AMERICAN CHEMISTRY COUNCIL PRODUCT APPROVAL CODE OF PRACTICE

APPENDIX F

Multiple Test Evaluation Procedures

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MULTIPLE TEST EVALUATION PROCEDURES

Introduction

Multiple Test Evaluation Procedures (MTEP) is any data-based approach for evaluation of the quality and performance of a candidate formulation where one or more tests have been conducted.

Purpose

The use of American Chemistry Council accepted MTEP ensures that all test sponsors base the performance representation of engine oils on a uniform treatment of data. This appendix provides detailed instructions on how to perform calculations using all of the relevant Multiple Test Evaluation Procedures and guidelines to use for specifications that do not indicate how to handle test data.

MTEP Guidelines

Passing limits in performance specifications may take a variety of forms, the two most common of which are a) a flat limit and b) a statistically-derived, tiered-set of limits. Many performance specifications also designate an MTEP method to be used in evaluating conformance of candidate test data with the passing limits. When this is the case, the MTEP technique designated in the specification shall be used. For specifications that do not include a designated MTEP, the method defined in this appendix shall be used.

All operationally valid and interpretable engine test results for a particular minor formulation modification must be included in the MTEP calculations, except as specified in Appendix E. All engine test data, test results, operational validity statements and other vital details, including the MTEP calculations, must be included in the Candidate Data Package.

Performance Specification Passing Limits

Flat Limit – The passing limit is expressed as a single value. The normal form would be as follows:

	Passing Limit
Rated Parameter	*a*

or, less often,

	1-Test Limit	2-Test Limit	3-Test Limit
Rated Parameter	*a*	*a*	*A*

where *a* is the required performance level irrespective of how many tests are run.

Tiered Limits – Passing limits are specified by a series of values, expressed as a function of the number of tests run. Typically, the limit would take the following form:

	1-Test Limit	2-Test Limit	3-Test Limit
Rated Parameter	*x*	*y*	*z*

Where, x to y to z increases or decreases depending on whether the test limit is a maximum or a minimum. The limits change as the number of tests increase because the confidence in the true performance of the oil increases as more tests are run. The differences between x and y and between y and z are derived statistically taking into account the precision of the test and the desired confidence level.

MTEP Calculations

There are many types of MTEP, but only three are described in this appendix. These are referred to as Multiple Test Acceptance Criteria (MTAC), Tiered Limit Method (TLM) and Merit Rating System (MRS). Care must be taken to understand each of these terms since they are sometimes used in other contexts where they may have different meanings.

MTAC – While MTAC is sometimes used broadly to refer to any technique for handling multiple test data, the term has been widely used in ASTM D4485 to refer to one specific technique, and that definition, as described below, is used in this appendix.

TLM – The term tiered limits is sometimes applied to both the method of deriving passing limits and to the method of handling data for comparison to tiered limits. In order to distinguish the two, tiered limits is used in this appendix as it applies to passing limits and TLM is used to refer to Tiered Limit Method.

MRS –A methodology which rewards test parameter performance better than the anchor point and penalizes test parameter performance poorer than the anchor point.

The following guidelines apply to all MTEP calculations:

1. Some rated parameters must be transformed during calculations. These are identified in the table in the next section. The specific form of the transformation may be found at the end of this appendix. Additional details may be found in the ASTM TMC Manual for LTMS (Technical Memorandum 94- 200).
2. The final adjusted test results as reported by the test laboratory are used in the MTEP calculations. These are the results that have been, if applicable, Outlier Screened, Industry adjusted, and severity adjusted.
3. Rounding in all calculations is to be carried out according to ASTM E29.
4. Two of the MTEP methods have provision for discarding a test result. In all cases, if at least one rated parameter of a test is discarded, the data for all rated parameters of that test are to be discarded. It should be noted that all data, including any discarded from MTEP calculations, must be included in the Candidate Data Package, per Appendix E.

Multiple Test Acceptance Criteria (MTAC)

One Test

1. Obtain the test result for the test parameter being evaluated.
2. Compare the result in step 1 to the passing limit in the specification. If limits in the specification are expressed as tiered limits, compare the result in step 1 to the one-test passing limit.

Two Tests

1. Obtain the test results in both tests for the test parameter being evaluated.
2. Transform data, if appropriate, for each test. Round transformed data to seven decimal places.
3. Total the values for the tests in step 2 [step 1 if there is no transform] and divide by two.
4. Transform the result in step 3 back to the original units, if applicable.
5. Round the value in step 4 [step 3 if there is no transform] to the same number of decimal places used for that parameter in the specification.

