaps n=21
  - PostMatrix_PistBatch3_ReducedRingGaps n=5

IIIH Data Analysis

- Plot of raw IIIH Test result data for LnMRV parameter



Legend:

"M" = Matrix, "PM" = PostMatrix

"2" or "3" = Piston batch

"Normal" or "Reduced" = Ring Gap

IIIH Data Analysis

- Analysis of IIIH Test Result Data for LnMRV parameter:
  - PM_BC2_Normal >PM_BC3_Normal, PM_BC2_Normal >M_BC2_Normal
  - No statistical difference between M_BC2_Normal and PM_BC3_Reduced

Response LnMRV

Whole Model

Effect Summary

Actual by Predicted Plot

Summary of Fit

RSquare	0.660614
RSquare Adj	0.55344
Root Mean Square Error	0.577011
Mean of Response	10.25842
Observations (or Sum Wgts)	76

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	18	36.940085	2.05223	6.1639
Error	57	18.977687	0.33294	Prob > F
C. Total	75	55.917772		<.0001*

Lack Of Fit

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
RefOil	2	2	17.310990	25.9970	<.0001*
LTMSLAB	4	4	2.865109	2.1514	0.0862
LTMSAPP[LTMSLAB]	9	9	3.651062	1.2185	0.3021
Matrix_PistBatch_RingGap	3	3	6.710363	6.7183	0.0006*

RefOil | LTMSLAB | LTMSAPP[LTMSLAB]

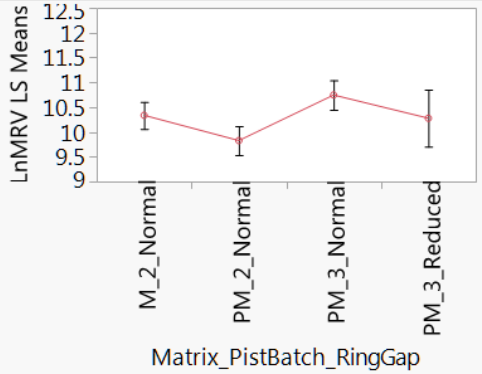
Matrix_PistBatch_RingGap

Leverage Plot

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
M_2_Normal	10.337400	0.13631791	10.3551
PM_2_Normal	9.827640	0.14703669	9.8902
PM_3_Normal	10.746560	0.14853232	10.6515
PM_3_Reduced	10.278484	0.28673524	9.6865

LS Means Plot



Contrast

LSMeans Differences Tukey HSD

Legend:
"M" = Matrix, "PM" = PostMatrix
"2" or "3" = Piston Batch
"Normal" or "Reduced" = Ring Gap

Phos Parameter Data Analysis

IIIH Data Analysis

- Available Blowby_Avg data for analysis:
  - Matrix_PistBatch2_NormalRingGaps n=28
  - PostMatrix_PistBatch2_NormalRingGaps n=22
  - PostMatrix_PistBatch3_NormalRingGaps n=23
  - PostMatrix_PistBatch3_ReducedRingGaps n=6

IIIH Data Analysis

- Plot of raw IIIH Test result data for Phos parameter

Legend:

"M" = Matrix, "PM" = PostMatrix

"2" or "3" = Piston batch

"Normal" or "Reduced" = Ring Gap

IIIH Data Analysis

- Analysis of IIIH Test Result Data for Phos parameter:
  - No statistical difference between M_BC2_Normal and PM_BC3_Reduced

Response PHOS

Whole Model

Effect Summary

Actual by Predicted Plot

Summary of Fit

RSquare	0.942338
RSquare Adj	0.925039
Root Mean Square Error	1.966461
Mean of Response	83.74266
Observations (or Sum Wgts)	79

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	18	3791.7109	210.651	54.4744
Error	60	232.0181	3.867	Prob > F
C. Total	78	4023.7289		<.0001*

Lack Of Fit

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
RefOil	2	2	2921.6220	377.7665	<.0001*
LTMSLAB	4	4	114.7230	7.4169	<.0001*
LTMSAPP[LTMSLAB]	9	9	39.6878	1.1404	0.3495
Matrix_PistBatch_RingGap	3	3	22.4624	1.9363	0.1334

RefOil | LTMSLAB | LTMSAPP[LTMSLAB]

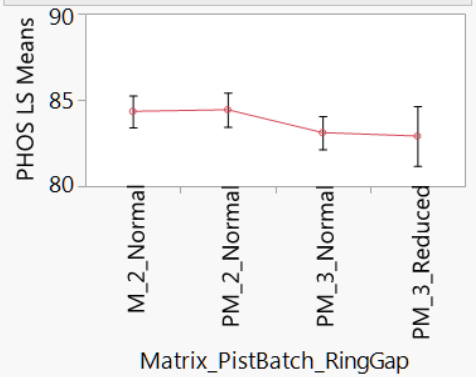
Matrix_PistBatch_RingGap

Leverage Plot

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
M_2_Normal	84.339972	0.46003706	84.1536
PM_2_Normal	84.438201	0.49724121	82.2973
PM_3_Normal	83.107985	0.47837265	83.5304
PM_3_Reduced	82.908912	0.86538444	87.9383

