GMOD – Data Review

04/17/2025

Statistics Team

- Team members
  - Amy Ross (Valvoline)
  - Dylan Beck (TMC)
  - Ricardo Affinito (Oronite)
  - Joephine Marinez (Oronite)
  - Martin Chadwick (Intertek)
  - Seth Demel (Shell)
  - Amanda Stone (Afton/New Market)
  - Todd Dvorak (Infineum)

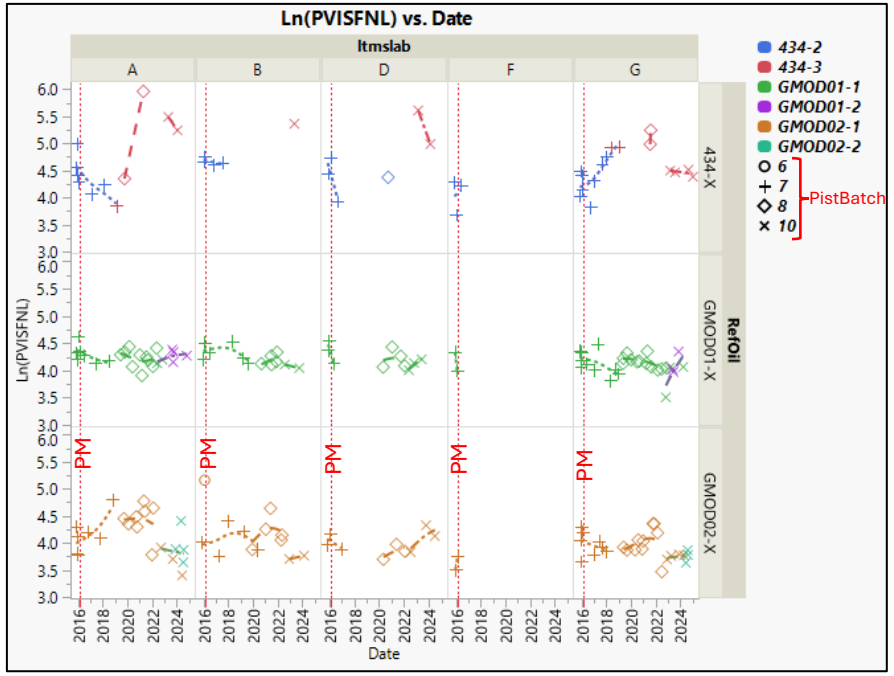
GMOD – Executive Summary

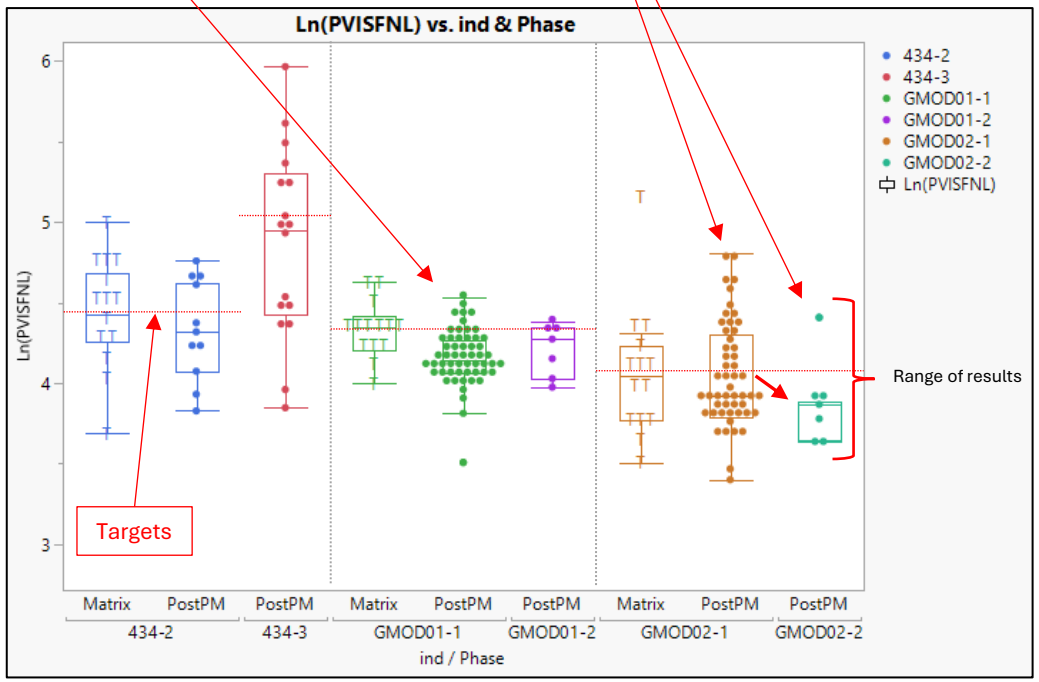
- TMC requested the Statistics Team to review the reference oil data determine if the RO targets need to be updated for GMOD2 re-blends
- Analysis included a review of piston hardware and targets for all reference oil re-blends
- Due to variability of WPDFNL & Ln(PVISFNL) on GMOD02-2, a follow-on data review is recommended to ensure target estimates are ‘good’
- For Ln(PVISFNL) and PHOSFNL parameters, recommend applying an ICF of $^{+}0.19$ and $^{-}1.4\%$ for piston batch 10, respectively

Ln(PVISFNL) Data Review

GMOD – PVIS Reference Oil Targets Review

- Ln(PVIS) Parameter
  - Plot of test results shown below with original and re-blend RO's
  - Variation of GMOD02-2 appears large while directionally lower than GMOD02-1
    - GMOD02-2 tests have been run on Piston Batch 10, exclusively
  - Post matrix, GMOD01-X appears lower than target value

