Sequence VH Surveillance Panel | MINUTES

REVISION DATE: 11/6/2017 1:35:00 PM

Relevant Test:	Sequence VG and VH
Note Taker:	Chris Mileti
Meeting Date:	11-03-2017
Comments:	Conference call to discuss Sequence VG to VH equivalency.

1. REVIEW OF STATISTICIAN PRESENTATION:

1.1. Background:

1.1.1. ***File name:*** *VH – VG Equivalency – 102017.pdf*

1.1.2. This material was presented by Doyle Boese.

1.2. Slide #3:

Executive Summary

- Four methods were utilized to develop proposed VH Equivalency Limits to VG SN limits.
- Recommended SN VH Equivalency Limits (and range of limits obtained via the four methods) for each VH pass/fail parameter follow:
  - AES: 7.2 (7.2 – 7.9)
  - AEV50: 8.6 (8.4 – 8.8)
  - RAC: 7.7 (6.5 – 7.8)
  - APV50: 7.4 (6.4 – 7.6)
  - OSCR: TBD upon collection of a sufficient sample size of accepted OSCR rated data.
  - HSR: 0
- The procedures used to obtain these SN Equivalency Limits can be utilized to obtain SJ, SL and SM Equivalency Limits.

1.2.1. The statisticians utilized four different methods to analyze this data.

1.2.1.1. This included two different mathematical techniques.

1.2.1.2. It also included two different subsets of data.

1.2.2. Oil Screen Clogging (OSC) is a rate-and-report parameter for the Sequence VH test, so the statisticians did not devote a lot of time to analyzing its data.

1.2.3. Recommended SN VH Equivalency Limits:

1.2.3.1. The statisticians recommended a limit for each of the four pass/fail parameters.
1.2.3.2. A range is also presented in parenthesis after the recommended limit.
1.2.3.2.1. This is the range of limits that resulted from the four different methods utilized by the statisticians.
1.2.3.3. Recommended Limits:
1.2.3.3.1. AES = 7.2
1.2.3.3.2. AEV50 = 8.6
1.2.3.3.3. RAC = 7.7
1.2.3.3.4. APV50 = 7.4
1.2.3.3.5. HSR = 0

1.3. Slide #4:

Data

- Fuel Batches listed in the TMC database as 0121LS01, NF0121LS and NF0121LS01 are combined into NF0121LS01 in this analysis.
- Data is as of August 21, 2017.
- The current fuel batch is DJ0121NX10. This batch was used for the VH Precision Matrix.

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1.3.1. Several names are used to identify the same fuel batch (NF0121LS01) in the TMC database.
1.3.1.1. The statisticians consolidated all the shortened names under the full name of the fuel batch.
1.3.2. The current fuel batch is DJ0121NX10.

1.4. Slide #5:

HSR and OSCR

- HSR
  - HSR VG Limits and Targets for ROs 940 and 1009 for VG are 0.
  - VH Targets for ROs 940 and 1009 are 0.
  - Recommend VH HSR Equivalency Limit be 0.
- OSCR
  - Data is being generated to develop Targets for the VH.

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1.4.1. OSC is now a rate-and-report parameter for the Sequence VH test.

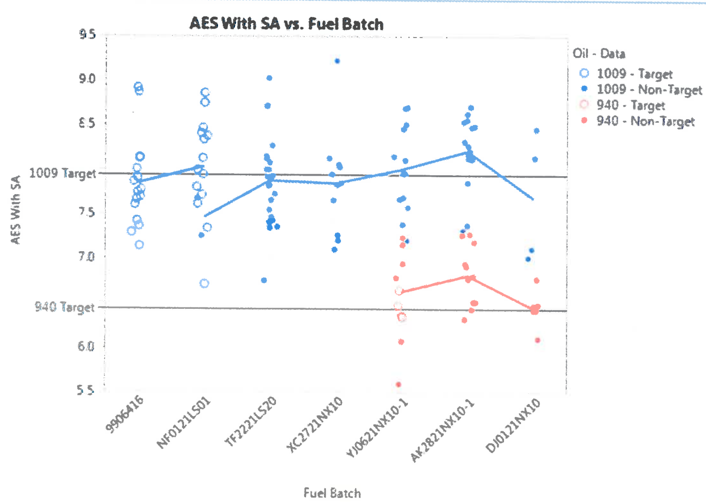
1.4.1.1. The statisticians require more data before they can set targets for this parameter.

1.4.2. The Sequence VG limit for Hot Stuck Rings (HSR) is currently zero.

1.4.2.1. The statisticians recommend maintaining this limit for the Sequence VH test.

1.5. Slide #6:

Adjusted VG AES Versus Fuel Batch



- The fuel batches are plotted in chronological order.
- The average severity adjusted AES result for both oils trend in parallel dependent on the Fuel Batch.

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1.5.1. The data presented in this graph is severity adjusted (so laboratory offset has been removed) and includes the fuel batch's correction factors.

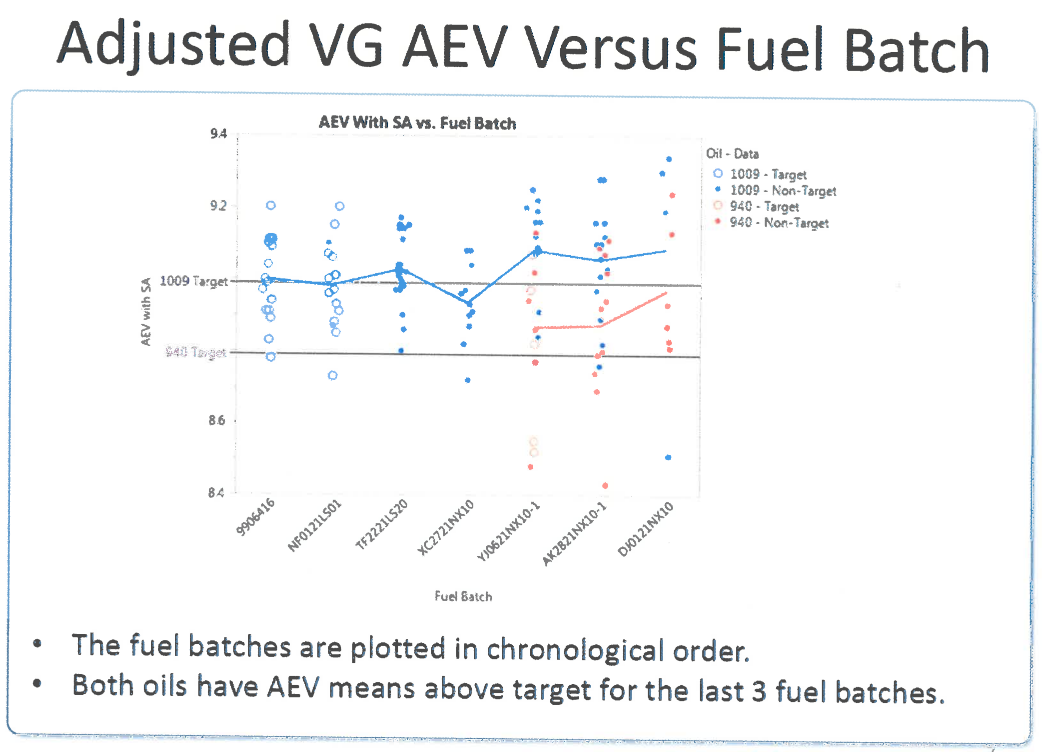
1.5.1.1. In other words, the statisticians treated the data as if it were from candidate oils and not reference oils.

1.5.2. The fuel batches are listed in chronological order along the x-axis.

1.5.3. The severity-adjusted AES curves for both oils (REO940 and REO1009) are parallel when graphed against the fuel batch.

1.5.3.1. In fact, this same parallel trend (between REO940 and REO1009) is present in (3) of the (4) pass/fail parameters.

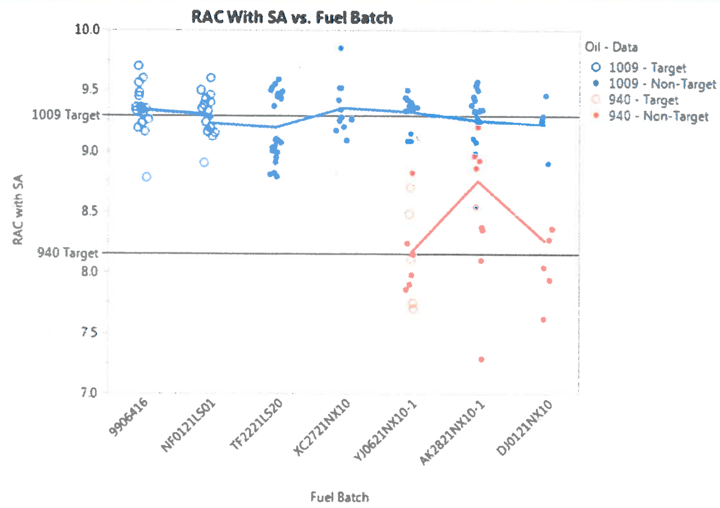
1.6. Slide #7:



1.6.1. The parallel trend between REO940 and REO1009 continues with the AEV (Average Engine Varnish) parameter.

1.7. Slide #8:

Adjusted VG RAC Versus Fuel Batch

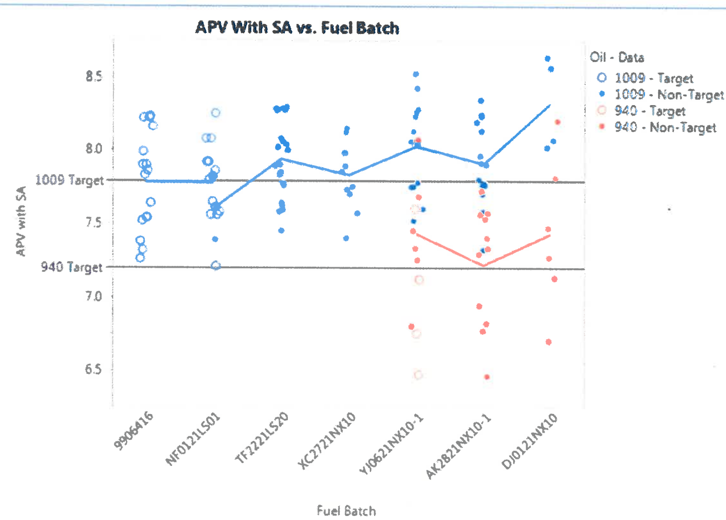


- The fuel batches are plotted in chronological order.
- The average of the severity adjusted RAC results for RO 940 are more variable than for 1009.