LS Means Plot



LSMeans Differences Tukey HSD

Legend:
"M" = Matrix, "PM" = PostMatrix
"2" or "3" = Piston Batch
"Normal" or "Reduced" = Ring Gap

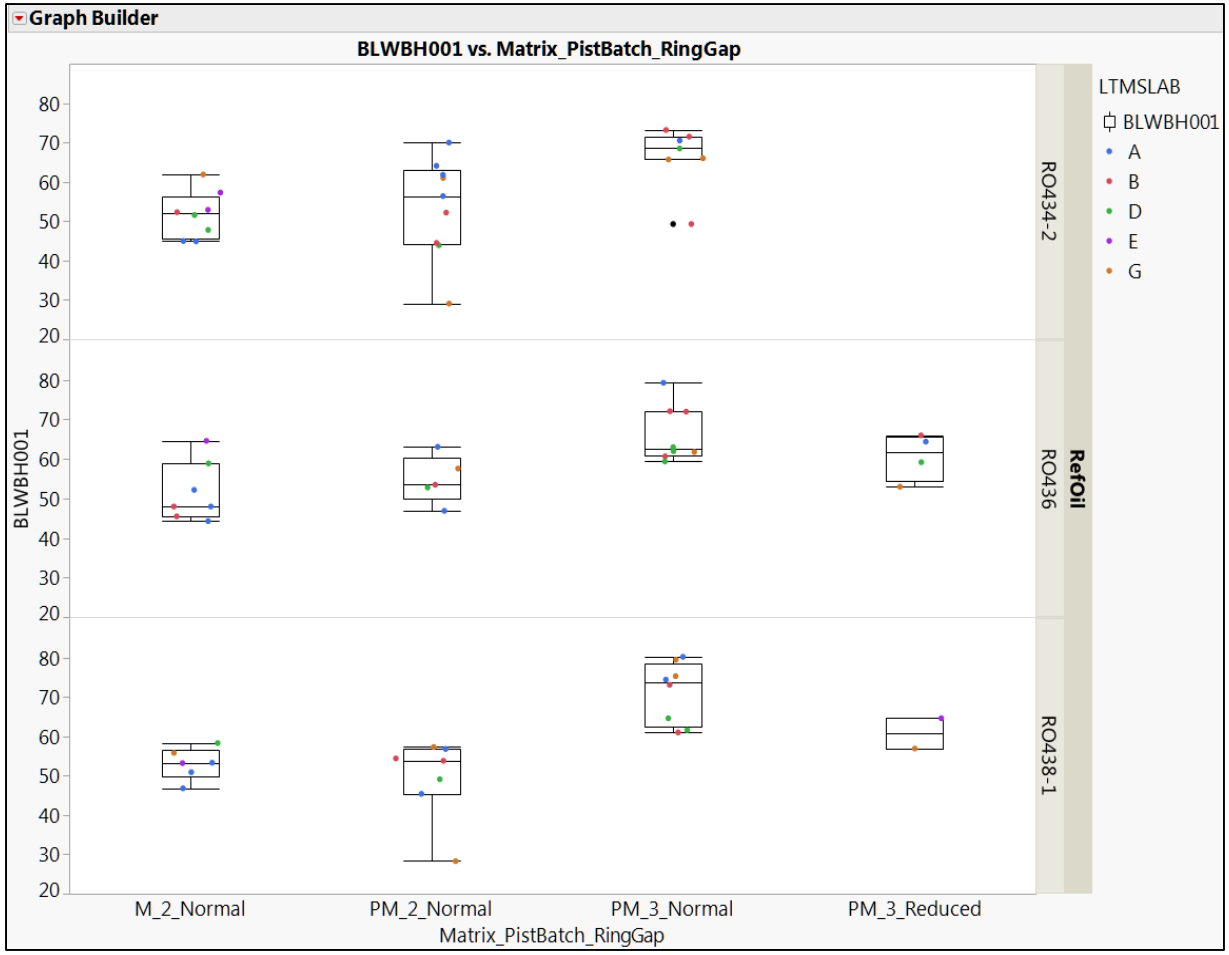
Blow-by-Hr1 Parameter Data Analysis

IIIH Data Analysis

- Available Blow-by-Hr1 data for analysis:
  - Matrix_PistBatch2_NormalRingGaps n=21
  - PostMatrix_PistBatch2_NormalRingGaps n=21
  - PostMatrix_PistBatch3_NormalRingGaps n=23
  - PostMatrix_PistBatch3_ReducedRingGaps n=6

IIIH Data Analysis

- Plot of raw IIIH Test result data for Blowby-Hr1 parameter



Legend:

"M" = Matrix, "PM" = PostMatrix

"2" or "3" = Piston batch

"Normal" or "Reduced" = Ring Gap

IIIH Data Analysis

- Analysis of IIIH Test Result Data for Blowby-Hr1 parameter:
  - PM_3_Normal>M_2_Normal, PM_2_Normal & (PM_3_Normal>PM_3_Reduced)
  - Statistical difference between PM_BC3_Reduced > M_BC2_Normal

Response BLWBH001

Whole Model

Effect Summary

Actual by Predicted Plot

Summary of Fit

RSquare	0.694194
RSquare Adj	0.588339
Root Mean Square Error	6.858436
Mean of Response	58.08873
Observations (or Sum Wgts)	71

