Single Technology Matrix Draft 4.5
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APPENDIX STM – API GUIDELINES FOR USE OF A SINGLE TECHNOLOGY MATRIX

STM.1 General

A Single Technology Matrix (STM) approach may be used in addition to the Base Oil Interchangeability and SAE Viscosity-Grade Testing Guidelines included in API 1509 Appendices E and F. The STM approach must follow the Guidelines outlined in STM.2, and any engine test specific amendments listed in STM.6.

STM.1.1 Introduction

The Guidelines in API 1509 are developed through industry consensus. Each Guideline is generally derived using the 'minimum quality and quantity of data' rule. This rule requires that three technologies from at least two companies agree on the characteristic behavior of the base oil and/or SAE viscosity grade. This process has the benefit of industry consensus and public display of data.

The limitations of the consensus process include development of timely Guidelines, over-testing in some areas, and limitations to the type of data that can be viewed.

A Single Technology Matrix approach encompasses a technology or family of technologies from a single supplier in lieu of at least three technologies from different suppliers. The purpose of this approach is to offer an alternate, cost-effective, and technically valid process to demonstrate the performance capability of an additive technology. The matrix can be as broad or narrow in its application as are the industry Guidelines. Note that while the Guidelines developed through the traditional three technologies approach applies to all technologies tested in the future, the Guidelines developed from a Single Technology Matrix approach apply only to the technology or technologies used in that Matrix.

The additive technology supplier will provide the Oil Marketer with sufficient information from the Single Technology Matrix, which the Oil Marketer may elect to utilize in applying for an API License.

STM.1.2 Definitions

STM.1.2.1 A *Single Technology* as designed for use in a Single Technology Matrix is a single additive package (DI) at a constant treat rate, with a single Viscosity Modifier, and in a single Viscosity Grade.

STM.1.2.2 A *Single Technology Matrix* is comprised of a group of data meeting the criteria outlined in STM.2. The test results in the matrix reflect data from a Single Technology as described in STM.1.2.1.

STM.1.2.3 A *Multiple Technology Matrix* is comprised of two or more Single Technology Matrices meeting the criteria outlined in STM.2. A Multiple Technology Matrix developed within an API Category cannot extend to future API Categories unless recommended by the API BOI/VGRA Task Force and approved by the API Lubricants Committee.

STM.1.2.4 A *Base Stock* is a lubricant component that is produced by a single manufacturer to the same specifications (independent of feed source or manufacturer's location); that meets the same manufacturer's specification; and that is identified by a unique formula, product identification number, or both. Base stocks may be manufactured using a variety of different processes including but not limited to distillation, solvent refining, hydrogen processing, oligomerization, esterification, and rerefining. Rerefined stock shall be substantially free from materials introduced through manufacturing, contamination or previous use.

STM.1.2.5 A *Base Oil* used in a Technology Matrix can be comprised of a single base stock, or a blend of base stocks. The *Base Oil* can be comprised of the same or multiple slates of base stocks. The *Base Oil* is defined, at minimum, by the following variables.

Base Oil ~~its~~ Saturates (ASTM D 2007)
Base Oil Sulfur (API Approved Tests from Appendix E, Table E-1)
Base Oil Viscosity at 100°C (ASTM D 445)
Base Oil Viscosity Index (ASTM D 2270)
Noack ~~VI analyses. (The~~ Volatility of the fully formulated oil (finished oil) (ASTM D 5800) ~~also must be re~~

STM.1.2.6 An *Outlier* is a test result in which the Studentized Residual for that observation from the analysis is at the one-sided 97.5th percentile, or beyond, on a Student T distribution.

STM.1.2.7 A *Spread Requirement* is a stipulation on the Base Oil variable results in the Matrix that facilitates a more even spread in those results throughout the Matrix.