6. Compare the result in step 5 to the passing limit in the specification. If limits in the specification are expressed as tiered limits, compare the result in step 5 to the two-test passing limit.

Three or More Tests

1. Obtain the test results in all valid and interpretable tests for the test parameter being evaluated.
2. (Optional) Discard the results from any one test. Revert to the previous calculation procedure for two tests, or run a fourth test and repeat the three-test calculation deleting the outlier result.
3. Transform data, if appropriate, for the retained tests. Round transformed data to seven decimal places.
4. Total the values for all tests in step 3 [data remaining after step 2 if there is no transform] and divide by the total number of test results retained.
5. Transform the result in step 4 back to the original units, if applicable.
6. Round the value in step 5 [step 4 if there is no transform] to the same number of decimal places used for that parameter in the specification.
7. Compare the result in step 6 to the passing limit in the specification. If limits in the specification are expressed as tiered limits, compare the result in step 6 to the three-test passing limit.

Tiered Limit Method (TLM)

One Test

1. Obtain the test result for the test parameter being evaluated.
2. Compare the result in step 1 to the one-test passing limit in the specification. If limits in the specification are expressed as flat limits, compare the result in step 1 to the passing limit.

Two Tests

1. Obtain the test results in both tests for the test parameter being evaluated.
2. Transform data, if appropriate, for each test. Round transformed data to seven decimal places.
3. Total the values for the tests in step 2 [step 1 if there is no transform] and divide by two.
4. Transform the result in step 3 back to the original units, if applicable.
5. Round the value in step 4 [step 3 if there is no transform] to the same number of decimal places used for that parameter in the specification.
6. Compare the result in step 5 to the two-test passing limit in the specification. If limits in the specification are expressed as flat limits, compare the result in step 5 to the passing limit.

Three Tests

1. Obtain the test results in all (three) valid tests for the test parameter being evaluated.
2. Transform data, if appropriate, for each test. Round transformed data to seven decimal places.
3. Total the values for all tests in step 2 [step 1 if there is no transform] and divide by three.
4. (Optional) One test may be discarded if it meets certain outlier criteria. Compare the suspect test result with the result of step 3 using ASTM E178 and the outlier test determination values listed in ASTM D4485. If the suspect test result may be discarded, revert to the previous calculation procedure for two tests, or run a fourth test and repeat the three-test calculation deleting the outlier result.
5. Transform the result in step 3 back to original units, if applicable.
6. Round the value in step 5 [step 3 if there is no transform] to the same number of decimal places used for that parameter in the specification.

7. Compare the result in step 6 to the three-test passing limit in the specification. If limits in the specification are expressed as flat limits, compare the result in step 6 to the passing limit.

Merit Rating System (MRS)

Each parameter is assigned a Weight, an Anchor (or target), a Minimum and a Maximum (or cap). The method for calculating Merits is generally as follows:

- Performance for any parameter at the Anchor value, results in Merits equal to the parameter Weight.
- Test results for any parameter at, or better than the Minimum results in Merits equal to twice the parameter Weight.
- Test results for any parameter at the Maximum results in zero Merits
- Test results for any parameter worse than the Maximum is an automatic test failure no matter the performance on all other parameters.
- Merits between the Minimum and Anchor are proportionally awarded based upon the test result's proximity to the Anchor and the range between the Minimum and the Anchor.
- Similarly, Merits between the Maximum and Anchor are proportionally awarded based upon the test result's proximity to the Anchor and the range between the Anchor and the Maximum.
- Some specifications may use Secondary Maximums (or Secondary Caps). These more restrictive limits result in a mandatory fail if the test result is worse than the Secondary Maximum just like the primary Maximum. The Merits are still calculated based upon the primary Maximum as defined in ASTM D4485.

Multiple test evaluation consists of averaging the test results for each test parameter across multiple tests and then putting that result into the Merit calculation system. Specifics of each Merit Calculation are referenced in ASTM D4485.

MTEP Methods for Rated Parameters

As indicated in the "MTEP Guidelines" section above, when a specification includes requirements for handling data from multiple tests, the specified MTEP method shall be used for that specification. However, for any specification that does not specify an MTEP method (e.g., an ACEA specification); the technique specified in the following table shall be used.