1.7.1. There is no parallel trend between REO940 and REO1009 with the RACS (Rocker Arm Cover Sludge) parameter.

1.8. Slide #9:

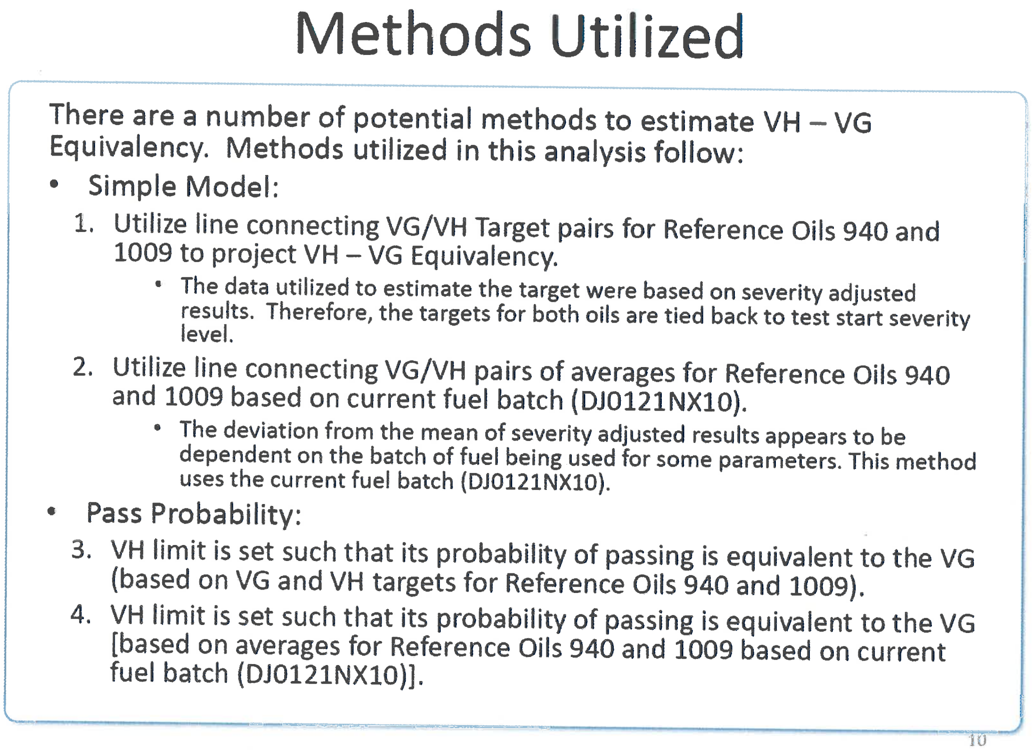
Adjusted VG APV Versus Fuel Batch



- The fuel batches are plotted in chronological order.
- The average severity adjusted APV result for both oils trend in parallel dependent on the Fuel Batch.

1.8.1. The parallel trend between REO940 and REO1009 continues with the APV (Average Piston Varnish) parameter.

1.9. Slide #10:



1.9.1. This slide explains the two mathematical methods used by the statisticians.

1.9.1.1. ***Method #1*** – Simple Model

1.9.1.2. ***Method #2*** – Pass Probability

1.10. Slide #11:

Methods Utilized (Continued)

- The sample sizes of the data sets used for the two methods are similar except for RO 1009 VG.

Sample Sizes of Data Sets Utilized

Oil	VG		VH	
	Target	Current Fuel Batch	Target	Current Fuel Batch
940	5	6	7	8
1009	30	4	8	8

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1.10.1. This slide provides an overview of the two different subsets of data used in the analysis.
1.10.2. There is a significant difference in the sample sizes used for REO1009/Sequence VG.

1.11. Slide #14:

Simple Model Method

- Both Methods 1 and 2 are based on severity adjusted reference oil results.
- The following two sections graphically illustrate the method, however, the numbers are calculated using models.

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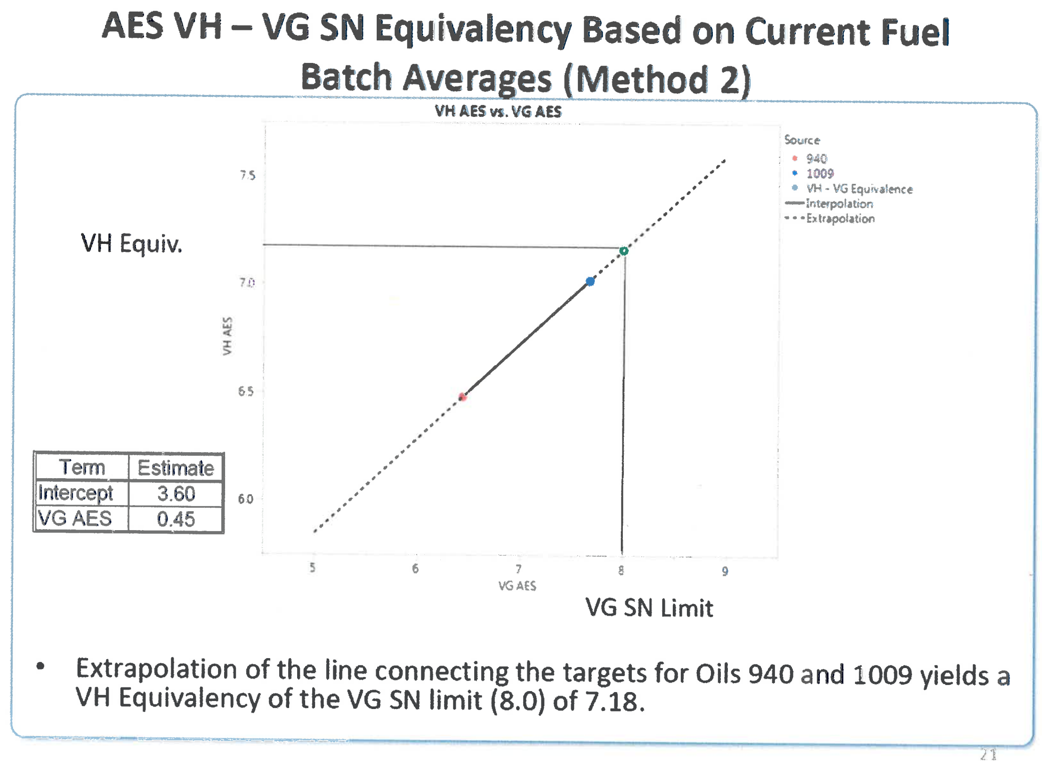
1.11.1. The plots in the upcoming slides are a graphical representation of the data.
1.11.1.1. Small discrepancies in the graphs can be disregarded.

1.11.2. The statisticians determined that Method #2 was the preferred method, so Boese skipped over the slides dealing with Method #1 to save time.

1.12. Slide #21:



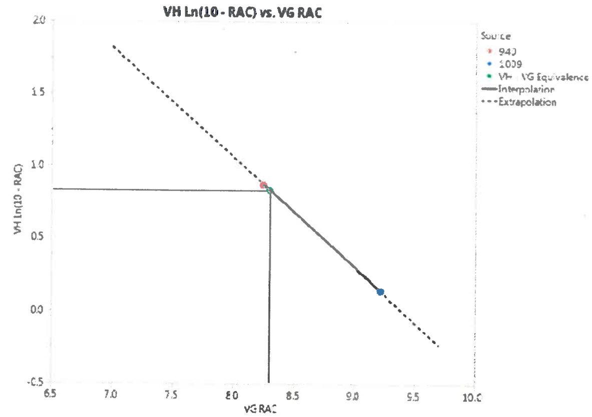
1.12.1. The y-axis contains Sequence VH data.
1.12.2. The x-axis contains Sequence VG SN Limit data.
1.12.3. The average result for REO1009 has more impact/leverage on equivalency than the average result for REO940.
1.12.4. The statisticians prefer Method #2 because it uses results from both oils, but the one that is the closest has more leverage on equivalency.
1.12.5. The statisticians also prefer Method #2 because all the results are from the same fuel batch.

1.13. Slide #23:

RAC VH – VG Equivalency Based on Current Fuel Batch Averages (Method 2)

VH Equiv.

Term	Estimate
Intercept	7.12
VG RAC	-0.76



VG SN Limit

- Interpolation of the line connecting the targets for Oils 940 and 1009 yields a VH Equivalency of the VG SN limit (8.3) of 7.70 [Ln(10-RAC) = 0.8340].
- Due to close proximity of VG RAC limit to 940 RAC average, there is increased confidence in the estimated equivalence.

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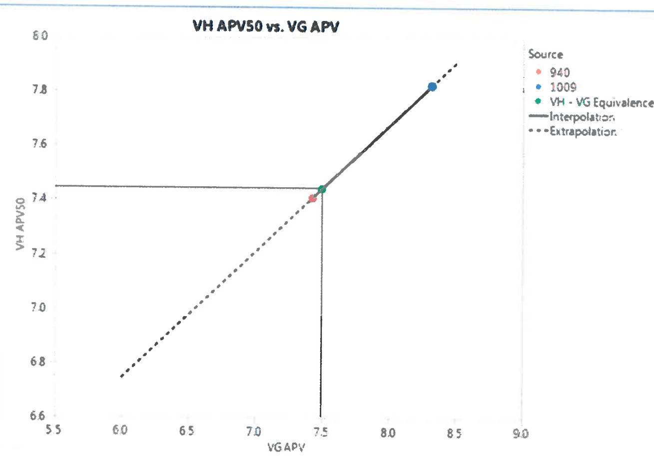
1.13.1. The slope of the interpolation/extrapolation line is negative (instead of positive) because a transformation is used for the RACS parameter.

1.14. Slide #24:

APV VH – VG Equivalency Based on Current Fuel Batch Averages (Method 2)

VH Equiv.

Term	Estimate
Intercept	3.95
VG APV	0.47



VG SN Limit

- Interpolation of the line connecting the targets for Oils 940 and 1009 yields a VH Equivalency of the SN VG limit (7.5) of 7.44.
- Due to close proximity of VG APV limit to 940 APV average, there is increased confidence in the estimated equivalence.

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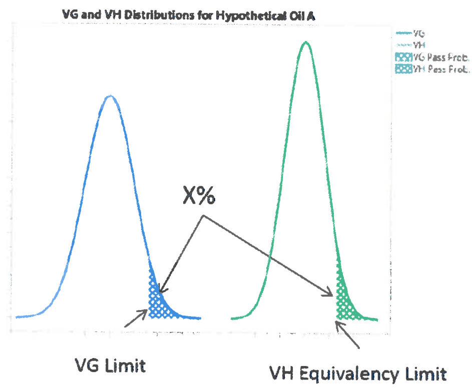
1.14.1. The VG limit is very close to the Sequence VH REO940 result.
1.14.2. This brings the equivalency line very close to the Sequence VH REO940 result.

1.15. Slide #26:

Probability Method

- The VH Equivalency Limit is calculated such that the probability of passing it is the same as for passing the VG for a particular oil.
  - For example, if the probability of Oil A passing the VG is 5%, the VH Equivalency Limit would be set such that the probability of Oil A passing the VH is 5%.
- The method is applied separately for ROs 940 and 1009.
- This method takes into account the differences in variability of the 2 tests, however, the limit is based on only one oil.
- Because the VG limits are specified to 1 decimal place and the results are specified to 2, the limit used to calculate the equivalency limit is the VG limit minus 0.04 or 0.05 per ASTM rounding guidelines.
- The LTMS standard deviations are used for both Methods 3 and 4.



1.15.1. This slide explains the "probability" approach used for the upcoming slides.

1.16. Slide #28:

AES VH - VG SN Equivalency Limit using Probability Method Based on Targets (Method 3)

- Due to the VG and VH Means being similar for RO 940 but differing for 1009, the limits associated with the two oils differs significantly.
- A general argument could be made for using the Average Equivalency Limit because both oils are utilized for its calculation.
- In this case, using the limit based on RO 1009 appears more proper because both oils are below the limit but RO 1009 is closer.