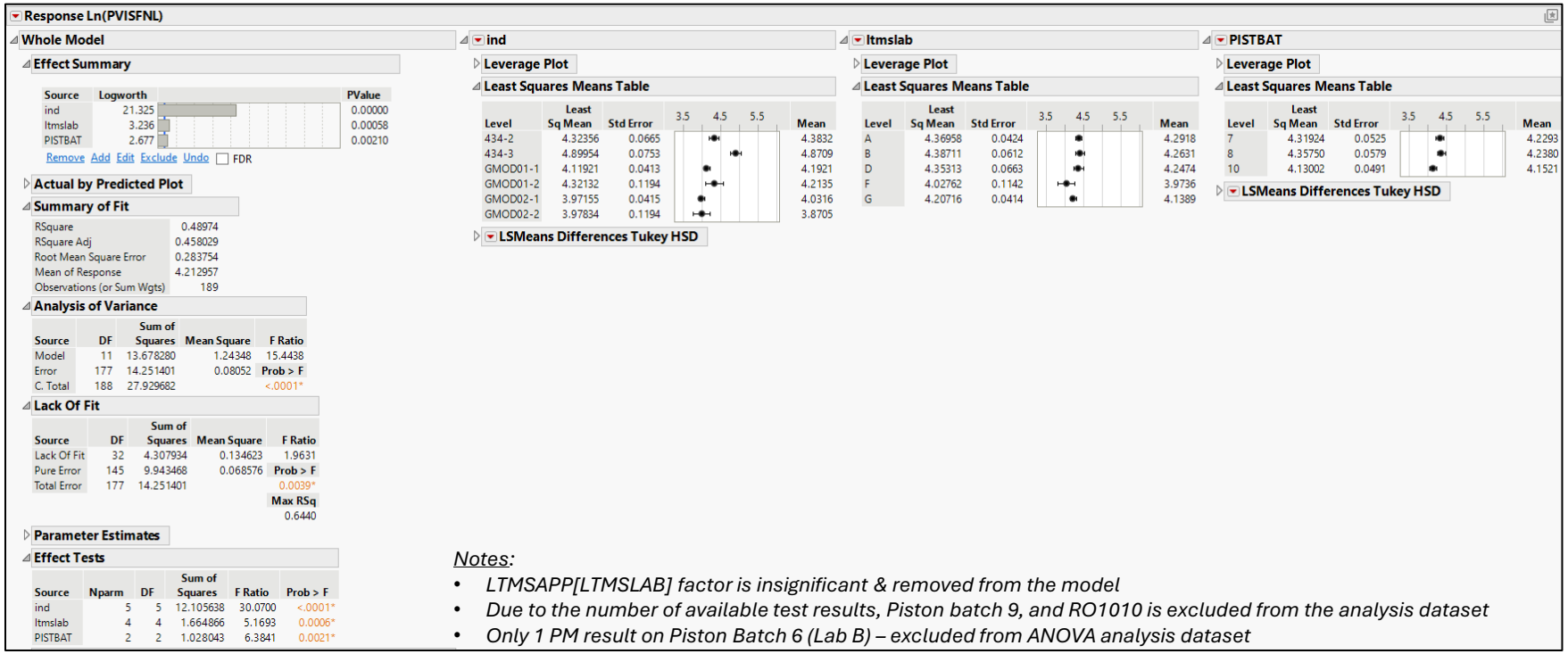




Includes PM (Chart = N), Chartable = Y, & GMOD02-2 (Chart=N) test results

GMOD – PVIS Reference Oil Targets Review

- Ln(PVIS) Parameter – ANOVA Analysis Highlights:
  - Dataset includes PM (Chart = N), Chartable (Y), & GMOD02-2 (Chart=N) test results (n = 189)
  - Significant difference between Piston Batches
    - Batch 10 pistons (vs. Batch 7 PM) are mild of target by 0.19 Ln(PVIS) units
  - GMOD02-1 & 2 Re-Blend LSMeans are nearly identical
    - Batch 10 piston is coincidental with GMOD02-2 re-blend



Notes:

- *LTMSAPP[LTMSLAB] factor is insignificant & removed from the model*
- *Due to the number of available test results, Piston batch 9, and RO1010 is excluded from the analysis dataset*
- *Only 1 PM result on Piston Batch 6 (Lab B) – excluded from ANOVA analysis dataset*

GMOD – PVIS Reference Oil Targets Review

- PVIS Parameter Summary (for targets):
  - LSMeans are based on Piston Batch 7 and equal weighting of labs A, B, D, & G
    - Lab F is excluded – only 1 result since PM
  - LSMeans vs. Targets are similar in magnitude