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	18	5552.5074	308.473	6.5579
Error	52	2445.9835	47.038	Prob > F
C. Total	70	7998.4910		<.0001*

Lack Of Fit

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
RefOil	2	2	30.5824	0.3251	0.7239
LTMSLAB	4	4	851.7938	4.5271	0.0033*
LTMSAPP[LTMSLAB]	9	9	1404.6910	3.3181	0.0029*
Matrix_PistBatch_RingGap	3	3	4290.6227	30.4053	<.0001*

RefOil | LTMSLAB | LTMSAPP[LTMSLAB]

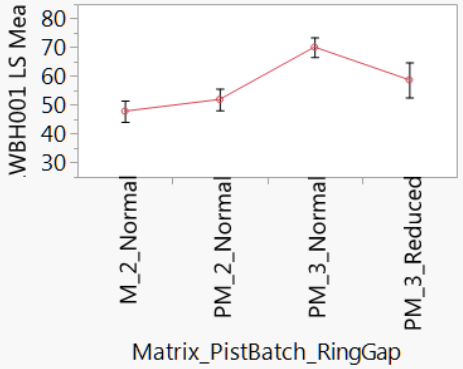
Matrix_PistBatch_RingGap

Leverage Plot

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
M_2_Normal	47.892817	1.8559366	52.0714
PM_2_Normal	51.976515	1.8592583	52.4762
PM_3_Normal	70.143413	1.6979569	68.0304
PM_3_Reduced	58.776324	3.0369344	60.6833

LS Means Plot



Legend:
"M" = Matrix, "PM" = PostMatrix
"2" or "3" = Piston Batch
"Normal" or "Reduced" = Ring Gap

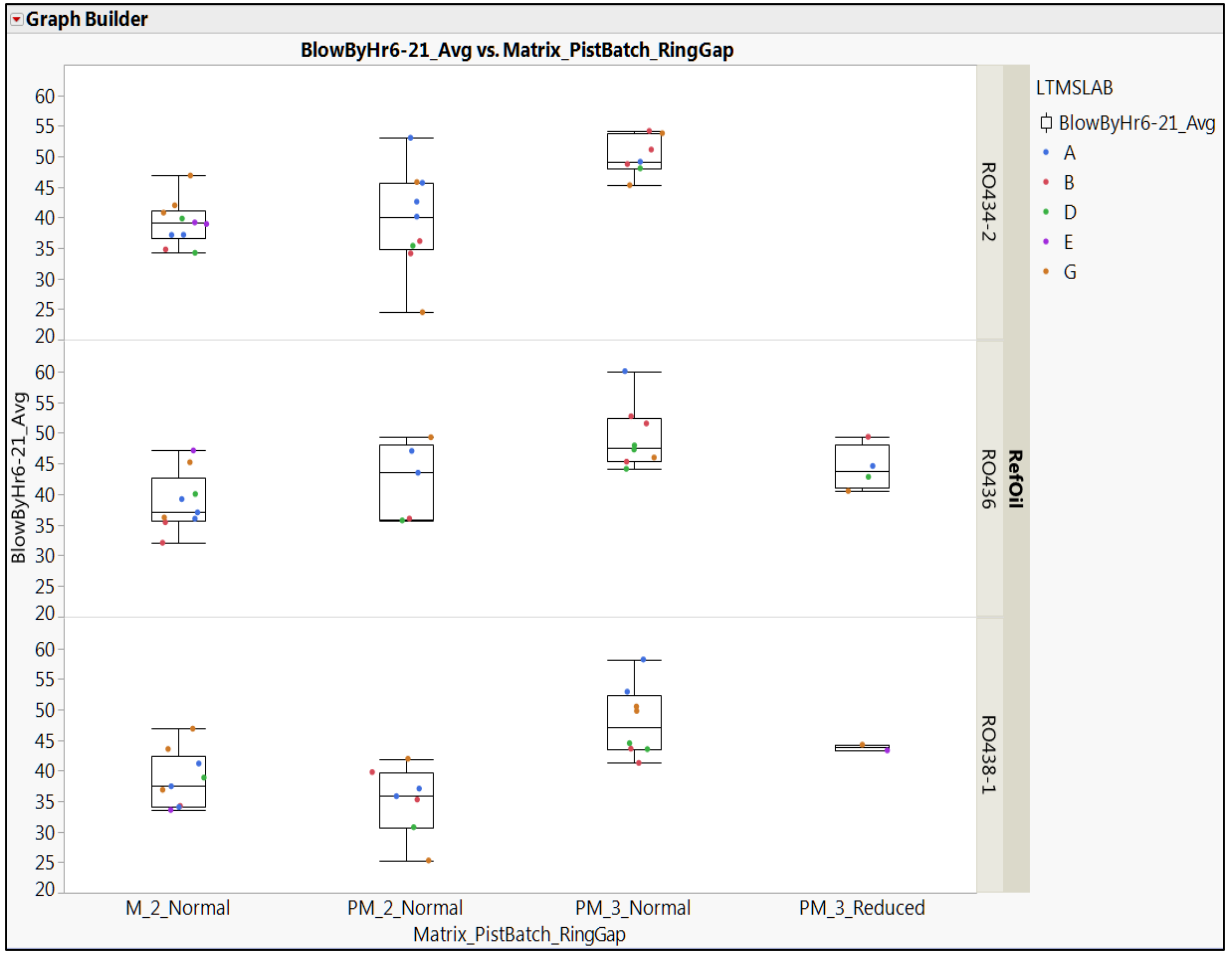
BlowbyHr6-21 Parameter Data Analysis

IIIH Data Analysis

- Available BlowbyHr6-21 data for analysis:
  - Matrix_PistBatch2_NormalRingGaps n=28
  - PostMatrix_PistBatch2_NormalRingGaps n=21
  - PostMatrix_PistBatch3_NormalRingGaps n=23
  - PostMatrix_PistBatch3_ReducedRingGaps n=6