Oil	VG		VH		VG Limit		Pass	VH Equiv.
	Mean	s	Mean	s	Specified	Effective	Probability	Limit
940	6.43	0.51	6.47	0.49	8.0	7.95	0.0014	7.93
1009	7.94	0.52	7.21	0.44	8.0	7.95	0.4923	7.22
Average								7.57

1.16.1. REO940 would have a 1% probability of passing the AES parameter if the equivalency limit is set using REO940 data.

1.16.2. REO1009 would have a 50% probability of passing the AES parameter if the equivalency limit is set using REO1009 data.

1.16.3. The statisticians recommend setting the equivalency by using the REO1009 data exclusively.

1.17. Slide #29:

AEV50 VH – VG SN Equivalency Limit using Probability Method Based on Targets (Method 3)

- Because RO 940's VG and VH means are so similar, it's associated VH Equivalency Limit is closer to the VG Limit.
- Because the means of ROs 940 and 1009 are on opposite sides of the VG Limit and nearly equidistant, recommend using the Average.

Oil	VG		VH		VG Limit		Pass	VH Equiv.
	Mean	s	Mean	s	Specified	Effective	Probability	Limit
940	8.79	0.25	8.77	0.28	8.9	8.86	0.3897	8.85
1009	8.99	0.22	8.81	0.40	8.9	8.86	0.7227	8.57
Average								8.71

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1.17.1. The statisticians recommend using an average of the equivalencies for both oils.

1.18. Slide #30:

RAC VH – VG SN Equivalency Limit using Probability Method Based on Targets (Method 3)

- In the VH, RAC is transformed as Ln(10 – RAC).
- This transformation tends to lengthen the tail the further the mean is above the limit, therefore the limit associated with RO 1009 is quite low.
- Because RO 940 is closer to the VG limit, recommend using the Equivalency Limit associated with RO 940.

Oil	VG		VH			VG Limit		Pass	VH Equiv Limit	
	Mean	s	Mean	Untrans. Mean	s	Specified	Effective	Probability	Transformed	Untransformed
940	8.15	0.92	0.9155	7.50	0.2260	8.3	8.26	0.4524	0.8885	7.57
1009	9.29	0.27	0.0515	8.95	0.3139	8.3	8.26	0.9999	1.2490	6.51
Average									1.0687	7.09

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1.18.1. Setting the equivalency for the RACS parameter is more complicated because a transformation is used.

1.18.2. There is a large disparity between an equivalency based on REO940 and an equivalency based on REO1009.

1.18.3. The statisticians recommend an equivalency based on REO940 alone.

1.19. Slide #31:

APV50 VH – VG SN Equivalency Limit using Probability Method Based on Targets (Method 3)

- Because the VG Means for the ROs are on either side of the VG limit, recommend using the Equivalency Limit associated with the Average.

Oil	VG		VH		VG Limit		Pass	VH Equiv.
	Mean	s	Mean	s	Specified	Effective	Probability	Limit
940	7.20	0.63	7.35	0.64	7.5	7.46	0.3399	7.61
1009	7.79	0.43	7.89	0.74	7.5	7.46	0.7786	7.32
Average								7.47

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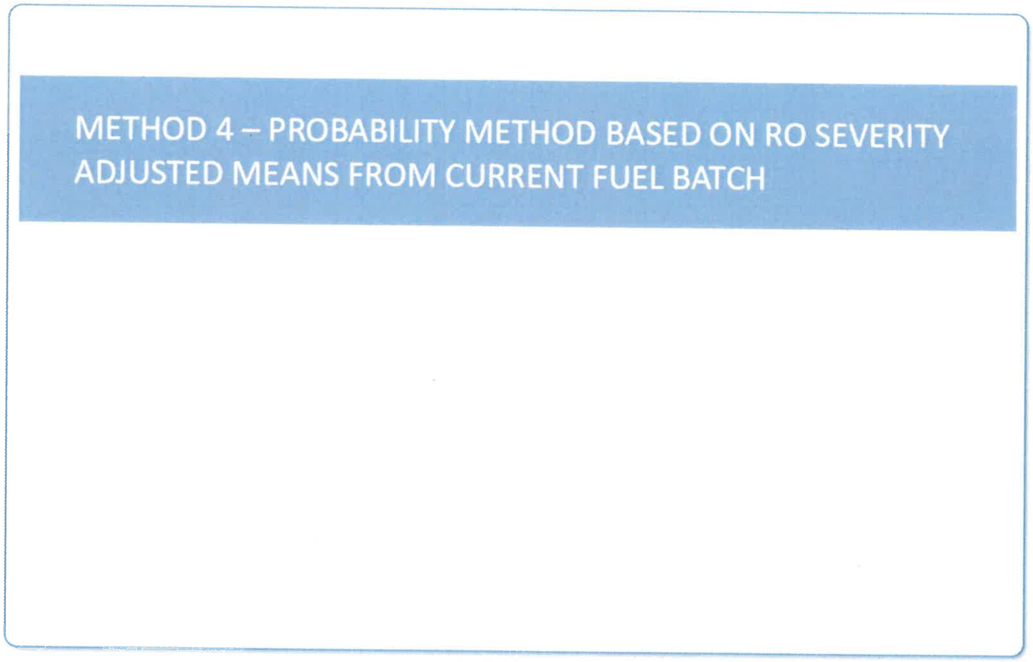
1.19.1. The statisticians recommend using an average of the equivalencies for both oils.

1.20. Slide #32:



1.20.1. Method #3 and Method #4 are very similar.
1.20.2. Boese skipped over the detailed slides for Method #4 and reviewed the summary slide (Slide #38).

1.21. Slide #38:

VH SN Equivalency Limit Selection

- The limits for each pass/fail parameter for the VH are tabulated below obtained via the four methods.
- Ranges of methods are:
  - AES: 7.2 – 7.9
  - AEV50: 8.4 – 8.8
  - RAC: 6.5 – 7.8
  - APV50: 6.4 – 7.6
- Recommend estimates based on Method 2 because:
  - This method more properly utilizes both reference oils.
  - This method is based on results using a common fuel batch which appears to impact the severity adjusted results.

Parameter	VG Limit	VH Equivalency		Pass Probability					
		Method 1	Method 2	Method 3			Method 4		
				940	1009	Average	940	1009	Average
AES	8.0	7.2	7.2	7.9	7.2	7.6	7.9	7.3	7.6
AEV(50)	8.9	8.8	8.6	8.8	8.6	8.7	8.5	8.4	8.4
RAC	8.3	7.8	7.7	7.6	6.5	7.1	7.6	6.5	7.1
APV(50)	7.5	7.6	7.4	7.6	7.3	7.5	7.4	6.4	7.3

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1.21.1. The statisticians recommend using Method #2 for each of the key parameters.
1.21.2. They prefer Method #2 because it uses both oils but adds more leverage to the oil that is closer to the SN limit.
1.21.2.1. Method #2 also uses the same fuel batch.

2. OPEN DISCUSSION:

2.1. Ford's Comments:

2.1.1. Ford is concerned about Method #2.
2.1.2. Ford's primary concern is with the AES parameter.
2.1.2.1. The limit for Average Engine Sludge is too low.
2.1.2.2. They do not want oils that are like REO940 being licensed.
2.1.2.3. They are not willing to accept a limit of 7.2 merits.
2.1.3. Ford may prefer to use one of the "probability" methods.
2.1.4. Boese's Comments:
2.1.4.1. It may be possible to use Method #2 for (3) parameters and another method for Average Engine Sludge.
2.1.5. Ford's Preferred Pass/Fail Limits:
2.1.5.1. AES = 7.6
2.1.5.2. RACS = 7.6
2.1.5.3. AEV50 = 8.6 to 8.7
2.1.5.4. APV50 = 7.5
2.1.5.5. This would put the limits for the Sequence VH closer to where they were with the VG.

2.2. Other Comments:

2.2.1. Andy Ritchie and Afton both share Ford's concerns regarding the AES parameter.
2.2.2. Lubrizol's Comments:

2.2.2.1. Lubrizol stressed that the job of the Surveillance Panel is to verify that the statistical analysis was done appropriately.

2.2.2.1.1. Lubrizol agrees with the analysis that the statisticians presented.

2.2.2.2. It is not the job of the Surveillance Panel to debate limits.

2.2.2.3. Debating and establishing limits is done by groups outside of the Surveillance Panel.

2.2.3. Ford's Response:

2.2.3.1. Ford does not agree with Lubrizol's position.

2.2.3.2. The CLOG group will be looking for a recommendation on limits from the Surveillance Panel.

2.2.4. Oronite's Response:

2.2.4.1. Oronite agrees with Lubrizol's position.

2.2.5. Southwest's Comments:

2.2.5.1. *Could Method #3 and Method #4 utilize something other than the average?*

Action Items	Person responsible	Completion Date

Follow-up Notes/Updates	Initials	Date Added

Attendees	Organization	Contact Information

VH – VG SN Equivalency Limits

Statistics Group

October 20, 2017

Statistics Group

- 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

Executive Summary

- Four methods were utilized to develop proposed VH Equivalency Limits to VG SN limits.
- Recommended SN VH Equivalency Limits (and range of limits obtained via the four methods) for each VH pass/fail parameter follow:
  - AES: 7.2 (7.2 – 7.9)
  - AEV50: 8.6 (8.4 – 8.8)
  - RAC: 7.7 (6.5 – 7.8)
  - APV50: 7.4 (6.4 – 7.6)
  - OSCR: TBD upon collection of a sufficient sample size of accepted OSCR rated data.
  - HSR: 0
- The procedures used to obtain these SN Equivalency Limits can be utilized to obtain SJ, SL and SM Equivalency Limits.