Test	Type of MTEP	Parameter (Units) (note 1)
Sequence IIIF	MTAC MTAC MTAC MTAC (note 2)	*Kinematic Viscosity (% increase at 40°C*) Avg. piston skirt varnish (merits) Weighted piston deposit (merits) Screened avg. cam plus lifter wear (µm) Hot stuck rings
Sequence IIIFHD	MTAC	*Kinematic Viscosity @ 60 h* (% increase)
Sequence IIIG	MTAC MTAC MTAC (note 2)	*Kinematic Viscosity (% increase at 40°C*) Weighted piston deposit (merits) *Avg. cam plus lifter wear (µm)* Hot stuck rings
Sequence IIIGA	None	No MTEP, No MTAC

Sequence IIIGB	MTAC	Phosphorus retention (%)
Sequence IIIH	MTAC MTAC	*Kinematic Viscosity (% increase at 40° C)* Weighted piston deposit (merits)
Sequence IIIHA	MTAC	*MRV Viscosity (%)*
Sequence IIIHB	MTAC	Phosphorus retention (%)
Sequence IIIH60	MTAC	*Kinematic Viscosity (% increase at 40° C)*
Sequence IIIH70	MTAC MTAC M	*Kinematic Viscosity (% increase at 40° C)* *Weighted piston deposit (merits)* *Average Piston Skirt Varnish (merits)*
Sequence IVA	MTAC	Avg. cam wear (µm)
Sequence IVB	MTAC MTAC	*Avg Volume Loss Intake Bucket Lifter(mm^3)* *End of Test Iron (mg/kg)*
Sequence VG	MTAC MTAC MTAC MTAC MTAC (note 3)	Avg. engine sludge (merits) Rocker arm cover sludge (merits) Avg. piston skirt varnish (merits) Avg. engine varnish (merits) *Oil screen clogging (%)* Hot stuck compression rings
Sequence VH	MTAC MTAC MTAC MTAC (note 3)	Avg. engine sludge (merits) *Rocker arm cover sludge (merits)* Avg. piston skirt varnish (merits) Avg. engine varnish (merits) Hot stuck compression rings
Sequence VID	MTAC MTAC	FEI 2 (%) FEI SUM (%)
Sequence VIE	MTAC MTAC	FEI 2 (%) FEI SUM (%)
Sequence VIF	MTAC MTAC	FEI 2 (%) FEI SUM (%)
Sequence VIII	MTAC	Bearing weight loss (mg)
Sequence IX	MTAC MTAC	*Average Number of Preignitions* *Maximum Event*
Sequence X	MTAC	*Chain Wear Stretch (%)*
Caterpillar 1K	TLM TLM TLM TLM (note 4) (note 5)	WDK (demerits) Top Groove Fill (%) *Top Land Heavy Carbon (%)* Avg. Oil Consumption (g/kW·h) Piston Ring Sticking (yes or no) Piston, Ring and Liner Scuffing (yes or no)
Caterpill ar 1MPC (note 5)	MTAC (note 6) MTAC (note 4) (note 7)	WTD (demerits) Top Groove Fill (%) Piston Ring Sticking (yes or no) Piston, Ring and Liner Scuffing (yes or no)

Caterpillar 1N	TLM TLM TLM TLM(note 4) (note 5)	WDN (demerits) Top Groove Fill (%) *Top Land Heavy Carbon (%)* Oil Consumption (g/kWh) Piston Ring Sticking (yes or no) Piston, Ring and Liner Scuffing (yes or no)
Caterpillar 1P	TLM TLM TLM TLM TLM(note 5)	WDP (demerits) Top Groove Carbon (demerits) Top Land Carbon (demerits) *Avg. Oil Consumption (0-360h) (g/h)* *Final Oil Consumption (312-360h) (g/h)* Piston, Ring and Liner Scuffing (yes or no)
Caterpillar 1R	TLM TLM TLM TLM TLM(note 5)	WDR (demerits) Top Groove Carbon (demerits) Top Land Carbon (demerits) Avg. Initial (0-252 h) Oil Consumption (g/h) Avg. Final (432-504 h) Oil Consumption (g/h) Piston, Ring and Liner Scuffing (yes or no)
Caterpillar C13	MRS (note 4) (note 8)	Caterpillar C13 Merits *Delta Oil Consumption (g/*h) Average Top Land Carbon (Demerits) Average Top Groove Carbon (Demerits) *Second Ring Top Carbon (Demerits)*
Cummins ISM	MRS (note 8) TLM	Cummins ISM Merits Crosshead Weight Loss (mg) Injector Screw Wear (mg) *Oil Filter Pressure Delta (kPa)* Sludge (merits) Top Ring Weight Loss (mg)
Cummins ISB	TLM TLM	Average Camshaft Wear (µm) Average Tappet Weight Loss (mg)
Mack T-8	TLM TLM TLM	Viscosity Increase at 3.8% soot (cSt) Filter Plugging, Differential Pressure (kPa) Oil Consumption (g/kWh)
Mack T-8E	TLM TLM	Viscosity Increase at 3.8% soot (cSt) Relative Viscosity at 4.8% soot (unitless number)
Mack T-11	TLM	TGA % Soot @ 4.0 cSt increase @ 100° C TGA % Soot @ 12.0 cSt increase @ 100° C TGA % Soot @ 15.0 cSt increase @ 100° C
Mack T-12 (note 9)	TLM	Liner Wear, µm Top Ring Mass Loss, mg Lead Content at EOT, mg/kg
Mack T-12 (note 10)	MRS	Cylinder Liner Wear, µm Top Ring Mass Loss, mg *Delta Pb @ EOT, mg/kg* *Delta Pb 250 to 300 hours, mg/kh* *Oil Consumption, g/hr*
Mack T-12 (note 11)	MTAC (note 12)	Top Ring Mass Loss, mg Cylinder Liner Wear, µm