STM.2 Scope and Criteria for a Single Technology Matrix

STM.2.1. Matrix Data Criteria

The Matrix data must be developed using a Single Technology as described in STM.1.2.1. A minimum of X ~~5~~ operationally valid tests on X different base oils is required for a suitable matrix. X is either equal to 5 or equal to the number of base oil variables of interest plus 2 (to ensure that there are enough degrees of freedom to estimate the error term from the matrix), whichever is greater. Base Oil variables of interest are determined by the API BOI/VGRA Task Force on a per test type basis. The range of Base Oil variables of interest, plus, if not included in that list, the ranges of Base Oil VI, Base Oil Sulfur, Base Oil Saturates, Base Oil -Viscosity at 100°C and finished oil Noack Volatility in that Matrix, must cover any Base Oil Interchange. To extend to another Base Oil beyond this range would require at least one additional test using a Base Oil that extends the range.

There is a Spread Requirement for the Base Oil Saturates in the Matrix. The maximum difference in Saturates, between two Base Oils sorted and listed by Saturates, can be no greater than the difference between the Base Oil with the highest Saturates and the Base Oil with the lowest Saturates, divided by 2.

To improve data efficiencies, multiple Single Technology Matrices may be combined and analyzed. This combination is known as the Multiple Technology Matrix. Whereas, X tests on X different Base Oils are required from the first Single Technology Matrix, only X-1 operationally valid tests on X-1 different Base Oils are required from an additional Single Technology Matrix if that second Matrix is combined and analyzed with the first. If a third Single Technology Matrix is combined with the first two, that third Matrix would need a minimum of X-2 operationally valid tests on X-2 different Base Oils. Any additional Single Technology Matrices combined and analyzed with the others would require a minimum of X-2 operationally valid tests on X-2 different Base Oils. Note that in this combined Multiple Technology Matrix, the extremes of the Base Oils in terms of Saturates, Sulfur, VI, ~~Volati~~Base Oil Viscosity, etc. must be represented. In addition, the maximum difference in Saturates, between two Base Oils sorted and listed by Saturates, can be no greater than the difference between the Base Oil with the highest Saturates and the Base Oil with the lowest Saturates, divided by 2 for the Second Technology only. The maximum difference in Saturates rule does not apply to the Third or subsequent added Technologies.

Note that a Multiple Technology Matrix developed within an API Category cannot extend to future API categories unless recommended by the API BOI/VGRA Task Force and approved by the API Lubricants Committee.

Technology in the Matrix	Minimum Number of Base Oils per Technology
First Technology	The Greater of 5 or (Defined Base Oil Variables + 2)
Second Technology	The Greater of 4 or (Defined Base Oil Variables + 1)
Third Technology and Subsequent Technologies	The Greater of 3 or (Defined Base Oil Variables)

STM.2.2 Interchange Criteria Based on Statistical Confidence Limits

Based on the Matrix and subsequent analysis, the predicted engine test result for the new Base Oil (Interchange Base Oil) must meet the performance specification of interest. In addition, the width of the 95% Confidence Interval (based upon the Student T distribution) for the predicted mean performance cannot be greater than the width of the 95% Confidence Interval (based upon the Normal Frequency Distribution and the current standard deviation of the test used in the calculation of severity adjustments) for an actual test result at the predicted performance level. Although the confidence intervals must be calculated in the appropriate transformed units, the comparison must be made in original units.

Given that the Interchange Criteria from the Matrix and statistical analysis are met, Base Oil Interchange may be used for the Technology from the Single Technology Matrix and/or the Technologies from the Multiple Technology Matrix. Base Oil Interchange may also be used for all Minor Formulation Modifications of these Technologies with the proper Level 1 and/or Level 2 Support as defined in Appendix H of the American Chemistry Council Product Approval Code of Practice.

The Matrix data and analysis must be shown to the Oil Marketer. A test result may be declared as an outlier and dropped from the analysis in accordance with STM.2.4. However, the minimum number of Base Oils per Technology criteria as outlined in STM.2.1 as well as all other analysis and confidence limit requirements must be met. The observation must be an outlier in order to be dropped from the analysis. While observations may be dropped according to the MTEP procedure to determine pass/fail, those observations may not be dropped from the Single Technology Matrix analysis unless declared an outlier according to STM 2.4.

Non-conformance through an audit will be subject to endorsement action as described in API 1509, Paragraph M.1 and Section 5—System Monitoring, Enforcement, and Conformance.