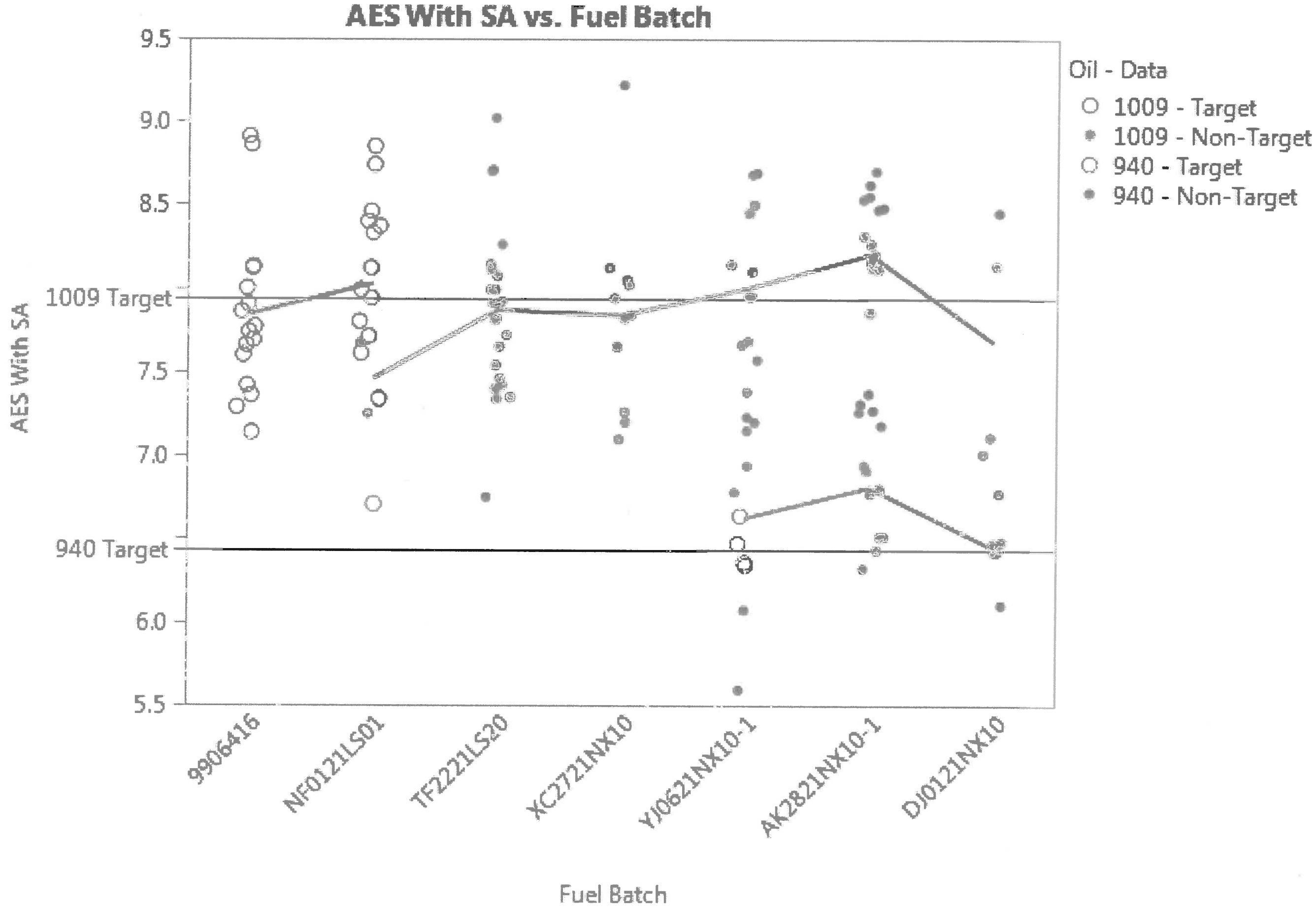
Data

- Fuel Batches listed in the TMC database as 0121LS01, NF0121LS and NF0121LS01 are combined into NF0121LS01 in this analysis.
- Data is as of August 21, 2017.
- The current fuel batch is DJ0121NX10. This batch was used for the VH Precision Matrix.

HSR and OSCR

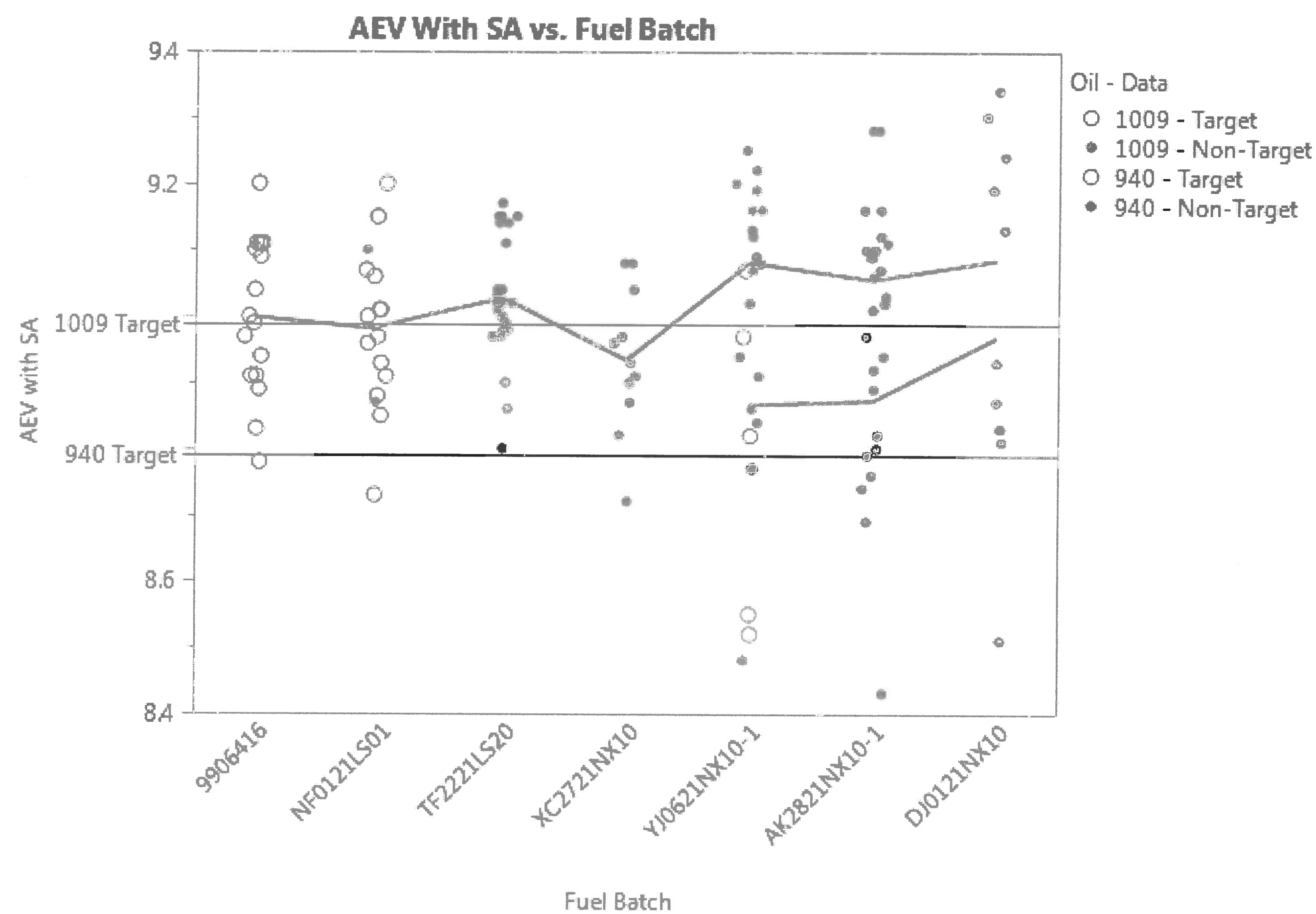
- HSR
  - HSR VG Limits and Targets for ROs 940 and 1009 for VG are 0.
  - VH Targets for ROs 940 and 1009 are 0.
  - Recommend VH HSR Equivalency Limit be 0.
- OSCR
  - Data is being generated to develop Targets for the VH.

Adjusted VG AES Versus Fuel Batch



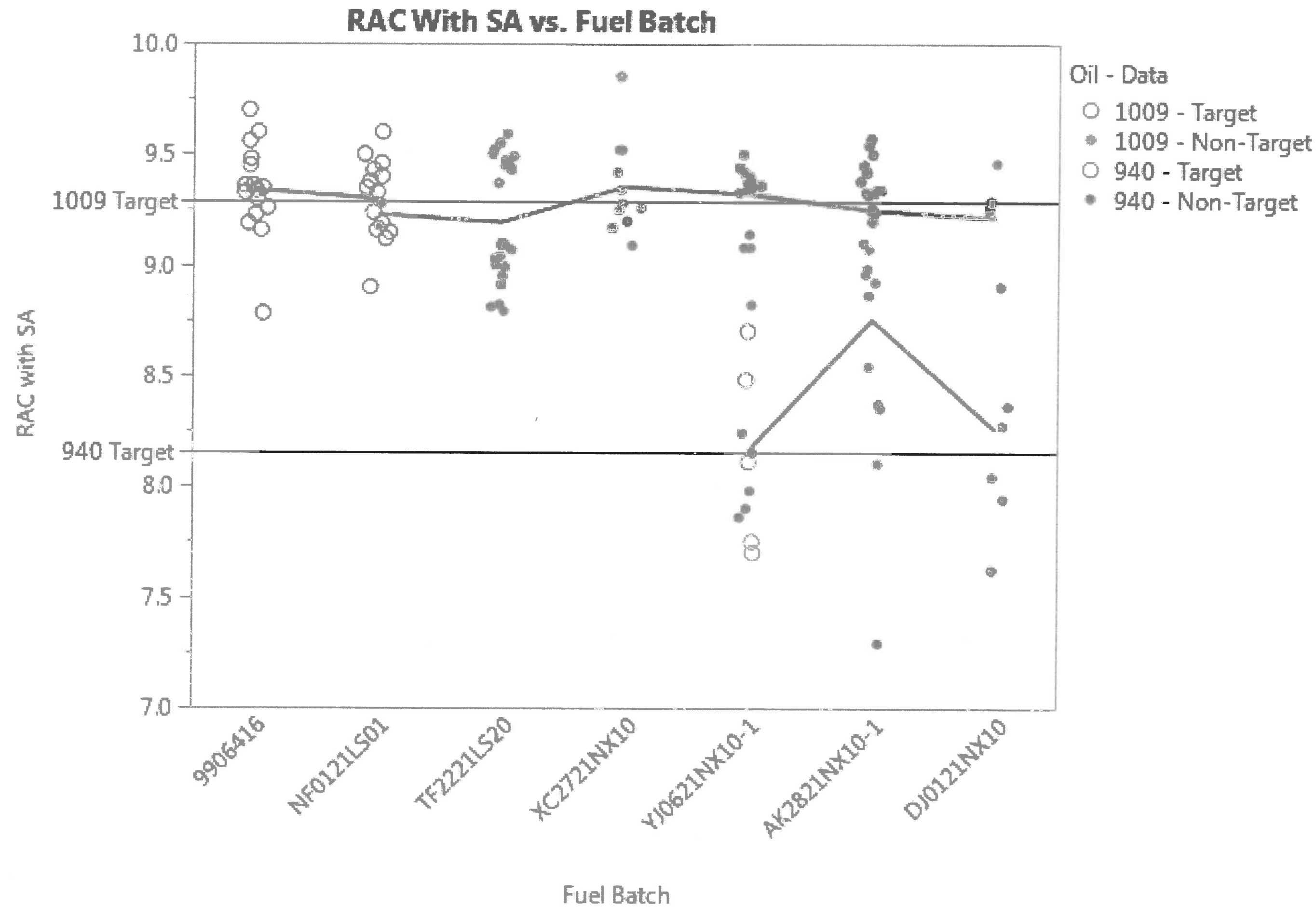
- The fuel batches are plotted in chronological order.
- The average severity adjusted AES result for both oils trend in parallel dependent on the Fuel Batch.