IIIH Data Analysis

- Plot of raw IIIH Test result data for Blowby-Hr6-21_Avg parameter



Legend:

"M" = Matrix, "PM" = PostMatrix

"2" or "3" = Piston batch

"Normal" or "Reduced" = Ring Gap

IIIH Data Analysis

- Analysis of IIIH Test Result Data for BlowbyHr6-21 parameter:
  - (PM_3_Normal>M_2_Normal, PM_2_Normal) & (PM_3_Normal>PM_3_Reduced)
  - Statistical difference between PM_3_Reduced > M_2_Normal

Response BlowByHr6-21_Avg

Whole Model

Effect Summary

Actual by Predicted Plot

Summary of Fit

RSquare	0.64394
RSquare Adj	0.535311
Root Mean Square Error	4.773015
Mean of Response	42.24679
Observations (or Sum Wgts)	78

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	18	2430.8581	135.048	5.9279
Error	59	1344.1185	22.782	Prob > F
C. Total	77	3774.9767		<.0001*

Lack Of Fit

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
RefOil	2	2	153.6544	3.3723	0.0410*
LTMSLAB	4	4	246.7109	2.7073	0.0387*
LTMSAPP[LTMSLAB]	9	9	335.9710	1.6386	0.1253
Matrix_PistBatch_RingGap	3	3	1746.4561	25.5535	<.0001*

RefOil | LTMSLAB | LTMSAPP[LTMSLAB]

Matrix_PistBatch_RingGap

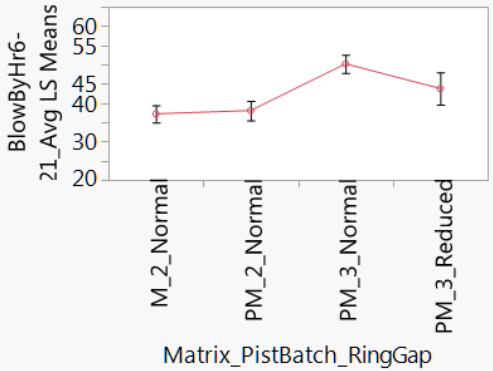
Leverage Plot

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
M_2_Normal	37.217517	1.1166072	38.7821
PM_2_Normal	38.058773	1.2789949	38.8071
PM_3_Normal	50.213489	1.1765485	49.1098
PM_3_Reduced	43.795431	2.1005259	44.1458