STM.2.3 Calculation of Width of 95% Confidence Interval

STM.2.3.1 Actual Test Result Confidence Interval Width

$2 \times Z_{0.05} \times \sigma$

Where:

$Z_{0.05} = 1.96$

σ = current standard deviation of the test used in the calculation of severity adjustments as defined in ASTM Test Monitoring Center Technical Memorandum 94-200

This is the shortcut method for calculating the width of the confidence interval. If a transformation is required, the shortcut method cannot be used. The actual confidence interval must be calculated for the predicted result for the oil on the transformed scale. This is done by adding and subtracting, $Z_{0.05} \times \sigma$, from the predicted test result, transforming the confidence limits back, and then subtracting the limits on the original scale.

STM.2.3.2 Predicted Test Result Confidence Interval Width

$2 \times t_{0.05,df} \times S \times \sqrt{h_i}$

Where:

$t_{0.05,df}$ = Student T distribution at the 95% Confidence Level with degrees of freedom equal to the degrees of freedom used in the estimate of the Root Mean Squared Error

S = Root Mean Squared Error (RMSE) from the Analysis

$h_i = x_i (X'X)^{-1} x_i'$

X = The factor matrix

x_i = A particular factor setting

This is the shortcut method for calculating the width of the confidence interval. If a transformation is required, the shortcut method cannot be used. The actual confidence interval must be calculated for the predicted result for the oil on the transformed scale. This is done by adding and subtracting, $t_{0.05,df} \times S \times \sqrt{h_i}$, from the transformed predicted result, transforming the confidence limits back, and then subtracting the limits on the original scale.

STM.2.4 Calculation of the Studentized Residual and Outlier Test

$e^*_i = e_i / (S(i) \times (\sqrt{1-h_i}))$

Where:

e^*_i = The Studentized Residual which is distributed closely to the Student T distribution. In this application, the ith observation may be declared as an outlier and removed from the analysis if e^*_i is greater than the one sided , $t_{0.025,df}$ with degrees of freedom equal to the degrees of freedom used in the estimate of the Root Mean Squared Error

e_i = The residual from the analysis, the actual test result for the ith observation minus the predicted test result for the ith observation

S(i) = Root Mean Squared Error (RMSE) from the Analysis with the ith observation removed from the analysis

$h_i = x_i (X'X)^{-1} x_i'$

X = The factor matrix

x_i = A particular factor setting

STM.3 Summary of Requirements for the Single Technology Matrix

- A new test is developed and introduced as a part of a new specification.
- The API BOI/VGRA Task Force reviews the new test, defines the critical Base Oil variables, and recommends use of the Single Technology Matrix.
- The API Lubricant Committee approves the critical Base Oil variables and use of the Single Technology Matrix for the new test.
- The Matrix Data Criteria must be met as defined in STM.2.1.
- All tests in the development of the Single Technology Matrix dataset and analysis must be registered according to the American Chemistry Council (ACC) Code of Practice.
- The technology must pass within a single test result or by using the appropriate Multiple Test Evaluation Procedure (MTEP) for each Base Oil in the Single Technology Matrix for all relevant test parameters.
- Test results or observations dropped for evaluation in an MTEP procedure may not be dropped from the Single Technology Matrix analysis unless declared an outlier according to STM.2.4.
- The width of the 95% Confidence Interval (based upon the Student T distribution) for the predicted mean performance based on the Single Technology Matrix model cannot be greater than the width of the 95% Confidence Interval (based upon the Normal Frequency Distribution and the current standard deviation of the test used in the calculation of severity adjustments) for an actual test result at the predicted performance level.
- Single Technology Matrix results must be included in ACC candidate data packages.
- Notification for use of Single Technology Matrix data for API License will be present on an Oil Marketer's API License Form and must be checked if used. An example is provided in STM.5.
- API Staff are directed to survey additive companies on a regular basis for Single Technology Matrix data. ~~also must be re~~

STM.4 Examples for Single Technology Matrix Approach

NOTE that not all of the required Base Oil variables are shown in the examples. Although not shown in these example settings, these Base Oil variables are still required for the Single Technology Matrix.