Adjusted VG AEV Versus Fuel Batch



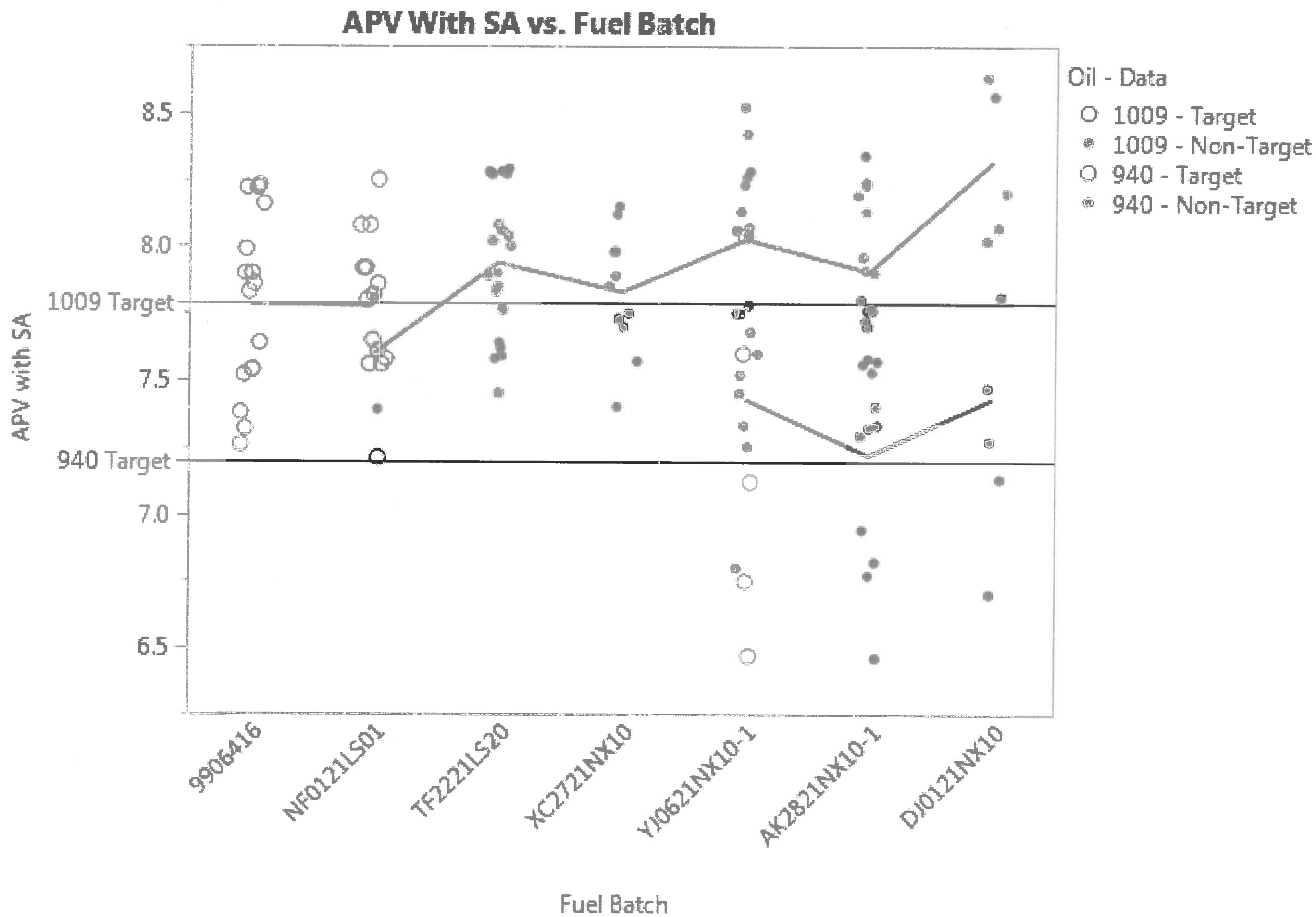
- The fuel batches are plotted in chronological order.
- Both oils have AEV means above target for the last 3 fuel batches.

Adjusted VG RAC Versus Fuel Batch



- The fuel batches are plotted in chronological order.
- The average of the severity adjusted RAC results for RO 940 are more variable than for 1009.

Adjusted VG APV Versus Fuel Batch



- The fuel batches are plotted in chronological order.
- The average severity adjusted APV result for both oils trend in parallel dependent on the Fuel Batch.

Methods Utilized

There are a number of potential methods to estimate VH – VG Equivalency. Methods utilized in this analysis follow:

- Simple Model:

1. Utilize line connecting VG/VH Target pairs for Reference Oils 940 and 1009 to project VH – VG Equivalency.
    - The data utilized to estimate the target were based on severity adjusted results. Therefore, the targets for both oils are tied back to test start severity level.
2. Utilize line connecting VG/VH pairs of averages for Reference Oils 940 and 1009 based on current fuel batch (DJ0121NX10).
    - The deviation from the mean of severity adjusted results appears to be dependent on the batch of fuel being used for some parameters. This method uses the current fuel batch (DJ0121NX10).

- Pass Probability:

3. VH limit is set such that its probability of passing is equivalent to the VG (based on VG and VH targets for Reference Oils 940 and 1009).
4. VH limit is set such that its probability of passing is equivalent to the VG [based on averages for Reference Oils 940 and 1009 based on current fuel batch (DJ0121NX10)].

Methods Utilized (Continued)

- The sample sizes of the data sets used for the two methods are similar except for RO 1009 VG.

Sample Sizes of Data Sets Utilized

Oil	VG		VH	
	Target	Current Fuel Batch	Target	Current Fuel Batch
940	5	6	7	8
1009	30	4	8	8

Data Utilized

- Both probability methods 3 and 4 utilize the LTMS standard deviations.
- The averages utilized are tabulated below.
  - The averages for Methods 1 and 3 are LTMS targets.
  - The averages for Methods 2 and 4 are of the current fuel batch (DJ0121NX10).
  - The VG averages (targets and current fuel batch) and VH current fuel batch averages are based on severity adjusted results.
  - The VH targets are LS means.

Parameter	VG				VH			
	LTMS Targets		Curent Fuel Batch		LTMS Targets		Curent Fuel Batch	
	940	1009	940	1009	940	1009	940	1009
AES	6.43	7.94	6.44	7.68	6.47	7.21	6.48	7.03
AEV(50)	8.79	8.99	8.97	9.09	8.77	8.81	8.64	8.78
RAC	8.15	9.29	8.25	9.22	7.50	8.95	7.61	8.85
APV(50)	7.20	7.79	7.43	8.32	7.35	7.89	7.41	7.83

SIMPLE MODEL

Simple Model Method

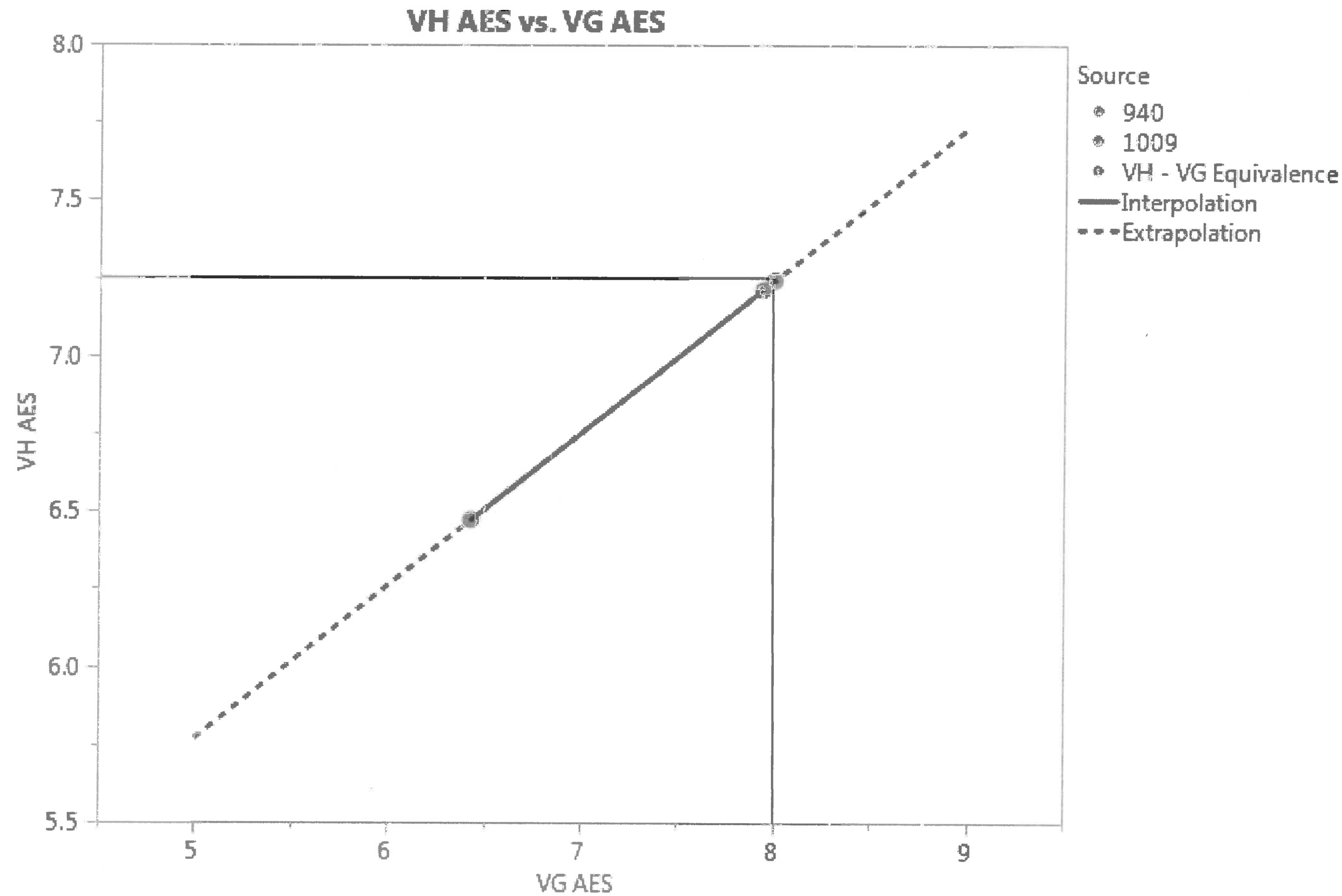
- Both Methods 1 and 2 are based on severity adjusted reference oil results.
- The following two sections graphically illustrate the method, however, the numbers are calculated using models.

METHOD 1

AES VH – VG SN Equivalency Based on VG and VH Targets (Method 1)

VH Equiv.