LSMeans Differences Tukey HSD

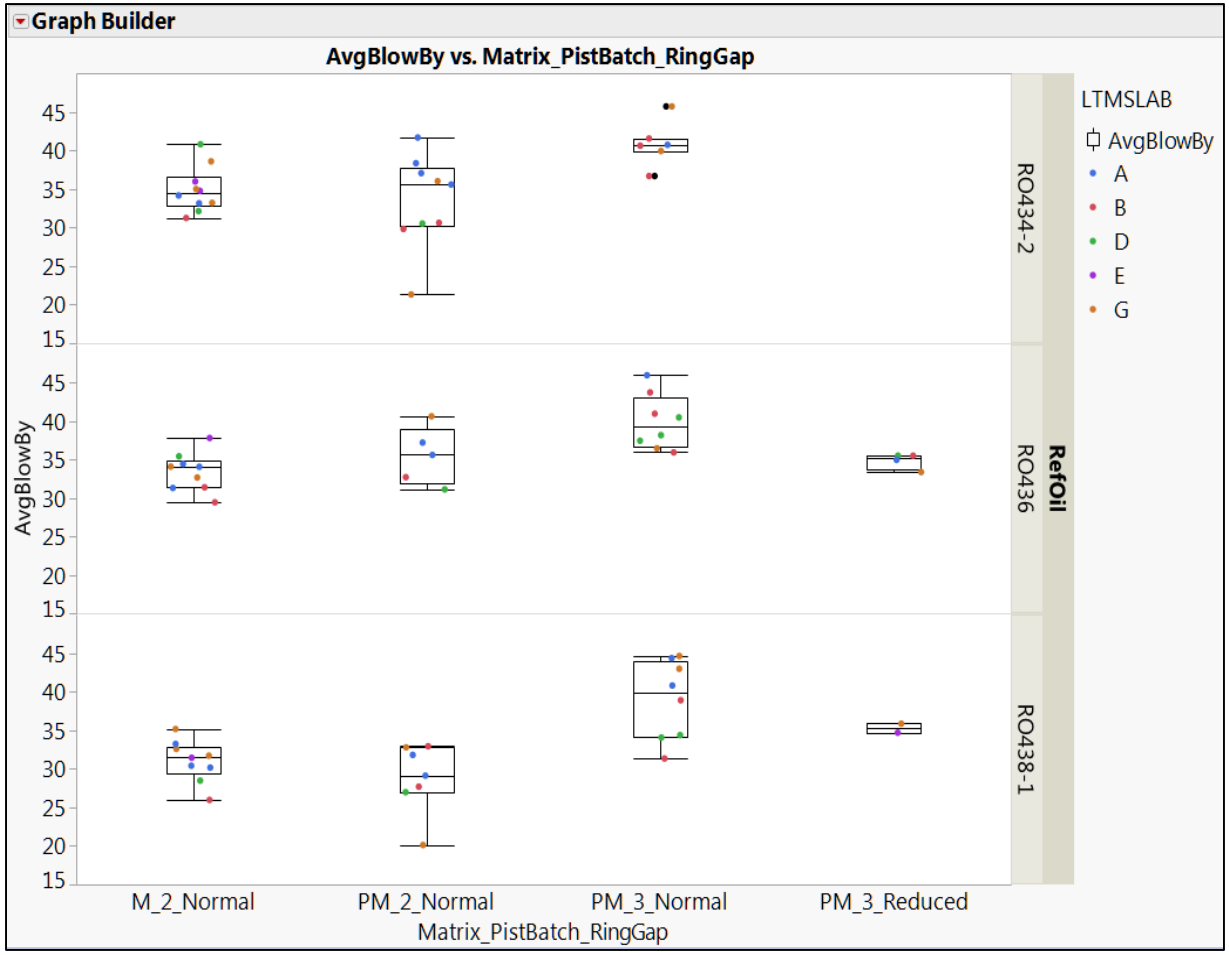
LS Means Plot



Legend:
"M" = Matrix, "PM" = PostMatrix
"2" or "3" = Piston Batch
"Normal" or "Reduced" = Ring Gap

IIIH Data Analysis

- Plot of raw IIIH Test result data for BlowbyAvg parameter



Legend:

"M" = Matrix, "PM" = PostMatrix

"2" or "3" = Piston batch

"Normal" or "Reduced" = Ring Gap

Blowby_Avg Parameter Data Analysis

IIIH Data Analysis

- Available Blowby_Avg data for analysis:
  - Matrix_PistBatch2_NormalRingGaps n=28
  - PostMatrix_PistBatch2_NormalRingGaps n=21
  - PostMatrix_PistBatch3_NormalRingGaps n=23
  - PostMatrix_PistBatch3_ReducedRingGaps n=6

IIIH Data Analysis

- Analysis of IIIH Test Result Data for BlowbyAvg parameter:
  - (PM_3_Normal>M_2_Normal, PM_2_Normal) & (PM_3_Normal>PM_3_Reduced)
  - No statistical difference between PM_3_Reduced & M_2_Normal

Response AvgBlowBy

Whole Model

Effect Summary

Actual by Predicted Plot

Summary of Fit

RSquare	0.6643
RSquare Adj	0.561882
Root Mean Square Error	3.35912
Mean of Response	35.06222
Observations (or Sum Wgts)	78

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	18	1317.3924	73.1885	6.4862
Error	59	665.7377	11.2837	Prob > F
C. Total	77	1983.1301		<.0001*

Lack Of Fit

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
RefOil	2	2	212.00956	9.3945	0.0003*
LTMSLAB	4	4	205.77560	4.5591	0.0028*
LTMSAPP[LTMSLAB]	9	9	201.52419	1.9844	0.0573
Matrix_PistBatch_RingGap	3	3	949.27991	28.0428	<.0001*

RefOil | LTMSLAB | LTMSAPP[LTMSLAB]

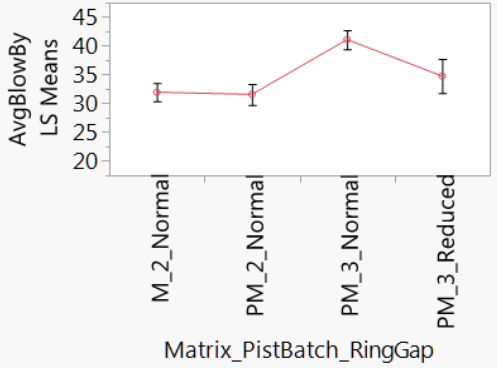
Matrix_PistBatch_RingGap

Leverage Plot

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
M_2_Normal	31.966533	0.7858383	33.1805
PM_2_Normal	31.576162	0.9001224	32.3730
PM_3_Normal	41.101361	0.8280234	39.8249
PM_3_Reduced	34.767521	1.4782941	34.9991

LS Means Plot



LSMeans Differences Tukey HSD

Legend:
"M" = Matrix, "PM" = PostMatrix
"2" or "3" = Piston Batch
"Normal" or "Reduced" = Ring Gap

Appendix

IIIH Blow-by Analysis for BC2 Pistons

- Analysis of Hr 1 Average Blow-by (batch 2 pistons, exclusively)
  - Analysis shown below suggests that factors Lab, Stand(Lab), and Matrix is significant
  - Reference oil factor is not significant (& excluded from below analysis summary)
  - Blow-by Targets and precision summarized in below table