STM.4.1 Example 1

Technology	Base Oil	Volatility	Saturates	Test Result
1	1	High	60	8.1
1	2	Medium High	70	8.6
1	3	Medium	80	8.4
1	4	Medium Low	90	8.9
1	5	Low	100	9.2

Do we have Base Oil Interchange for Technology 1 in a new Base Oil that is 75% Saturates in a test where the pass limit is a minimum of 8.0?

The difference between the Base Oil with the highest Saturates and the Base Oil with the lowest Saturates, divided by 2 is equal to 20. No two consecutive Base Oils sorted by Saturate amount have a difference greater than 20.

The Model based on Saturates has an R^2 of 85% with a RMSE of 0.1889 with 3 degrees of freedom. The width of the 95% Confidence Interval for Technology 1 in the new Base Oil is 0.5702.

The Industry standard deviation for the test is 0.25, therefore, a reasonable and fair estimate of the width of the 95% Confidence Interval for a new actual test result is 0.98.

Since the width of the Confidence Interval from the Model is less than the width of the Confidence Interval for an actual test result, we have Base Oil Interchange.

STM.4.2 Example 2

Technology	Base Oil	Volatility	Saturates	Test Result
1	1	High	60	8.6
1	2	Medium High	70	8.4
1	3	Medium	80	9.2
1	4	Medium Low	90	8.1
1	5	Low	100	8.9

Do we have Base Oil Interchange for Technology 1 in a new Base Oil that is 75% Saturates in a test where the pass limit is a minimum of 8.0?

The difference between the Base Oil with the highest Saturates and the Base Oil with the lowest Saturates, divided by 2 is equal to 20. No two consecutive Base Oils sorted by Saturate amount have a difference greater than 20.

The Model is just the mean of the data with a RMSE of 0.4278 with 4 degrees of freedom. The width of the 95% Confidence Interval for Technology 1 in the new Base Oil is 0.5311.

The Industry standard deviation for the test is 0.25, therefore, a reasonable and fair estimate of the width of the 95% Confidence Interval for the new Candidate Oil is 0.98.

Since the width of the Confidence Interval from the Model is less than the width of the Confidence Interval for an actual test result, we have Base Oil Interchange.

STM.4.3 Example 3

Technology	Base Oil	Volatility	Saturates	Test Result
1	1	High	***60***	8.6
1	2	Medium High	***81***	8.4
1	3	Medium	85	9.2
1	4	Medium Low	90	8.1
1	5	Low	100	8.9

Do we have Base Oil Interchange for Technology 1 in a new Base Oil that is 75% Saturates in a test where the pass limit is a minimum of 8.0?

No. The difference between the Base Oil with the highest Saturates and the Base Oil with the lowest Saturates, divided by 2 is equal to 20. However, the difference in Saturates between the two Base Oils with the lowest amount of Saturates is 21. Since we have two consecutive Base Oils sorted by Saturate amount which have a difference greater than 20, we cannot analyze this Matrix for Base Oil Interchange.

STM.4.4 Example 4

Technology	Base Oil	Volatility	Saturates	Test Result
1	1	High	60	9.8
1	2	Medium High	70	7.1
1	2	Medium High	70	8.9
1	3	Medium	80	8.9
1	4	Medium Low	90	***5.0***
1	4	Medium Low	90	7.9
1	4	Medium Low	90	8.1
1	5	Low	100	9.4

Do we have Base Oil Interchange for Technology 1 in a new Base Oil that is 75% Saturates in a test where the pass limit is a minimum of 8.0?

The difference between the Base Oil with the highest Saturates and the Base Oil with the lowest Saturates, divided by 2 is equal to 20. No two consecutive Base Oils sorted by Saturate amount have a difference greater than 20.

The Model is just the mean of the data with a RMSE of 1.535 with 7 degrees of freedom. The width of the 95% Confidence Interval for Technology 1 in the New Base Oil is 2.5670.

The Industry standard deviation for the test is 0.25, therefore, a reasonable and fair estimate of the width of the 95% Confidence Interval for the new Candidate Oil is 0.98.