Term	Estimate
Intercept	3.32
VG AES	0.49

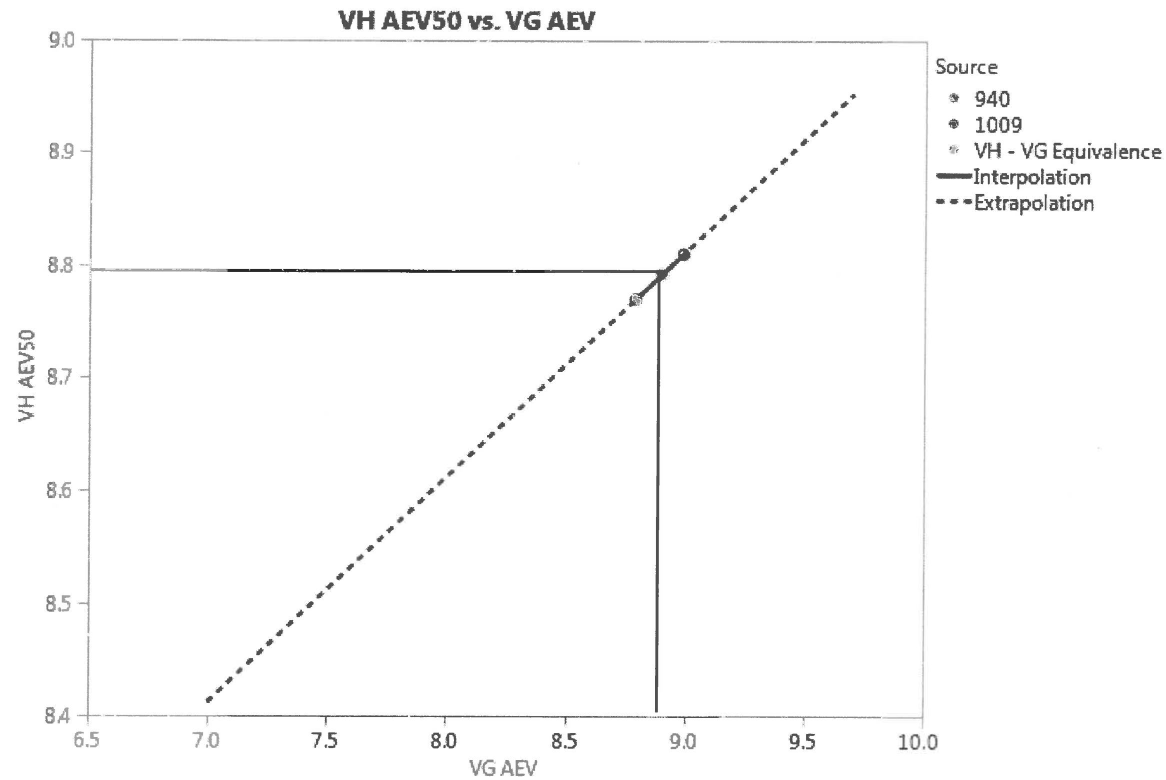


VG SN Limit

- Extrapolation of the line connecting the targets for Oils 940 and 1009 yields a VH Equivalency of the VG SN limit (8.0) of 7.24.

AEV VH – VG SN Equivalency Based on VG and VH Targets (Method 1)

VH Equiv.



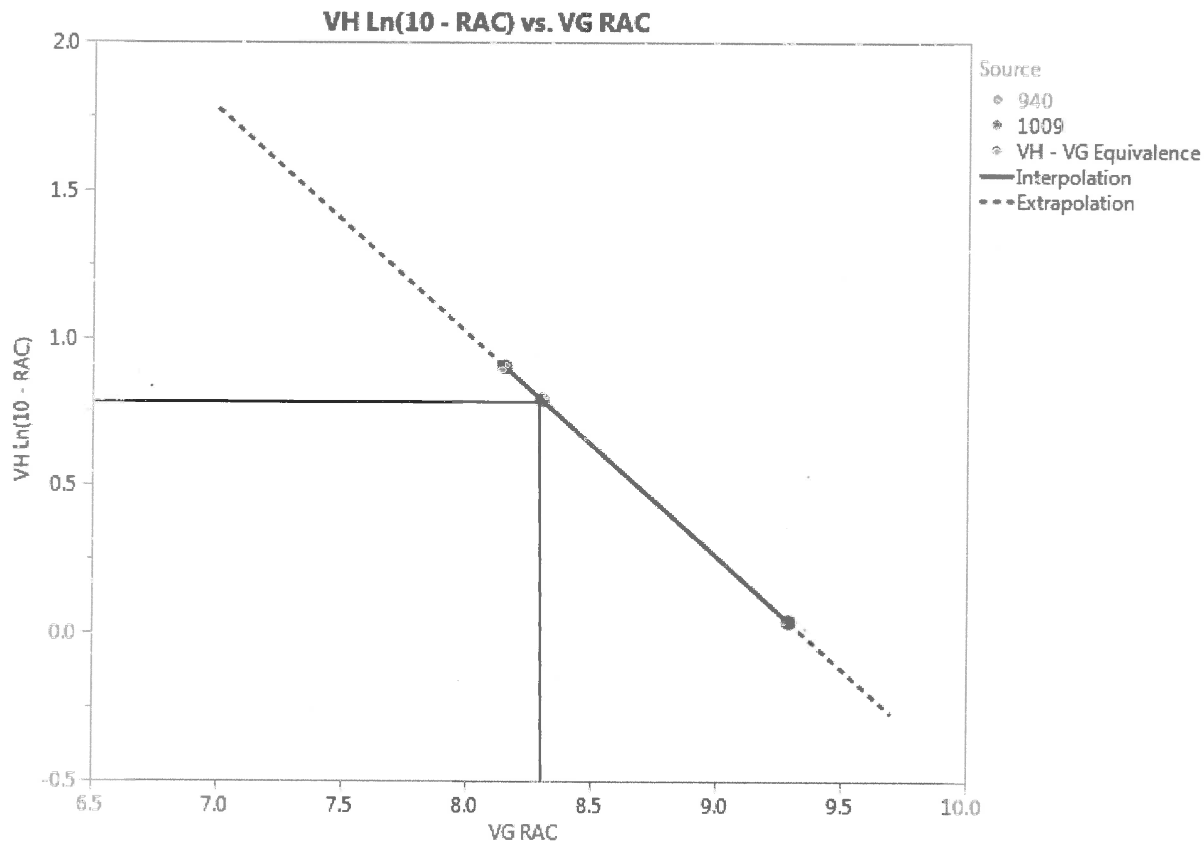
Term	Estimate
Intercept	7.01
VG AEV	0.20

VG SN Limit

- Interpolation of the line connecting the targets for Oils 940 and 1009 yields a VH Equivalency of the VG SN limit (8.9) of 8.79.
- Due to small difference in VG limits for ROs 940 and 1009, the equation of the line is suspect resulting in a low slope (0.2), however, because VG limit is between ROs and there is little separation between them, the resulting VH Equivalence is likely proper.

RAC VH – VG SN Equivalency Based on VG and VH Targets (Method 1)

VH Equiv.



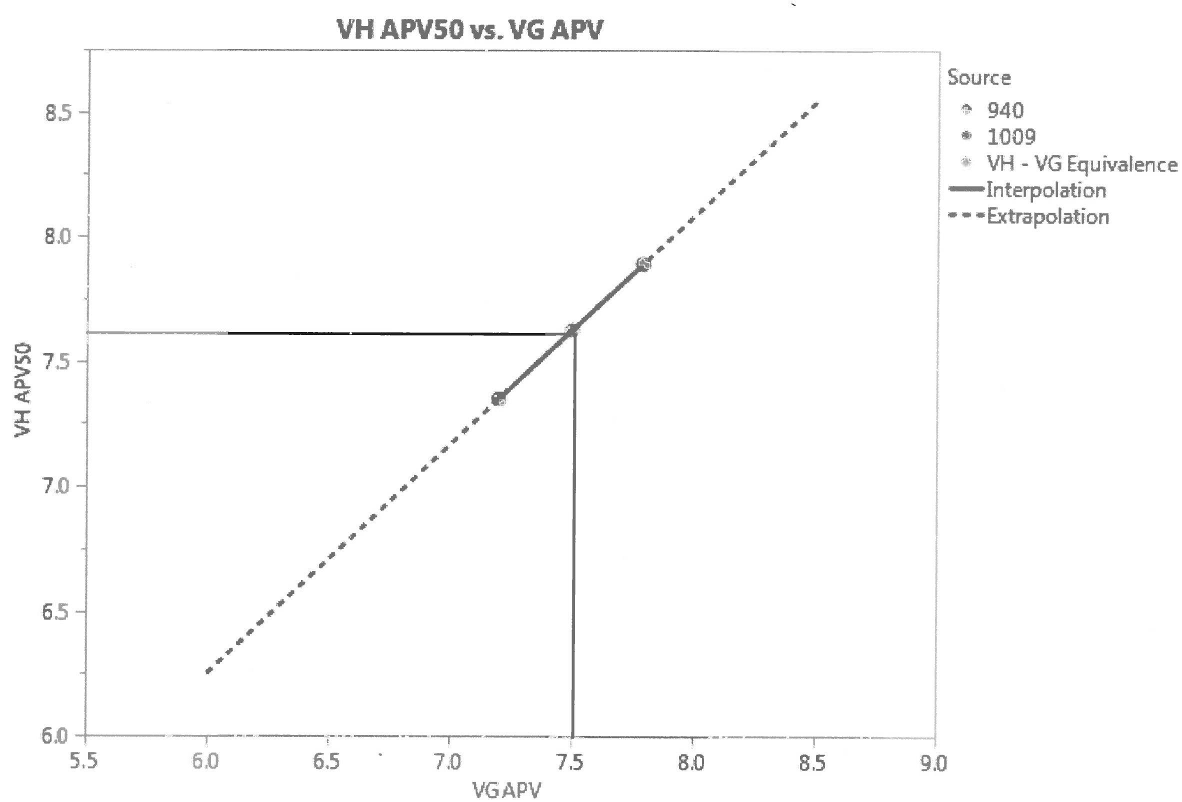
VG SN Limit

Term	Estimate
Intercept	7.09
VG RAC	-0.76

- Interpolation of the line connecting the targets for Oils 940 and 1009 yields a VH Equivalency of the VG limit (8.3) of 7.77 [Ln(10-RAC) = 0.8018].
- Due to close proximity of VG SN RAC limit to 940 RAC Target, there is increased confidence in the estimated equivalence.

APV VH – VG SN Equivalency Based on VG and VH Targets (Method 1)

VH Equiv.