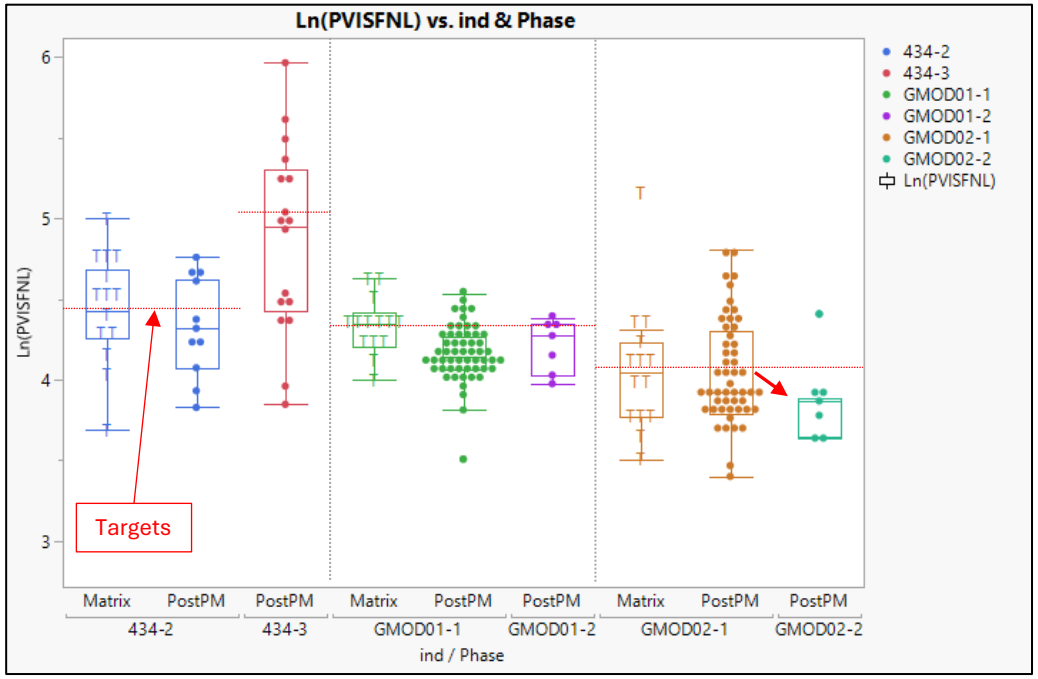
			Current LTMS Targets Ln(PVISFNL)		Descriptive Statistics Ln(PVISFNL)		Regression Ln(PVISFNL)
ind	Phase	n	Mean	Std Dev	Raw Means	Raw StdDevs	LS Means
434-2	Matrix	14	4.4245	0.33008	4.4245	0.33008	4.4342
434-2	PostPM	11	4.4245	0.33008	4.3307	0.30755	4.4342
434-3	PostPM	17	5.0137	0.40031	4.8709	0.58620	5.0102
GMOD01-1	Matrix	14	4.3201	0.17583	4.3201	0.17582	4.2299
GMOD01-1	PostPM	55	4.3201	0.17583	4.1595	0.17011	4.2299
GMOD01-2	PostPM	7			4.2135	0.16429	4.4320
GMOD02-1	Matrix	13	4.0608	0.40031	3.9760	0.25432	4.0822
GMOD02-1	PostPM	51	4.0608	0.40031	4.0457	0.32647	4.0822
GMOD02-2	PostPM	7			3.8705	0.25970	4.0890

  - Recommend no changes to targets at this time for GMOD01-2 & GMOD02-2 Targets
    - Follow-on target review should be performed when additional data becomes available
  - Recommend applying +0.19 ICF to test results for batch 10 pistons

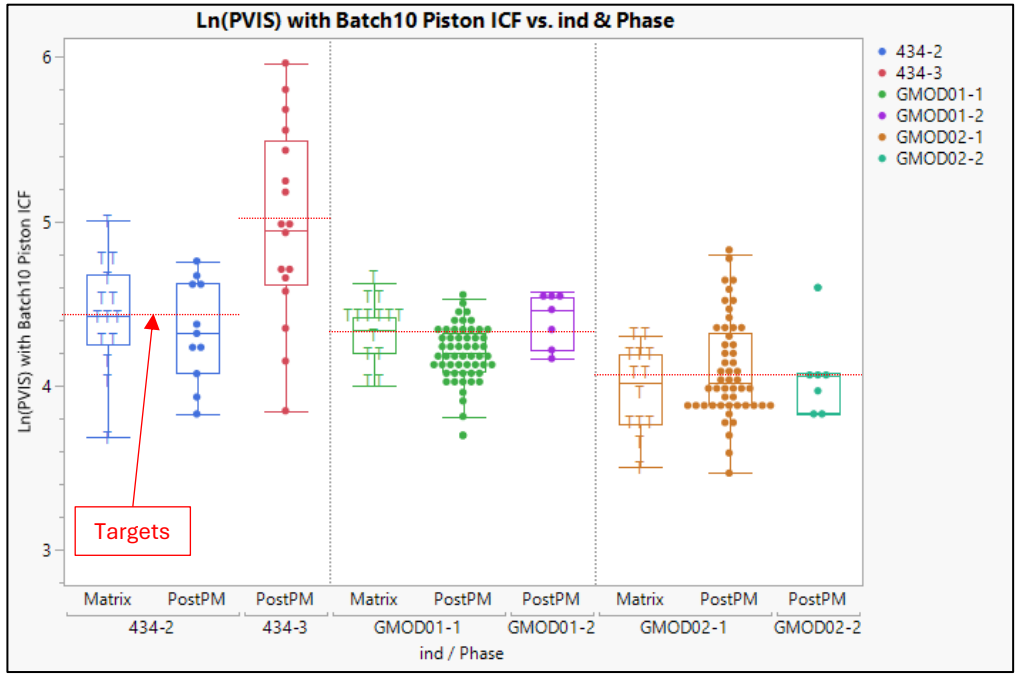
GMOD – PVIS Reference Oil Targets Review