Since the width of the Confidence Interval from the Model is more than the width of the Confidence Interval for an actual test result, we DO NOT have Base Oil Interchange.

HOWEVER, we notice that the test result of 5.0 is unusually low. The Studentized Residual for this observation is 3.6 which is greater than the one sided , $t_{0.025,7}$ of 2.4. The observation may then be removed from the analysis since the number of base oils remains at five.

STM.4.5 Example 5

Technology	Base Oil	Volatility	Saturates	Test Result
1	1	High	60	9.8
1	2	Medium High	70	***7.1***
1	2	Medium High	70	***8.0***
1	3	Medium	80	8.9
1	4	Medium Low	90	5.0
1	4	Medium Low	90	7.9
1	4	Medium Low	90	8.1
1	5	Low	100	9.4

Do we have Base Oil Interchange for Technology 1 in a new Base Oil that is 75% Saturates in a test where the pass limit is a minimum of 8.0?

No. We do not have a pass in Base Oil Number 2 for this Technology. Note that we do have a pass in Base Oil Number 4 using MTAC.

STM.4.6 Example 6

Technology	Base Oil	Base Oil Characteristics	Test Result
1	1	Extreme High	8.1
1	2	Medium	8.6
1	3	Low	8.4
1	4	High	8.9
1	5	Extreme Low	9.2
2	1	Extreme High	8.9
2	6	Medium	9.2
2	7	High	9.6
2	5	Extreme Low	8.8

Do we have Base Oil Interchange for both Technology 1 and Technology 2 in a new Base Oil that falls between the extremes of the Base Oil Characteristics in a test where the pass limit is a minimum of 8.0?

The Model based on Technology has an R^2 of 32% with a RMSE of 0.3999 with 7 degrees of freedom. The width of the 95% Confidence Interval for Technology 1 in the new Base Oil is 0.846. The width of the 95% Confidence Interval for Technology 2 in the new Base Oil is 0.946.

The Industry standard deviation for the test is 0.25, therefore, a reasonable and fair estimate of the width of the 95% Confidence Interval for the new Candidate Oil is 0.98.

Since the width of the Confidence Interval from the Model is less the width of the Confidence Interval for an actual test result for both Technologies, we have Base Oil Interchange for both Technologies.

STM.5 Notification of Single Technology Matrix use to API

Notification of the use of Single Technology Matrix data for API License will be present on the Oil Marketer API License Form. The Oil Marketer will mark the appropriate check box(s) where support data exists for API BOI (check box 1) and/or from STM (check box 2). A subset of test choices will be present for the STM check boxes. The subset reflects which test(s) use STM support data. The STM support data will be provided to the Oil Marketer.

Example:

BOI Applied √

STM Tests Applied

Sequence IIIF	√
Sequence VG	no
Sequence IVA	no
Sequence VIII	no
Sequence VIB	no

STM.6 Requirement Amendments

STM.6.1 Engine Tests

STM.6.1.1 Sequence IIIF

The critical base oil variables are:

Base Oil Saturates (ASTM D 2007)
Base Oil Sulfur (API Approved Tests from Appendix E, Table E-1)
Base Oil Viscosity at 100°C (ASTM D 445)
Base Oil Viscosity Index (ASTM D 2270)
Noack Volatility of the fully formulated oil (finished oil) (ASTM D 5800)

The Single Technology Matrix must consist of at least 7 different Base Oils.

The relevant test parameters are:

Percent Viscosity Increase at 80 Hours
Weighted Piston Deposits
Average Piston Varnish
Average Camshaft plus Lifter Wear
Stuck Rings

Each technology in the STM must pass each relevant test parameter (within 1 test or by MTAC), in each Base Oil.

Confidence Intervals are applicable to each relevant test parameter except Average Camshaft plus Lifter Wear and Stuck Rings. ~~also must be re~~

Passenger Car Motor Oil (PCMO) technologies cannot be used with Heavy Duty Diesel Oil (HDDO) technologies in the same Multiple Technology Matrix. If a Multiple Technology Matrix is used it must consist of either all PCMO technology or all HDDO technology.