Response BLWBH001

Whole Model

Effect Summary

Source	LogWorth	PValue
LTMSAPP[LTMSLAB]	3.711	0.00019
LTMSLAB	2.185	0.00653 ^
Test_Period	1.311	0.04885

Remove Add Edit FDR ('^' denotes effects with containing effects above them)

Actual by Predicted Plot

Summary of Fit

RSquare	0.592892
RSquare Adj	0.443619
Root Mean Square Error	6.204639
Mean of Response	52.27381
Observations (or Sum Wgts)	42

Analysis of Variance

Lack Of Fit

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	50.99184	1.129744	45.14	<.0001*
LTMSLAB [A]	1.72531	1.808983	0.95	0.3478
LTMSLAB [B]	-1.51774	2.118258	-0.72	0.4792
LTMSLAB [D]	0.00021	2.305784	0.00	0.9999
LTMSLAB [E]	8.67291	3.013586	2.88	0.0073*
LTMSLAB [A]:LTMSAPP[1]	1.3921	2.516514	0.55	0.5842
LTMSLAB [A]:LTMSAPP[2]	-0.1783	2.913539	-0.06	0.9516
LTMSLAB [A]:LTMSAPP[3]	2.3181	3.694236	0.63	0.5351
LTMSLAB [B]:LTMSAPP[1]	1.53885	2.395692	0.64	0.5255
LTMSLAB [D]:LTMSAPP[1]	2.7068	2.795532	0.97	0.3407
LTMSLAB [G]:LTMSAPP[1]	-16.0759	2.646989	-6.07	<.0001*
Test_Period[MATRIX]	-2.66475	1.297793	-2.05	0.0489*

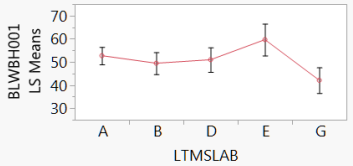
LTMSLAB

Leverage Plot

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
A	52.717150	1.8432059	53.1188
B	49.474100	2.3243253	50.5250
D	50.992050	2.6085322	51.7714
E	59.664750	3.3628339	57.0000
G	42.111150	2.7098719	50.1429

LS Means Plot

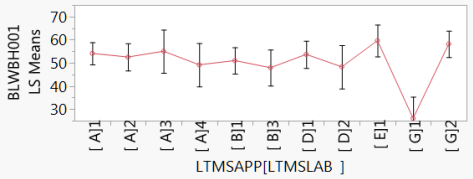


LTMSAPP[LTMSLAB]

Leverage Plot

Least Squares Means Table

LS Means Plot



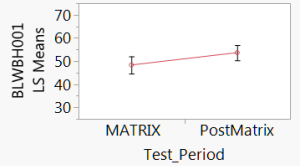
Test_Period

Leverage Plot

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
MATRIX	48.327090	1.8185343	52.0714
PostMatrix	53.656590	1.6168213	52.4762

LS Means Plot



HR1 Blow-by Avg Summary

	LSMeans
Intercept	51.0
Matrix	48.3
PostMatrix	53.7
RMSE	6.2

IIIH Blow-by Analysis for BC2 Pistons

- Analysis of Hr 6-21 Average Blow-by (batch 2 pistons, exclusively)
  - Analysis shown below suggests that factors Lab & Stand(Lab) is significant ($p \leq 0.10$)
  - Reference oil & Matrix factor is not significant (& excluded from analysis summary)
  - Blow-by Target and precision summarized in below table

Response BlowBy-Avg-6-21Hr

Whole Model

Effect Summary

Source	LogWorth	PValue
LTMSLAB	0.883	0.13081
LTMSAPP[LTMSLAB]	0.573	0.26710

Remove Add Edit FDR

Actual by Predicted Plot

Summary of Fit

RSquare	0.291974
RSquare Adj	0.105651
Root Mean Square Error	5.355086
Mean of Response	38.79286
Observations (or Sum Wgts)	49

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	10	449.3771	44.9377	1.5670
Error	38	1089.7241	28.6770	Prob > F
C. Total	48	1539.1012		0.1543

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	38.186661	0.903287	42.28	<.0001*
LTMSLAB [A]	2.2096786	1.503335	1.47	0.1498
LTMSLAB [B]	-2.913744	1.722411	-1.69	0.0989
LTMSLAB [D]	-2.735411	1.956274	-1.40	0.1701
LTMSLAB [E]	1.5258393	2.262183	0.67	0.5041
LTMSLAB [A]:LTMSAPP[1]	-0.728482	2.110727	-0.35	0.7319
LTMSLAB [A]:LTMSAPP[2]	0.4836607	2.29663	0.21	0.8343
LTMSLAB [A]:LTMSAPP[3]	0.3536607	3.09452	0.11	0.9096
LTMSLAB [B]:LTMSAPP[1]	0.13125	1.893309	0.07	0.9451
LTMSLAB [D]:LTMSAPP[1]	2.21375	2.240193	0.99	0.3293
LTMSLAB [G]:LTMSAPP[1]	-3.896131	1.489648	-2.62	0.0127*