Volvo T-13	TLM	IR Peak at EOT, Abs., cm^{-1} Kinematic Viscosity Increase at 40°C, %
COAT	MTAC (note 12)	Average Aeration, 40h to 50h, %

Notes:

1. Units for parameters in italics are transformed. See next section for specific transformations.
2. The majority of retained tests must not have ring sticking (hot stuck).
3. The majority of retained tests must not have compression ring sticking (hot stuck).
4. None of the retained tests may have piston ring sticking.
5. If three or more operationally valid tests have been run, the majority of these tests must not have scuffing. Any scuffed tests are considered non-interpretable, and no data from these tests are to be used in MTEP calculations.
6. Two methods of calculating WTD are used, one for API Category CF and a different one for API Category CF-2. Both methods use MTAC for handling test results.
7. None of the retained tests may have piston, ring or liner scuffing.
8. The parameters used in calculating the Merit Rating value are shown.
9. This TLM applies to Mack T-12 used in API Category CH-4.
10. This MRS applies to Mack T-12 used in API Category CI-4 and CJ-4.
11. This MTAC applies to Mack T-12 used in API Category CK-4 and FA-4.
12. The MTAC provision to discard any valid test result is not applicable (See Appendix F, pg. F-3, Three or More Tests, Number 2)

List of Transformations of Rated Parameters

Test	Parameter	Transformation
Sequence IIIF	Viscosity, % Increase	1/square root of the % increase at 80 hours
Sequence IIIFHD	Viscosity, % Increase	LN (PVISH060)
Sequence IIIG	Viscosity, % Increase Avg. cam plus lifter wear	LN (PVISH100) LN (ACLW)
Sequence IIIH	Kinematic Viscosity (% increase at 40°C)	LN (PVIS)
Sequence IIIHA	MRV Viscosity (%)	LN (MRV)
Sequence IIIH60	Kinematic Viscosity (% increase at 40°C)	LN(PVISH060)
Sequence IIIH70	Kinematic Viscosity (% increase at 40°C)	LN(PVISH070)
Sequence IVB	Avg Volume Loss Intake Bucket Lifter End of Test Iron	Square root (AVLI) LN (FEWMEOT)
Sequence VG	Oil Screen Clogging	LN (oil screen clogging +1)
Sequence VH	Rocker Arm Cover Sludge	LN(10 – RCS)
Sequence IX	Average Number of Preignitions	Square root (AVPIE + 0.5)
Sequence X	Chain Wear Stretch (%)	LN(Chain Wear Stretch)

Caterpillar 1K	Top Land Heavy Carbon	LN (TLHC + 1)
Caterpillar 1N	Top Land Heavy Carbon	LN (TLHC + 1)
Caterpillar 1P	Average Oil Consumption Final Oil Consumption	LN (AOC) LN (FOC)
Caterpillar C13	Delta Oil Consumption (g/h) Second Ring Top Carbon	Square root (Delta OC) LN(R2TC)
Mack T-12	Delta Pb @ EOT Delta Pb 250 to 300 hours Oil Consumption	LN (DPbEOT) LN (DPb250300) LN (OC)
Cummins ISM	Oil Filter Pressure Delta	LN (OFDP)
Volvo T-13	Kinematic Viscosity Increase at 40°C	Square root (KV40)