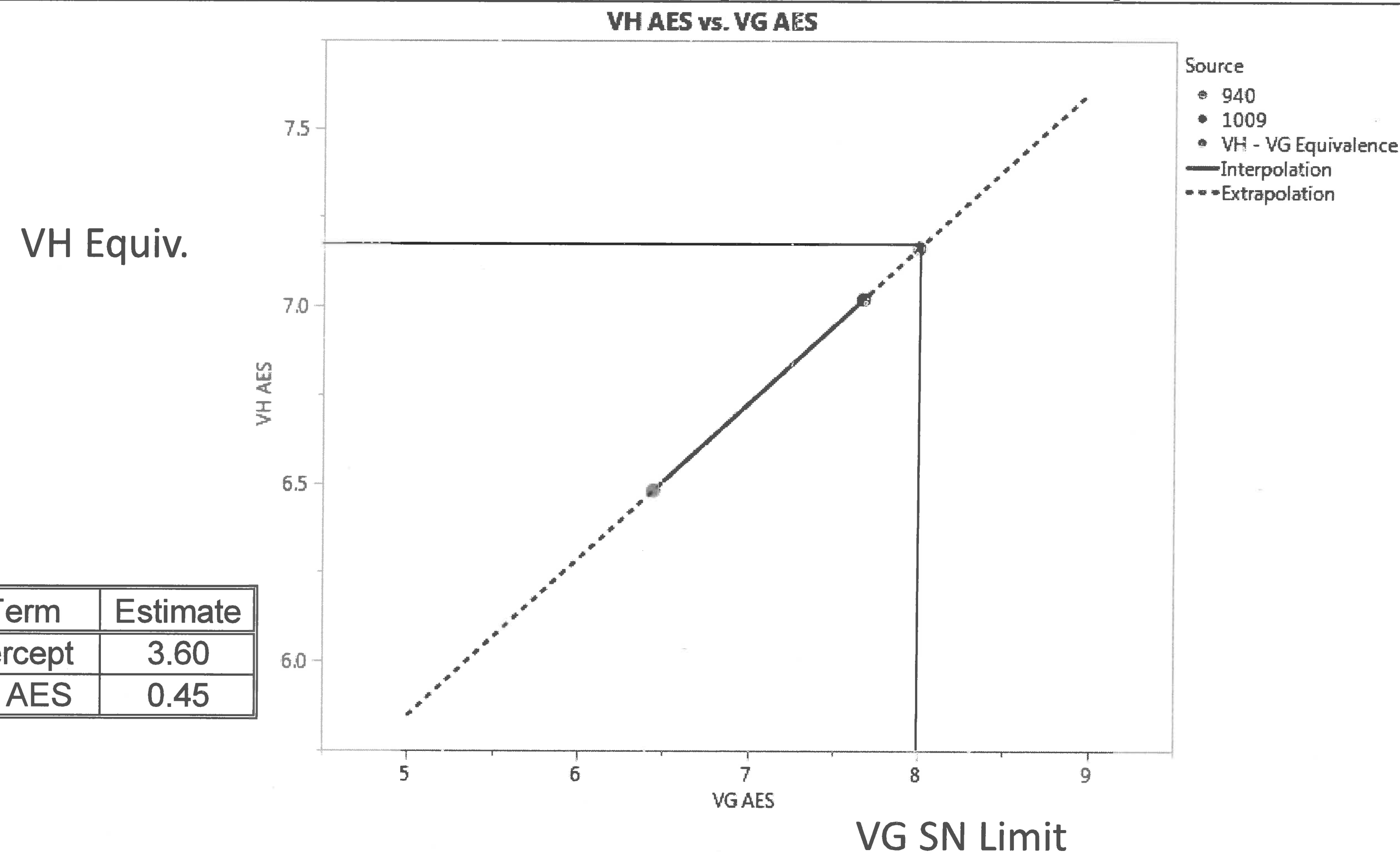
Term	Estimate
Intercept	0.76
VG APV	0.92

VG SN Limit

- Interpolation of the line connecting the targets for Oils 940 and 1009 yields a VH Equivalency of the VG SN limit (7.5) of 7.62.

METHOD 2

AES VH – VG SN Equivalency Based on Current Fuel Batch Averages (Method 2)



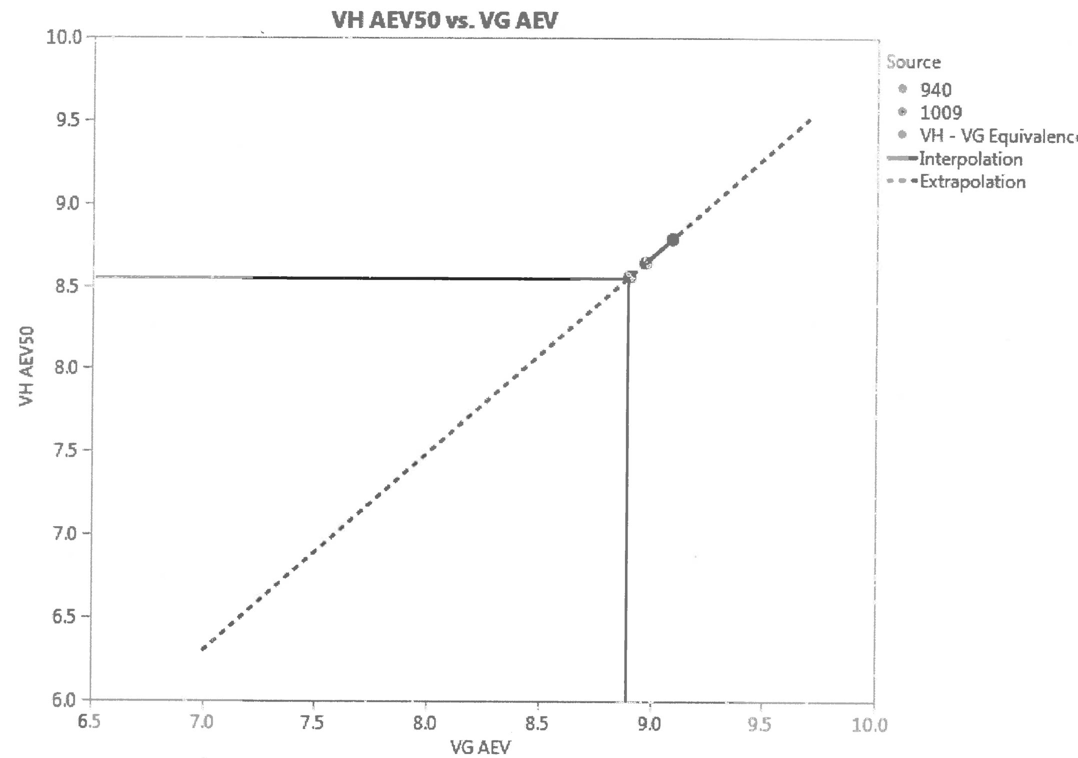
Term	Estimate
Intercept	3.60
VG AES	0.45

- Extrapolation of the line connecting the targets for Oils 940 and 1009 yields a VH Equivalency of the VG SN limit (8.0) of 7.18.

AEV VH – VG Equivalency Based on Current Fuel Batch Averages (Method 2)

VH Equiv.

Term	Estimate
Intercept	-2.03
VG AEV	1.19



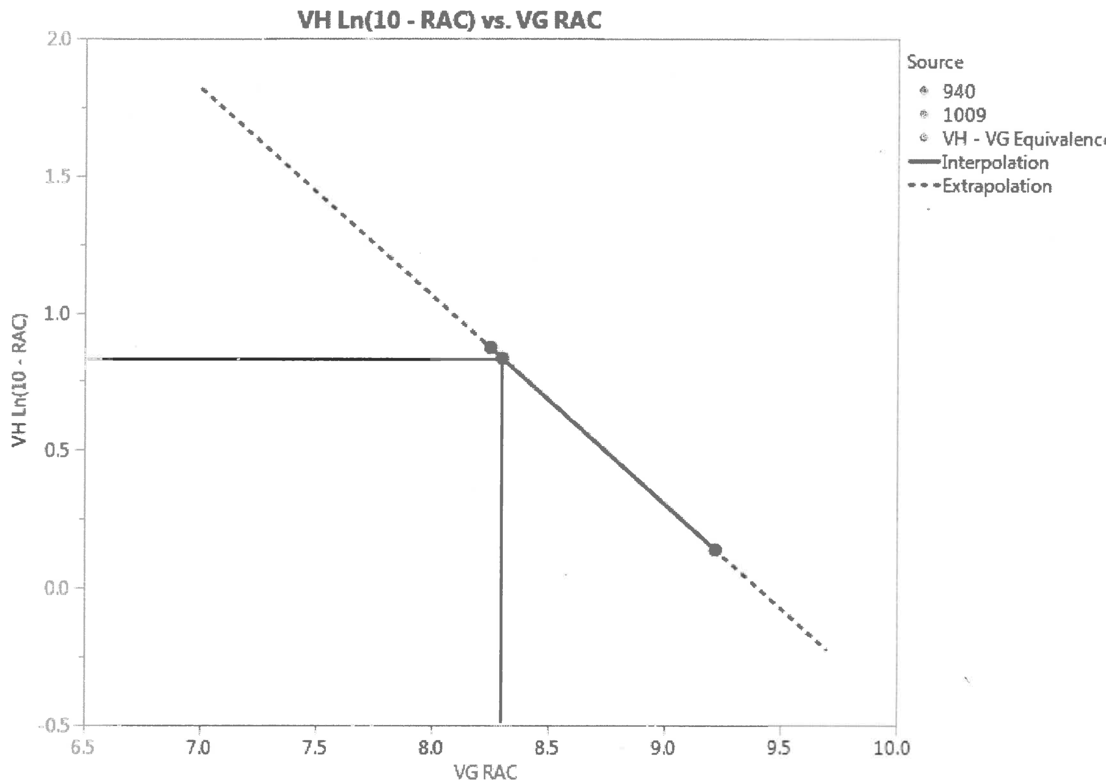
VG SN Limit

- The VG SN limit is slightly lower than the averages of both Oils 940 and 1009, however since they are similar both should be used which yields a VH Equivalency of the VG SN limit (8.9) of 8.56.
- Due to small difference between the AEV averages of RO 940 and 1009 and the VG SN limit being close to the RO 940 VG average, the VH Equivalence is relatively tightly bound.

RAC VH – VG Equivalency Based on Current Fuel Batch Averages (Method 2)

VH Equiv.

Term	Estimate
Intercept	7.12
VG RAC	-0.76

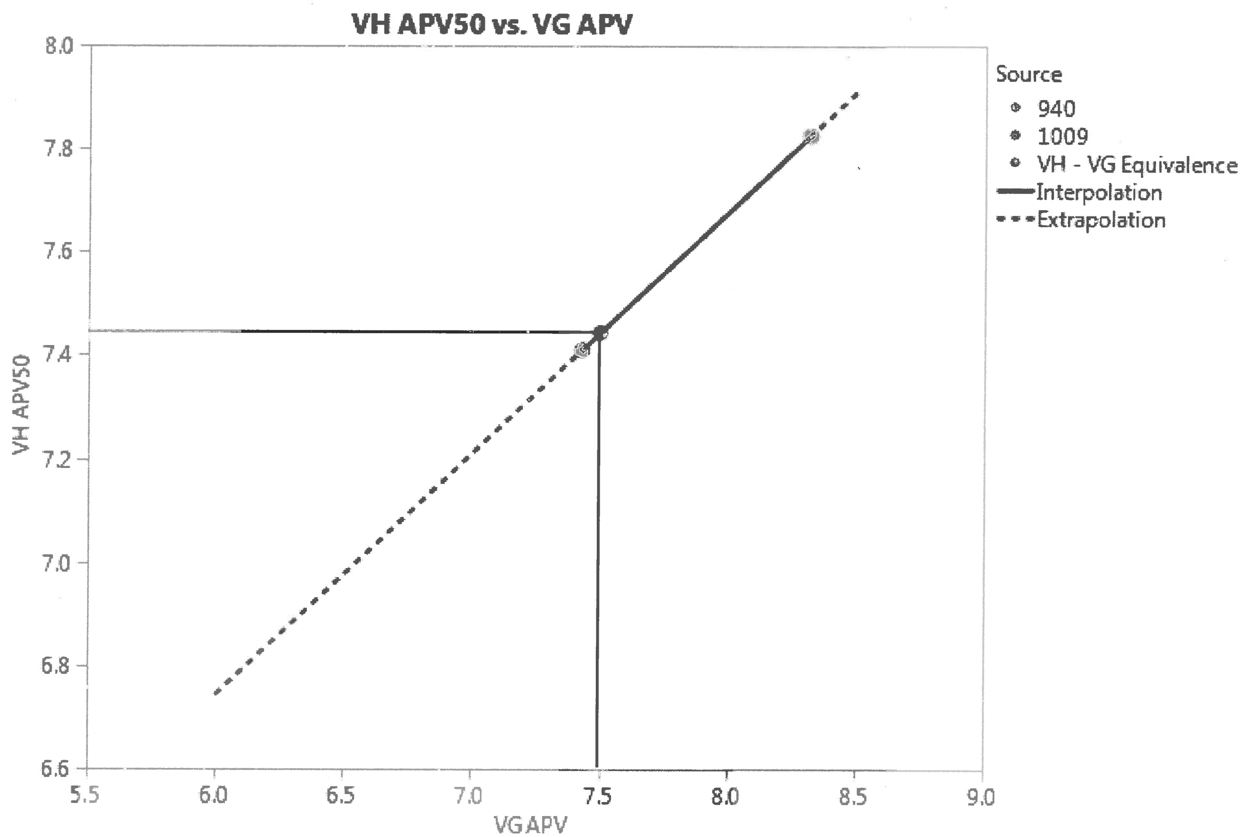


VG SN Limit

- Interpolation of the line connecting the targets for Oils 940 and 1009 yields a VH Equivalency of the VG SN limit (8.3) of 7.70 [Ln(10-RAC) = 0.8340].
- Due to close proximity of VG RAC limit to 940 RAC average, there is increased confidence in the estimated equivalence.