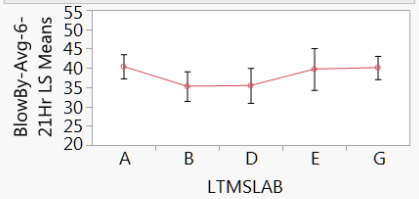
LTMSLAB

Leverage Plot

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
A	40.396339	1.5513915	40.2594
B	35.272917	1.8933090	35.3167
D	35.451250	2.2401934	36.4000
E	39.712500	2.6775432	39.7125
G	40.100298	1.4896475	40.4000

LS Means Plot



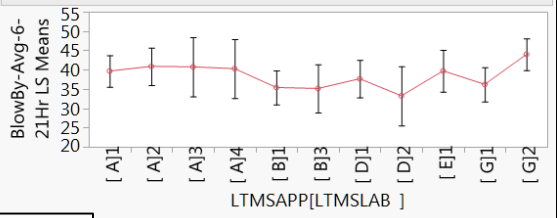
LTMSAPP[LTMSLAB]

Leverage Plot

Least Squares Means Table

Level	Least Sq Mean	Std Error
[A]1	39.667857	2.0240324
[A]2	40.880000	2.3948675
[A]3	40.750000	3.7866179
[A]4	40.287500	3.7866179
[B]1	35.404167	2.1862049
[B]3	35.141667	3.0917606
[D]1	37.665000	2.3948675
[D]2	33.237500	3.7866179
[E]1	39.712500	2.6775432
[G]1	36.204167	2.1862049
[G]2	43.996429	2.0240324

LS Means Plot

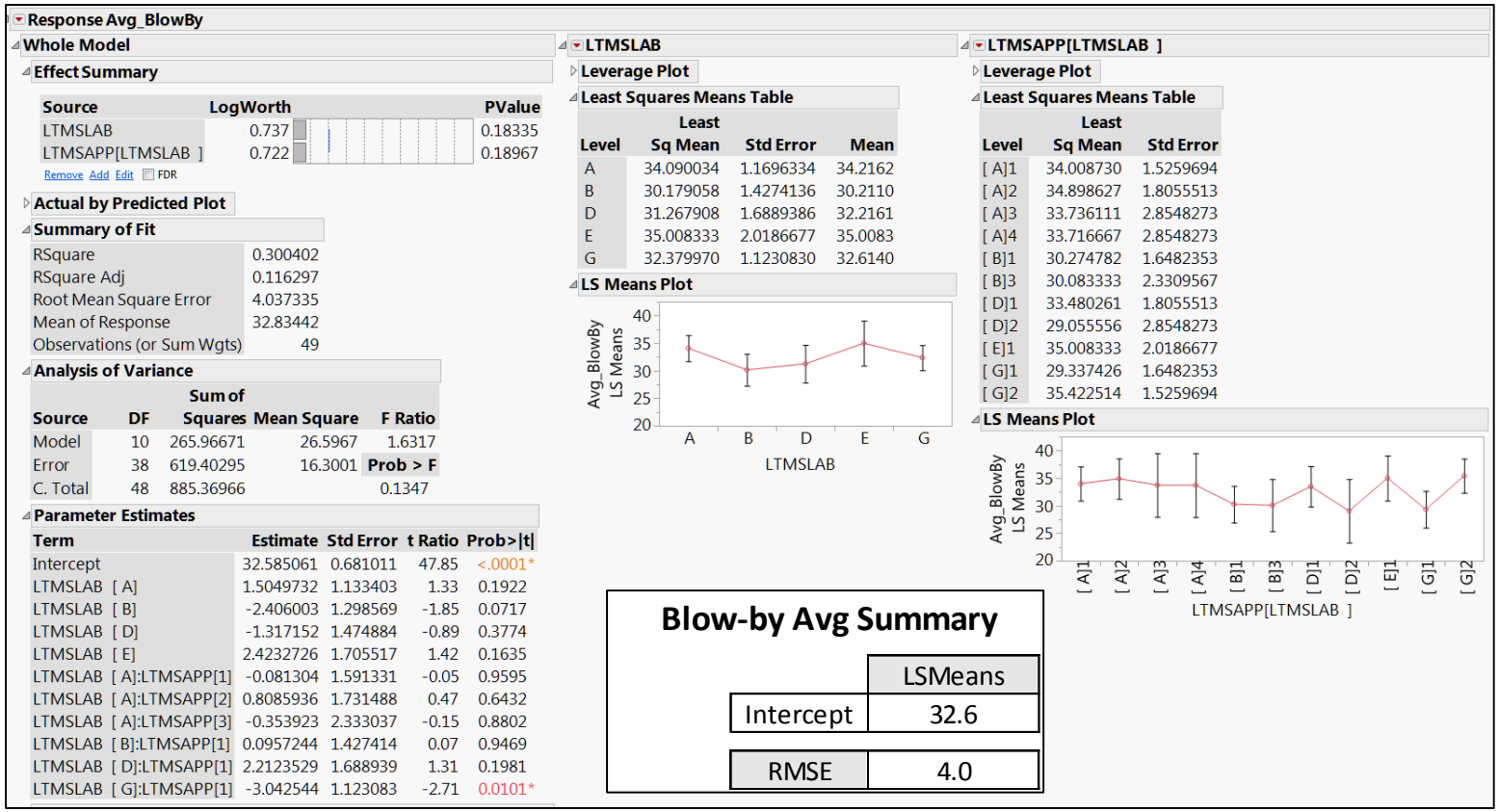


HR 6-21 Blow-by Avg Summary

	LSMeans
Intercept	38.2
RMSE	5.4

IIIH Blow-by Analysis for BC2 Pistons

- Analysis of Average Blow-by (batch 2 pistons, exclusively)
  - Analysis shown below suggests that factors Lab & Stand(Lab) is significant ($p \leq 0.10$)
  - Reference oil & Matrix factor is not significant (& excluded from analysis summary)
  - Blow-by Target and precision summarized in below table