- Plot of Ln(PVIS) parameter with Batch 10 Piston ICF shown below

Uncorrected Data Plot



With Batch 10 Piston +0.19 ICF Data Plot

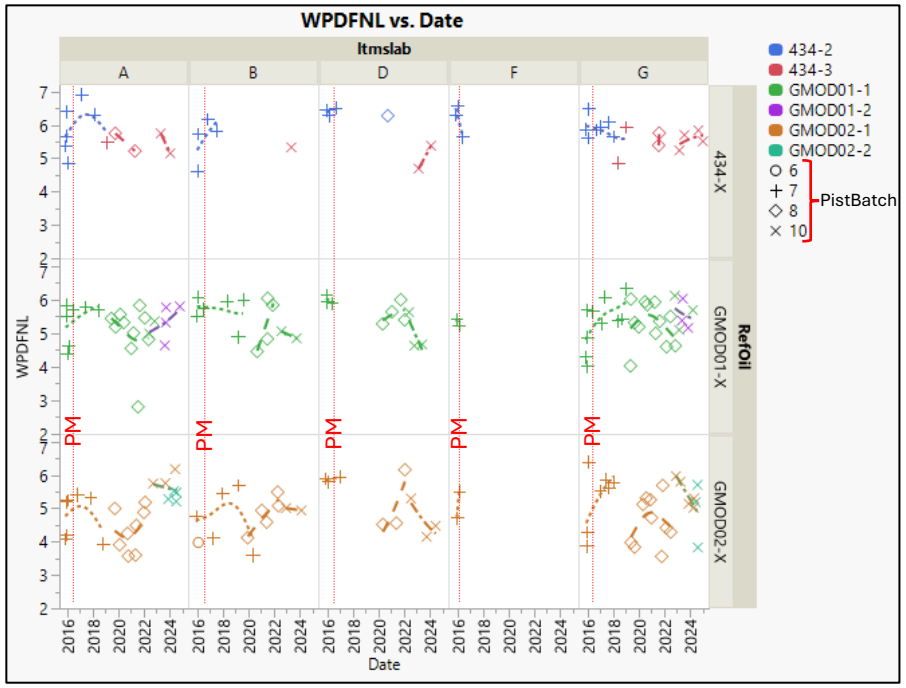


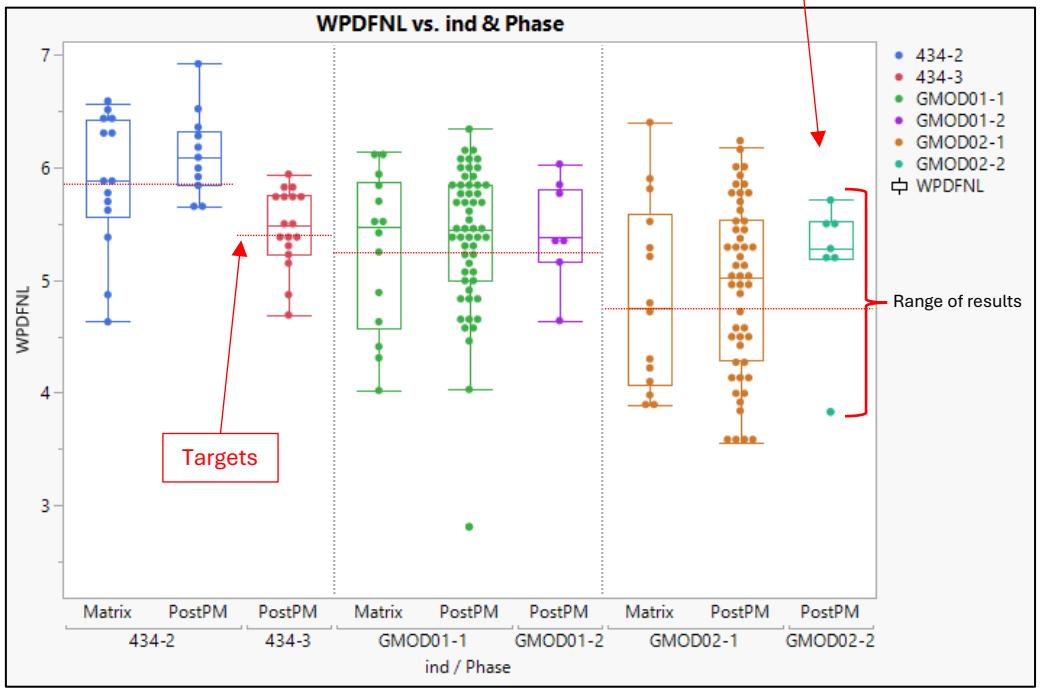
Includes PM (Chart = N), Chartable = Y, & GMOD02-2 (Chart=N) test results

WPDFNL Data Review

GMOD WPD - Reference Oil Targets Review

- WPD Parameter
  - Plot of test results shown below with original and re-blend RO's
  - Low result for GMOD02-2 suggests some uncertainty about setting the target mean and stdev