In addition to a Spread Requirement for the Base Oil Saturates in the matrix, there is a Spread Requirement for Base Oil Viscosity Index. The maximum difference in Base Oil Viscosity Index, between two base oils sorted and listed by Base Oil Viscosity Index, can be no greater than the difference between the base oil with the highest Base Oil Viscosity Index and the base oil with the lowest Base Oil Viscosity Index, divided by 2.

STM.6.1.1.1 Detailed Example using the Sequence IIIF

Base Oil	Base Oil Saturates D 2007	Base Oil Sulfur D 4294	Finished Oil Noack Volatility D 5800	Base Oil Viscosity @ 100°C D 445	Base Oil Viscosity Index D 2270	IIIF Percent Viscosity Increase	IIIF Weighted Piston Deposits	IIIF Average Piston Varnish	IIIF Average Cam plus Lifter Wear	IIIF Stuck Rings
1	75.4	0.2049	16.9	5.61	105	311.2	4.92	9.1	10.8	0
1	75.4	0.2049	16.9	5.61	105	190	4.44	9.4	7.0	0
2	68.3	0.3055	18.2	4.46	100	270.4	4.17	9.1	7.9	0
3	70.7	0.3132	15.8	4.39	102	108.3	3.76	8.9	6.8	0
3	70.7	0.3132	15.8	4.39	102	268	4.44	9.1	8.2	0
4	66.7	0.2171	16.6	4.86	104	111.4	5.20	9.2	7.7	0
5	73.9	0.3423	13.9	5.10	103	162.1	4.32	9.2	5.6	0
6	84.1	0.0740	14.7	5.47	102	67	4.2	9.4	5.1	0
7	61.2	0.3641	16.0	4.31	96	311.1	3.95	9.5	8.7	0
7	61.2	0.3641	16.0	4.31	96	212	3.97	9.5	5.7	0
New	72	0.25	16.2	5.00	102					

Do we have Base Oil Interchange for Technology 1 in a new Base Oil that is within the Ranges for Base Oil Saturates, Sulfur, Viscosity, Viscosity Index and Blend Volatility in the IIIF?

Step 1: Do we have enough Base Oils in the Matrix?

Yes. We have 7 Base Oils in the Matrix. The minimum number of tests is the number of critical Base Oil variables (Saturates, Sulfur, Viscosity at 100°C, and Viscosity Index) and the Noack ~~VI analyses. (The~~ Volatility of the fully formulated oil plus two.

Step 2: Do we have an approximate evenly distributed spread of Base Oils in the Matrix?

Yes. Maximum Saturates minus minimum Saturates divided by 2 equals 11.45 ((84.1-61.2)/2 = 11.45). This represents the maximum allowable difference in Saturates between two consecutive Base Oils sorted by Saturate level. The maximum difference from the actual Matrix is 8.7 (84.1 – 75.4 = 8.7). Maximum Base Oil Viscosity Index minus minimum Base Oil Viscosity Index divided by 2 equals 4.5 ((105-96)/2 = 4.5). This represents the maximum allowable difference in Base Oil Viscosity Index between two consecutive Base Oils sorted by Base Oil Viscosity Index. The maximum difference from the actual Matrix is 4 (100 – 96 = 4).

Step 3: Do we pass Technology 1 in every Base Oil in the Matrix?

Yes. Some pass with one test and some pass by MTAC.

Step 4: Do we predict a pass for Technology 1 in the new Base Oil based on the analysis of the Matrix?

Yes. The prediction for the new Base Oil is based on a very simple Model, the average over all other Base Oils since no Base Oil effects were evident with this technology over the range tested.

Base Oil	Base Oil Saturates D 2007	Base Oil Sulfur D 4294	Finished Oil Noack Volatility D 5800	Base Oil Viscosity @ 100°C D 445	Base Oil Viscosity Index D 2270	Model Predicted				
						IIIF Percent Viscosity Increase	IIIF Weighted Piston Deposits	IIIF Average Piston Varnish	IIIF Average Cam plus Lifter Wear	IIIF Stuck Rings
New	72	0.25	16.2	5.00	102	201	4.3	9.2	7.4	0

Step 5: Are there any outliers?