Response Avg_BlowBy

Whole Model

Effect Summary

Source	LogWorth	PValue
LTMSLAB	0.737	0.18335
LTMSAPP[LTMSLAB]	0.722	0.18967

Remove Add Edit FDR

Actual by Predicted Plot

Summary of Fit

RSquare	0.300402
RSquare Adj	0.116297
Root Mean Square Error	4.037335
Mean of Response	32.83442
Observations (or Sum Wgts)	49

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	10	265.96671	26.5967	1.6317
Error	38	619.40295	16.3001	Prob > F
C. Total	48	885.36966		0.1347

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	32.585061	0.681011	47.85	<.0001*
LTMSLAB [A]	1.5049732	1.133403	1.33	0.1922
LTMSLAB [B]	-2.406003	1.298569	-1.85	0.0717
LTMSLAB [D]	-1.317152	1.474884	-0.89	0.3774
LTMSLAB [E]	2.4232726	1.705517	1.42	0.1635
LTMSLAB [A]:LTMSAPP[1]	-0.081304	1.591331	-0.05	0.9595
LTMSLAB [A]:LTMSAPP[2]	0.8085936	1.731488	0.47	0.6432
LTMSLAB [A]:LTMSAPP[3]	-0.353923	2.333037	-0.15	0.8802
LTMSLAB [B]:LTMSAPP[1]	0.0957244	1.427414	0.07	0.9469
LTMSLAB [D]:LTMSAPP[1]	2.2123529	1.688939	1.31	0.1981
LTMSLAB [G]:LTMSAPP[1]	-3.042544	1.123083	-2.71	0.0101*

LTMSLAB

Leverage Plot

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
A	34.090034	1.1696334	34.2162
B	30.179058	1.4274136	30.2110
D	31.267908	1.6889386	32.2161
E	35.008333	2.0186677	35.0083
G	32.379970	1.1230830	32.6140

LS Means Plot

LTMSAPP[LTMSLAB]

Leverage Plot

Least Squares Means Table

Level	Least Sq Mean	Std Error
[A]1	34.008730	1.5259694
[A]2	34.898627	1.8055513
[A]3	33.736111	2.8548273
[A]4	33.716667	2.8548273
[B]1	30.274782	1.6482353
[B]3	30.083333	2.3309567
[D]1	33.480261	1.8055513
[D]2	29.055556	2.8548273
[E]1	35.008333	2.0186677
[G]1	29.337426	1.6482353
[G]2	35.422514	1.5259694

LS Means Plot

Blow-by Avg Summary

	LSMeans
Intercept	32.6
RMSE	4.0

Attachment #5

Seq. IIIH Severity Task Force

Motion and Action Items

March 1, 2017

Motions:

Motion #1: Jason Bowden / Addison Schweitzer: Jason Bowden / Addison Schweitzer: Task Force recommend to the Surveillance Panel that the schematic (shown in figure A3.1) for the canister in the blowby circuit be modified to be shown in a horizontal line. – **Passed - Unanimous**

Motion # 2: Jason Bowden / George Szappanos: Task Force recommends to the Seq. III Surveillance Panel that labs must run entire calibration period on same batch of critical parts the stand was referenced on. - **Motion passed with one waive.**

Action Items:

Action Item #1: Addison will develop a calibration procedure for the JTEC and have the Task Force review.

Action Item # 2: Labs to provide actual ring gaps to TMC for tests run in Task Force Ring Gap DOE and prior reference oil 436/438 runs on the stands used in in the DOE.

Action Item # 3: Jason Bowden to summarize Ring Gap DOE and prior Ref Oil results on each stand.

Action Item #4: Southwest to run BC4 piston screener test**.**

Action Item #5: OHT to donate one engine set of BC4 pistons to Southwest.

Prior Action Items-Ongoing:

- Confirm how the JTEC data is being collected. Ankit will survey the labs to have them provide the raw data that is being collected along with each labs practices for measuring barometric pressure, JTEC flow, temp, etc.)-Ankit Chaudhry – **Ongoing**
- Todd Dvorak will review honing analysis he prepared for the November 2016 Panel meeting comparing the correlation pre and post matrix by lab vs. blowby and output results – Todd Dvorak **Ongoing**
- Amol will survey the labs to determine how they are insulating the exhaust downpipes and how the exhaust systems are routed- Amol Savant- **Ongoing**
- Labs to provide results to the Task Force on prior 436 results in stand being used in Ring Gap DOE. Valvoline to report 438 results. – All Labs- **Ongoing** (Awaiting one MRV & PHOS).