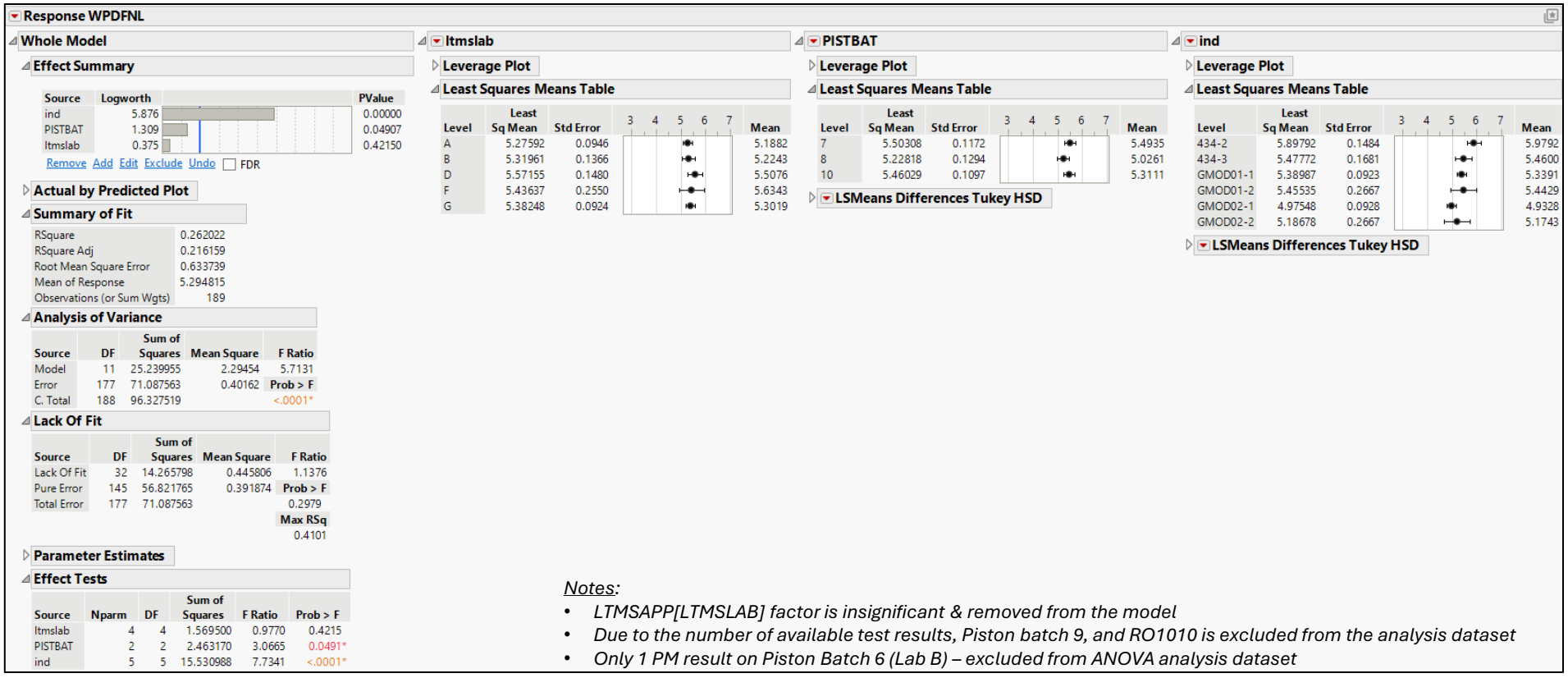




Includes chartable & GMOD02-2 (Chart=N) test results

GMOD – WPD Reference Oil Targets Review

- WPD Parameter – Analysis Highlights:
  - Dataset includes PM (Chart = N), Chartable (Y), & GMOD02-2 (Chart=N) test results (n = 189)
  - No significant difference between Piston Batches 7 (PM) vs. 10 and reference oil GMOD0X re-blends



Notes:

- *LTMSAPP[LTMSLAB] factor is insignificant & removed from the model*
- *Due to the number of available test results, Piston batch 9, and RO1010 is excluded from the analysis dataset*
- *Only 1 PM result on Piston Batch 6 (Lab B) – excluded from ANOVA analysis dataset*

GMOD - WPD Reference Oil Targets Review

- WPD Parameter Summary (for targets):
  - LSMeans are based on Piston Batch 7 and equal weighting of labs A, B, D, & G
    - Lab F is excluded – only 1 result since PM

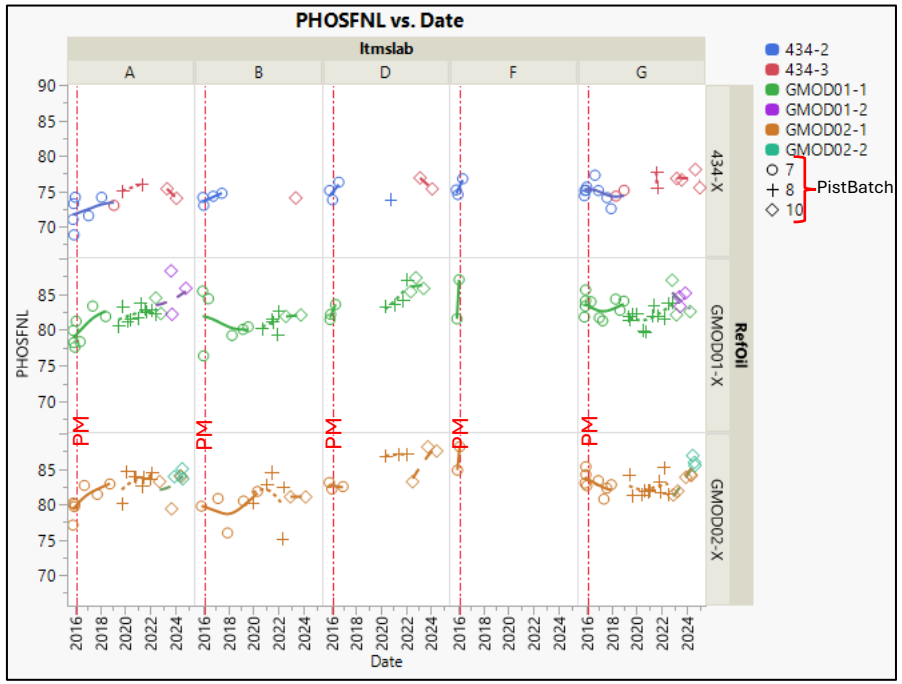
			Current LTMS Targets WPDFNL		Descriptive Statistics WPDFNL		Regression WPDFNL
ind	Phase	n	Mean	Std Dev	Raw Means	Raw StdDevs	LS Means
434-2	Matrix	14	5.87	0.608	5.87	0.608	5.99
434-2	PostPM	11	5.87	0.608	6.11	0.385	5.99
434-3	PostPM	17	5.42	0.608	5.46	0.352	5.57
GMOD01-1	Matrix	14	5.26	0.693	5.26	0.697	5.49
GMOD01-1	PostPM	55	5.26	0.693	5.36	0.617	5.49
GMOD01-2	PostPM	7			5.44	0.470	5.55
GMOD02-1	Matrix	13	4.77	0.715	4.92	0.827	5.07
GMOD02-1	PostPM	51	4.77	0.715	4.94	0.747	5.07
GMOD02-2	PostPM	7			5.17	0.622	5.28