APV VH – VG Equivalency Based on Current Fuel Batch Averages (Method 2)

VH Equiv.



Term	Estimate
Intercept	3.95
VG APV	0.47

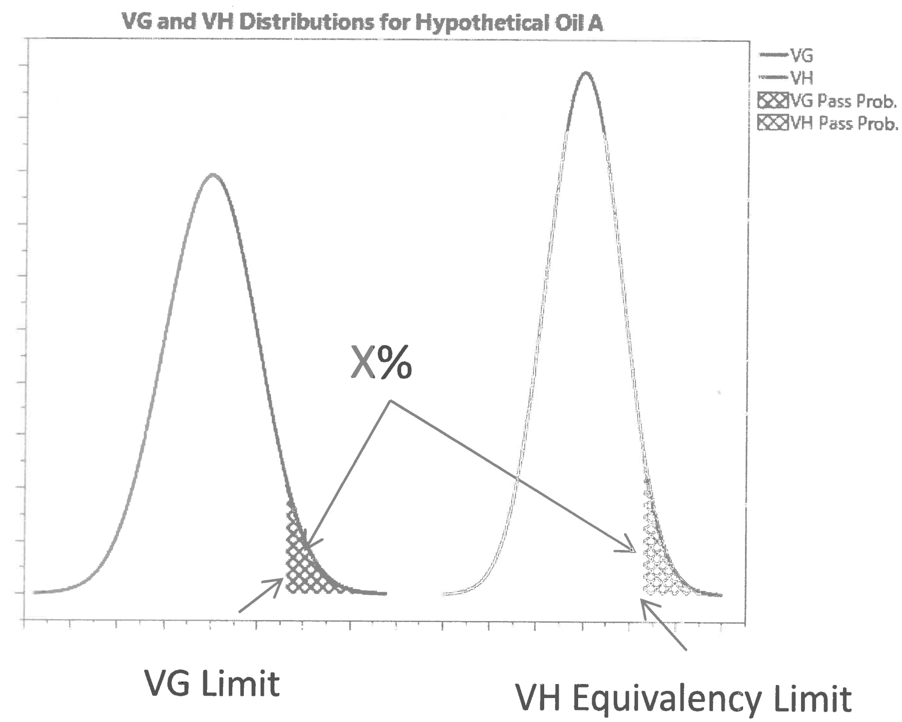
VG SN Limit

- Interpolation of the line connecting the targets for Oils 940 and 1009 yields a VH Equivalency of the SN VG limit (7.5) of 7.44.
- Due to close proximity of VG APV limit to 940 APV average, there is increased confidence in the estimated equivalence.

PROBABILITY METHODS

Probability Method

- The VH Equivalency Limit is calculated such that the probability of passing it is the same as for passing the VG for a particular oil.
  - For example, if the probability of Oil A passing the VG is 5%, the VH Equivalency Limit would be set such that the probability of Oil A passing the VH is 5%.
- The method is applied separately for ROs 940 and 1009.
- This method takes into account the differences in variability of the 2 tests, however, the limit is based on only one oil.
- Because the VG limits are specified to 1 decimal place and the results are specified to 2, the limit used to calculate the equivalency limit is the VG limit minus 0.04 or 0.05 per ASTM rounding guidelines.
- The LTMS standard deviations are used for both Methods 3 and 4.



METHOD 3 – PROBABILITY METHOD BASED ON RO TARGETS

AES VH - VG SN Equivalency Limit using Probability Method Based on Targets (Method 3)

- Due to the VG and VH Means being similar for RO 940 but differing for 1009, the limits associated with the two oils differs significantly.
- A general argument could be made for using the Average Equivalency Limit because both oils are utilized for its calculation.
- In this case, using the limit based on RO 1009 appears more proper because both oils are below the limit but RO 1009 is closer.

Oil	VG		VH		VG Limit		Pass	VH Equiv.
	Mean	s	Mean	s	Specified	Effective	Probability	Limit
940	6.43	0.51	6.47	0.49	8.0	7.95	0.0014	7.93
1009	7.94	0.52	7.21	0.44	8.0	7.95	0.4923	7.22
Average								7.57

AEV50 VH – VG SN Equivalency Limit using Probability Method Based on Targets (Method 3)

- Because RO 940's VG and VH means are so similar, it's associated VH Equivalency Limit is closer to the VG Limit.
- Because the means of ROs 940 and 1009 are on opposite sides of the VG Limit and nearly equidistant, recommend using the Average.

Oil	VG		VH		VG Limit		Pass	VH Equiv.
	Mean	s	Mean	s	Specified	Effective	Probability	Limit
940	8.79	0.25	8.77	0.28	8.9	8.86	0.3897	8.85
1009	8.99	0.22	8.81	0.40	8.9	8.86	0.7227	8.57
Average								8.71

RAC VH – VG SN Equivalency Limit using Probability Method Based on Targets (Method 3)

- In the VH, RAC is transformed as Ln(10 – RAC).
- This transformation tends to lengthen the tail the further the mean is above the limit, therefore the limit associated with RO 1009 is quite low.
- Because RO 940 is closer to the VG limit, recommend using the Equivalency Limit associated with RO 940.

Oil	VG		VH			VG Limit		Pass	VH Equiv Limit	
	Mean	s	Mean	Untrans. Mean	s	Specified	Effective	Probability	Transformed	Untransformed
940	8.15	0.92	0.9155	7.50	0.2260	8.3	8.26	0.4524	0.8885	7.57
1009	9.29	0.27	0.0515	8.95	0.3139	8.3	8.26	0.9999	1.2490	6.51
Average									1.0687	7.09

APV50 VH – VG SN Equivalency Limit using Probability Method Based on Targets (Method 3)

- Because the VG Means for the ROs are on either side of the VG limit, recommend using the Equivalency Limit associated with the Average.

Oil	VG		VH		VG Limit		Pass Probability	VH Equiv. Limit
	Mean	s	Mean	s	Specified	Effective		
940	7.20	0.63	7.35	0.64	7.5	7.46	0.3399	7.61
1009	7.79	0.43	7.89	0.74	7.5	7.46	0.7786	7.32
Average								7.47

METHOD 4 – PROBABILITY METHOD BASED ON RO SEVERITY ADJUSTED MEANS FROM CURRENT FUEL BATCH

AES VH - VG SN Equivalency Limit using Probability Method Based on SA Results from Current Fuel Batch (Method 4)

- Due to the VG and VH Means being similar for RO 940 but differing for 1009, the limits associated with the two oils differs significantly.
- Recommend using the limit based on RO 1009 because both oils are below the limit but RO 1009 is closer.

Oil	VG		VH		VG Limit		Pass	VH Equiv.
	Mean	s	Mean	s	Specified	Effective	Probability	Limit
940	6.44	0.51	6.48	0.49	8.0	7.95	0.0016	7.93
1009	7.68	0.52	7.03	0.44	8.0	7.95	0.2985	7.26
Average								7.60

AEV50 VH – VG SN Equivalency Limit using Probability Method Based on SA Results from Current Fuel Batch (Method 4)

- Because the VG limits for both RO 940 and 1009 are very close to the VG limit, recommend using the Average.

Oil	VG		VH		VG Limit		Pass Probability	VH Equiv. Limit
	Mean	s	Mean	s	Specified	Effective		
940	8.97	0.25	8.64	0.28	8.9	8.85	0.6820	8.51
1009	9.09	0.22	8.78	0.40	8.9	8.85	0.8573	8.35
Average								8.43

RAC VH – VG SN Equivalency Limit using Probability Method Based on SA Results from Current Fuel Batch (Method 4)

- The VH RAC is transformed as Ln(10 – RAC).
- This transformation tends to lengthen the tail the further the mean is above the limit, therefore the limit associated with RO 1009 is quite low.
- Because RO 940 is closer to the VG limit, recommend using the Equivalency Limit associated with RO 940.

Oil	VG		VH			VG Limit		Pass	VH Equiv Limit	
	Mean	s	Mean	Untrans. Mean	s	Specified	Effective	Probability	Transformed	Untransformed
940	8.25	0.92	0.8693	7.61	0.2260	8.3	8.25	0.5014	0.8701	7.61
1009	9.22	0.27	0.1415	8.85	0.3139	8.3	8.25	0.9998	1.2634	6.46
Average									1.0668	7.09

APV50 VH – VG SN Equivalency Limit using Probability Method Based on SA Results from Current Fuel Batch (Method 4)

- Because the VG APV mean for RO 940 is very close to the SN VG limit, recommend using the Equivalency Limit associated with RO 940.

Oil	VG		VH		VG Limit		Pass	VH Equiv.
	Mean	s	Mean	s	Specified	Effective	Probability	Limit
940	7.43	0.63	7.41	0.64	7.5	7.46	0.4810	7.44
1009	8.32	0.43	7.83	0.74	7.5	7.46	0.9772	6.35
Average								6.90

SELECTION OF VH EQUIVALENCY

VH SN Equivalency Limit Selection

- The limits for each pass/fail parameter for the VH are tabulated below obtained via the four methods.
- Ranges of methods are:
  - AES: 7.2 – 7.9
  - AEV50: 8.4 – 8.8
  - RAC: 6.5 – 7.8
  - APV50: 6.4 – 7.6
- Recommend estimates based on Method 2 because:
  - This method more properly utilizes both reference oils.
  - This method is based on results using a common fuel batch which appears to impact the severity adjusted results.

Parameter	VG Limit	VH Equivalency		Pass Probability					
		Method 1	Method 2	Method 3			Method 4		
				940	1009	Average	940	1009	Average
AES	8.0	7.2	7.2	7.9	7.2	7.6	7.9	7.3	7.6
AEV(50)	8.9	8.8	8.6	8.8	8.6	8.7	8.5	8.4	8.4
RAC	8.3	7.8	7.7	7.6	6.5	7.1	7.6	6.5	7.1
APV(50)	7.5	7.6	7.4	7.6	7.3	7.5	7.4	6.4	7.3