Possible outliers would include test results in which the Studentized Residuals exceed the Student T distribution at the one sided 0.025 percentile with degrees of freedom used in the calculation of the Root Mean Squared Error from the model, which is 9.

$t_{0.05,9} = 2.262$

Studentized Residuals

Test Number	IIIF Percent Viscosity Increase	IIIF Weighted Piston Deposits	IIIF Average Piston Varnish	IIIF Average Cam plus Lifter Wear
1	1.38	1.47	-0.71	***2.86***
2	-0.13	0.23	0.82	-0.20
3	0.81	-0.38	-0.71	0.32
4	-1.13	-1.45	-2.09	-0.32
5	0.78	0.23	-0.71	0.50
6	-1.08	***2.65***	-0.20	0.20
7	-0.45	-0.04	-0.20	-1.09
8	-1.79	-0.31	0.82	-1.48
9	1.38	-0.91	1.44	0.82
10	0.12	-0.86	1.44	-1.02

According to the calculations in STM.2.4, there are two possible outliers. These outliers should be investigated as to their possible cause. Given that an investigation has not yet taken place, the outliers are not removed in this example.

Step 6: Is the width of the 95% Confidence Interval (based upon the Student T distribution) for the predicted mean performance based on the Single Technology Matrix model less than or equal to the width of the 95% Confidence Interval (based upon the Normal Frequency Distribution and the current standard deviation of the test used in the calculation of severity adjustments) for an actual test result at the predicted performance level for all relevant test parameters?.

Yes. Calculations are presented below for Percent Viscosity Increase and summarized for all other test parameters.

Actual Test Result Confidence Interval:

Transform(Result) + $(Z_{0.05} \times \sigma)$ to Transform(Result) - $(Z_{0.05} \times \sigma)$

where:

Result = predicted test result for the new Base Oil based on the STM analysis
Transform = Industry transformation for this test; the inverse square root
(2) = current Industry standard deviation

$1/(\text{Result})^{1/2} + (1.96 \times 0.0129546)$ to $1/(\text{Result})^{1/2} - (1.96 \times 0.0129546)$

$1/(201)^{1/2} + (1.96 \times 0.0129546)$ to $1/(201)^{1/2} - (1.96 \times 0.0129546)$

0.0959 to 0.0451 in transformed units

95% Confidence Interval for the true mean of Percent Viscosity Increase based on a single actual test result using the Industry published standard deviation = 109 to 491

The width of the Confidence Interval in original units = 491 – 109 = 382

Predicted Test Result Confidence Interval Width:

Transform(Result) + $(t_{0.05,df} \times S \times \sqrt{h_i})$ to Transform(Result) - $(t_{0.05,df} \times S \times \sqrt{h_i})$

where:

Result = predicted test result for the new Base Oil based on the STM analysis
Transform = transformation used in this STM analysis; none
S = Root Mean Squared Error (RMSE) from this STM analysis
df = degrees of freedom used in calculating the RMSE

(Result) - (2.262 x 88.13112 x 0.3162) to (Result) + (2.262 x 88.13112 x 0.3162)

(201) - (63.0353) to (201) + (63.0353)

95% Confidence Interval for the true mean of Percent Viscosity Increase based on the data and analysis of the STM = 138 to 264

The width of the Confidence Interval in original units = 264 – 138 = 126

Summary of Confidence Interval Widths

IIIF Parameter	Actual Test Result Confidence Interval Width	Predicted Test Result Confidence Interval Width	Predicted Test Result CI Width Smaller?
Percent Viscosity Increase	382	126	YES
Weighted Piston Deposits	2.58	0.63	YES
Average Piston Varnish	0.86	0.29	YES
Average Cam plus Lifter Wear	NA	2.44	NA

Step 7: Do we have Base Oil Interchange for Technology 1 in a new Base Oil that is within the Ranges for Base Oil Saturates, Sulfur, Viscosity, Viscosity Index, and Blend Volatility in the Sequence IIIF?

Yes