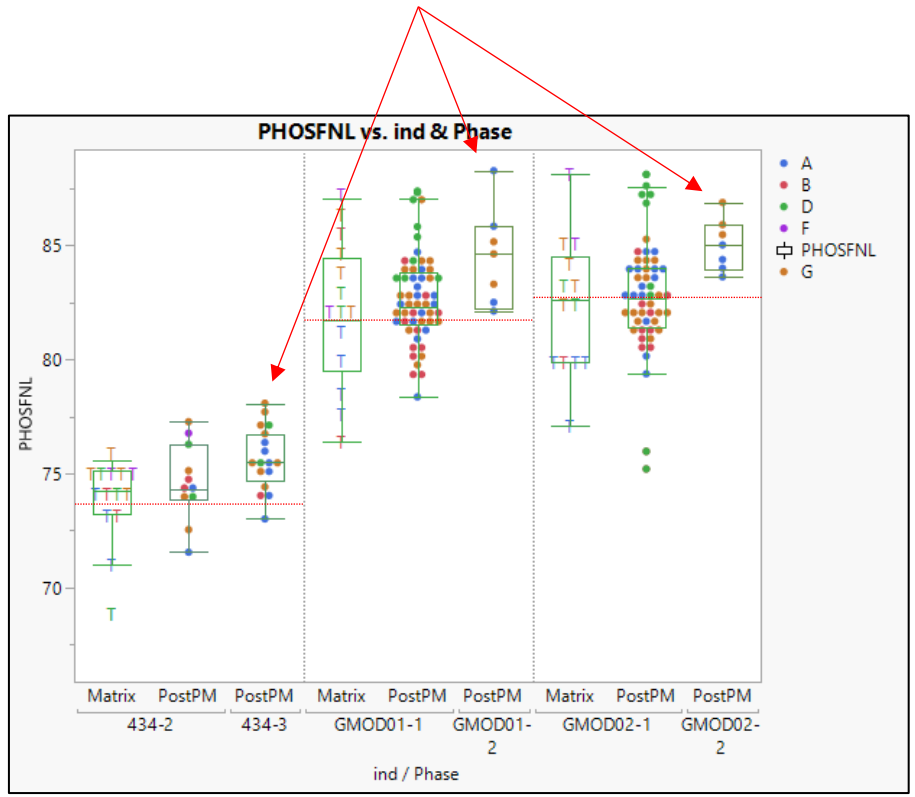
  - Recommend no changes to targets for GMOD01-2 & GMOD02-2 at this time
    - Insufficient data to determine ‘good’ estimate of GMOD02-2 re-blend targets
    - Both RO (GMOD01-2 & GMOD02-2) targets should be re-evaluated when additional test data is available

PHOSFNL Data Review

GMOD - Reference Oil Targets Review

- Phos Parameter
  - Plot of test results shown below with original and re-blend RO's
  - Directionally, Phos results for the latest reference oil re-blends appear higher

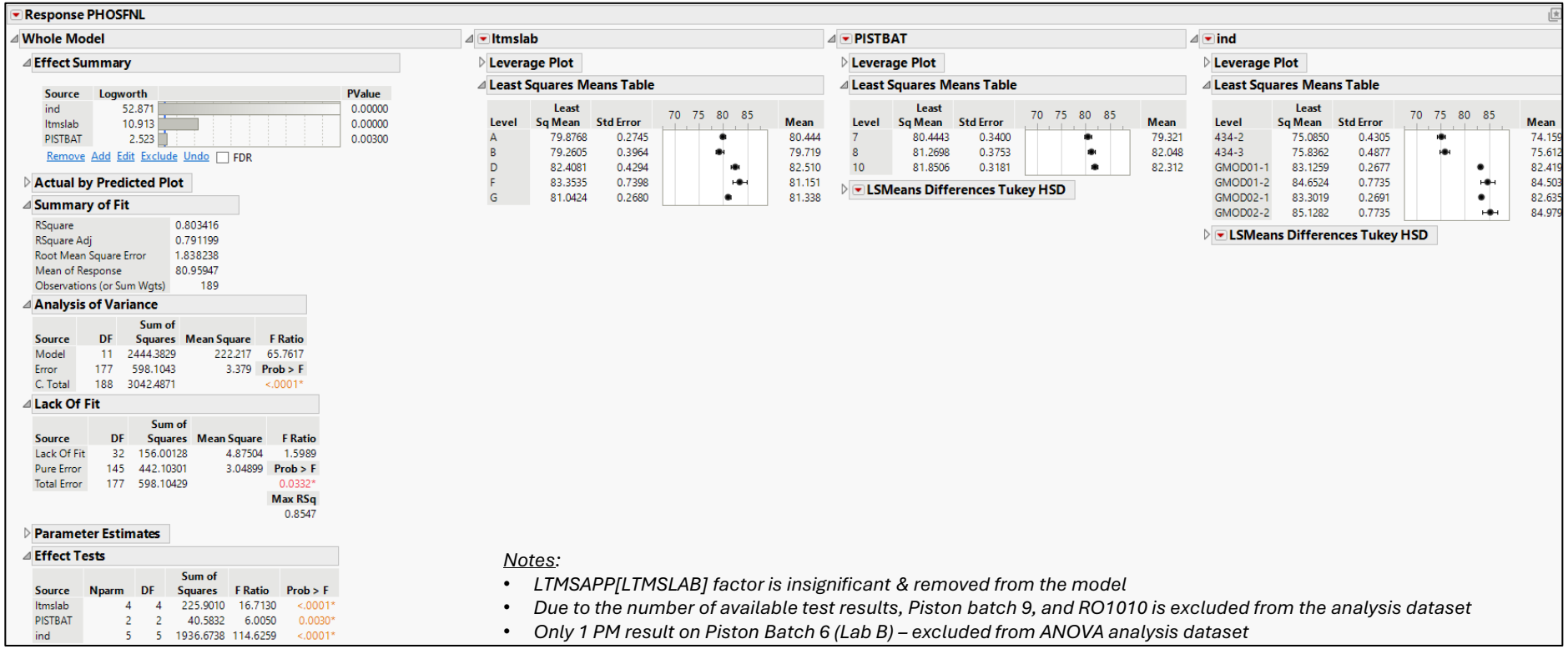




Includes chartable & GMOD02-2 (Chart=N) test results

GMOD - Reference Oil Targets Review

- Phos Parameter – ANOVA Analysis Highlights:
  - Dataset includes PM (Chart = N), Chartable (Y), & GMOD02-2 (Chart=N) test results (n = 189)
  - Significant difference between Piston Batches
    - Batch 10 is milder than Batch 7 (PM) by 1.4%
  - No significant difference between Re-Blends - within a reference oil



Notes:

- *LTMSAPP[LTMSLAB] factor is insignificant & removed from the model*
- *Due to the number of available test results, Piston batch 9, and RO1010 is excluded from the analysis dataset*
- *Only 1 PM result on Piston Batch 6 (Lab B) – excluded from ANOVA analysis dataset*

GMOD - Reference Oil Targets Review

- PHOS Parameter Summary (for targets):
  - LSMeans are based on Piston Batch 7 and equal weighting of labs A, B, D, & G
    - Lab F is excluded – only 1 result since PM

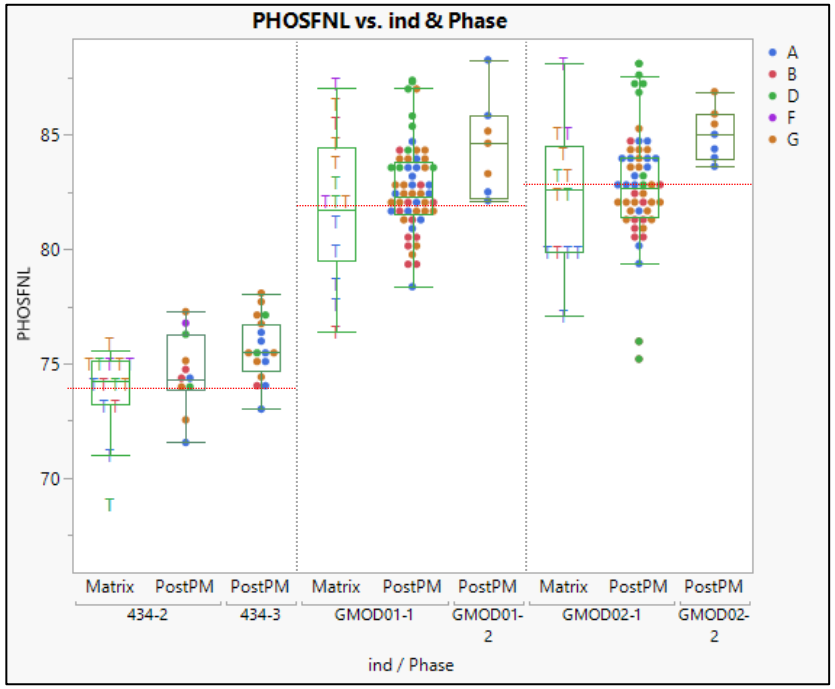
			Current LTMS Targets PHOSFNL		Descriptive Statistics PHOSFNL		Regression PHOSFNL
ind	Phase	n	Mean	Std Dev	Raw Means	Raw StdDevs	LS Means
434-2	Matrix	14	73.81	1.854	73.81	1.854	73.80
434-2	PostPM	11	73.81	1.854	74.60	1.719	73.80
434-3	PostPM	17	73.81	1.854	75.61	1.343	74.55
GMOD01-1	Matrix	14	81.86	3.123	81.86	3.123	81.84
GMOD01-1	PostPM	55	81.86	3.123	82.56	1.890	81.84
GMOD01-2	PostPM	7			84.50	2.193	83.37
GMOD02-1	Matrix	13	82.85	3.480	82.31	2.953	82.02
GMOD02-1	PostPM	51	82.85	3.480	82.72	2.435	82.02
GMOD02-2	PostPM	7			84.98	1.197	83.84

  - Recommend applying -1.4% ICF for Batch 10 pistons

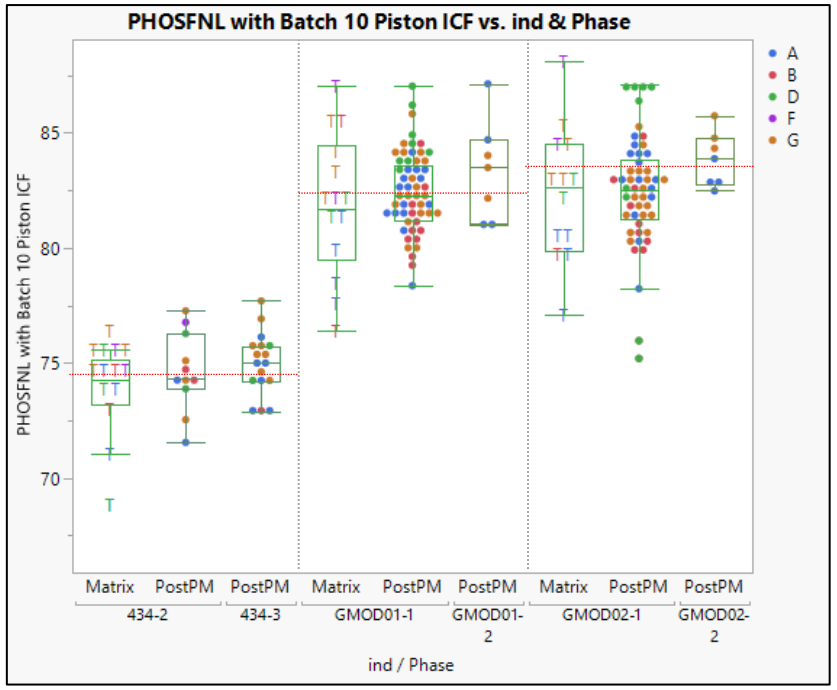
GMOD - Reference Oil Targets Review

- Plot of PHOSFNL parameter with Batch 10 Piston ICF shown below

Uncorrected Plot



With Batch 10 Piston -1.4 ICF Plot



Includes chartable & GMOD02-2 (Chart=N) test results

Appendix

Expanded Estimates for PVIS, WPD, & PHOS Parameters

LnPVIS – Expanded Estimates

- Expanded Estimates for Ln(PVIS)

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	4.268919	0.039765	107.35	<.0001
ind[434-2]	0.054642	0.067227	0.81	0.4174
ind[434-3]	0.630622	0.064513	9.78	<.0001
ind[GMOD01-1]	-0.14971	0.047226	-3.17	0.0018
ind[GMOD01-2]	0.052399	0.098704	0.53	0.5962
ind[GMOD02-1]	-0.29737	0.046302	-6.42	<.0001
ind[GMOD02-2]	-0.29058	0.098704	-2.94	0.0037
ltmslab[A]	0.100665	0.041943	2.4	0.0174
ltmslab[B]	0.11819	0.049485	2.39	0.018
ltmslab[D]	0.084207	0.053394	1.58	0.1166
ltmslab[F]	-0.2413	0.090414	-2.67	0.0083
ltmslab[G]	-0.06176	0.039276	-1.57	0.1176
PISTBAT[7]	0.050319	0.033535	1.5	0.1353
PISTBAT[8]	0.08858	0.032419	2.73	0.0069
PISTBAT[10]	-0.1389	0.040026	-3.47	0.0007

WPDFNL – Expanded Estimates

- Expanded Estimates for WPDFNL

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	5.397185	0.088811	60.77	<.0001
ltmslab[A]	-0.12126	0.093677	-1.29	0.1972
ltmslab[B]	-0.07758	0.110521	-0.7	0.4836
ltmslab[D]	0.174361	0.119251	1.46	0.1455
ltmslab[F]	0.039181	0.201931	0.19	0.8464
ltmslab[G]	-0.0147	0.087719	-0.17	0.8671
PISTBAT[7]	0.105899	0.074898	1.41	0.1591
PISTBAT[8]	-0.169	0.072405	-2.33	0.0207
PISTBAT[10]	0.063103	0.089395	0.71	0.4812
ind[434-2]	0.500733	0.150144	3.34	0.001
ind[434-3]	0.08054	0.144084	0.56	0.5769
ind[GMOD01-1]	-0.00732	0.105476	-0.07	0.9448
ind[GMOD01-2]	0.058162	0.220445	0.26	0.7922
ind[GMOD02-1]	-0.42171	0.103411	-4.08	<.0001
ind[GMOD02-2]	-0.21041	0.220445	-0.95	0.3411

PHOSFNL – Expanded Estimates

- Expanded Estimates for PHOSFNL

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	81.18826023	0.257607558	315.16	<.0001
ltmslab[A]	-1.311437358	0.27172168	-4.83	<.0001
ltmslab[B]	-1.927795858	0.320578702	-6.01	<.0001
ltmslab[D]	1.219836021	0.345902257	3.53	0.0005
ltmslab[F]	2.16528267	0.585727445	3.7	0.0003
ltmslab[G]	-0.145885474	0.254439407	-0.57	0.5671
PISTBAT[7]	-0.743911389	0.217249961	-3.42	0.0008
PISTBAT[8]	0.08158563	0.210019925	0.39	0.6981
PISTBAT[10]	0.662325759	0.259301775	2.55	0.0115
ind[434-2]	-6.103300747	0.435512829	-14.01	<.0001
ind[434-3]	-5.352026943	0.417934037	-12.81	<.0001
ind[GMOD01-1]	1.93759447	0.305945574	6.33	<.0001
ind[GMOD01-2]	3.464186279	0.639428993	5.42	<.0001
ind[GMOD02-1]	2.113646376	0.299955734	7.05	<.0001
ind[GMOD02-2]	3.939900565	0.639428993	6.16	<.0001