ANNEX E—API BASE OIL INTERCHANGEABILITY GUIDELINES FOR PASSENGER CAR MOTOR OILS AND DIESEL ENGINE OILS

E.1 General

E.1.1 INTRODUCTION

Not all base oils have similar physical or chemical properties or provide equivalent engine oil performance in engine testing. During engine oil manufacture, marketers and blenders have legitimate needs for flexibility in base oil usage. The API Base Oil Interchangeability Guidelines (BOI) were developed to ensure that the performance of engine oil products is not adversely affected when different base oils are used interchangeably by engine oil blenders.

The API Base Oil Interchangeability Guidelines define the minimum prudent physical and engine testing necessary to ensure that engine oil performance is not adversely affected by substitution of one base oil for another. The Guidelines are based on actual engine test data, using different base oils, for both gasoline and diesel engine oil performance. The Passenger Car Motor Oil (PCMO) Guidelines were based on the use of API Service Category SG performance level additive technology and updated for API SH, SJ, SL, and SM quality levels. The Diesel Engine Oil Guidelines were based on the use of API Service Categories CD and CD-II performance level additive technologies and updated for CE, CF, CF-2, CG-4, CH-4, CI-4, and CJ-4 quality levels. At these relatively high levels of additive formulation, many of the base oil differences are "overwhelmed" by the additive performance package. For this reason, these guidelines should not be used to predict equivalent interchange at additive performance levels lower than API Service Categories SH and CD.

These Guidelines define the minimum acceptable level of testing for interchanging a base oil that every marketer must perform as a condition for obtaining a license.

It is understood that when comparing base stock properties, the precision of the methods listed in Table E-1 is taken into consideration.

Use of these Guidelines does not absolve the marketer of the responsibility for the actual performance of the licensed product sold in the aftermarket. The licensee must still ensure all of the engine and bench test results.

These Guidelines are subject to modifications based on new data, new or revised test methods, and/or new performance specifications. The current Guidelines must always be used.

E.1.2 DEFINITIONS

The definitions in E.1.2.1 through E.1.2.3 apply to these Guidelines.

E.1.2.1 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.

E.1.2.2 A *base stock slate* is a product line of base stocks that have different viscosities but are in the same base stock grouping and from the same manufacturer.

E.1.2.3 A *base oil* is the base stock or blend of base stocks used in an API-licensed oil.

E.1.3 BASE STOCK CATEGORIES

All base stocks are divided into five general categories:

a. Group I base stocks contain less than 90 percent saturates and/or greater than 0.03 percent sulfur and have a viscosity index greater than or equal to 80 and less than 120 using the test methods specified in Table E-1.

b. Group II base stocks contain greater than or equal to 90 percent saturates and less than or equal to 0.03 percent sulfur and have a viscosity index greater than or equal to 80 and less than 120 using the test methods specified in Table E-1.
c. Group III base stocks contain greater than or equal to 90 percent saturates and less than or equal to 0.03 percent sulfur and have a viscosity index greater than or equal to 120 using the test methods specified in Table E-1.
d. Group IV base stocks are polyalphaolefins (PAO). PAOs can be interchanged without additional qualification testing as long as the interchange PAO meets the original PAO manufacturer's specifications in physical and chemical properties. The following key properties need to be met in the substituted stock:

1) Kinematic viscosity at 100°C, 40°C, and -40°C
2) Viscosity index
3) NOACK volatility
4) Pour point
5) Unsaturates

e. Group V base stocks include all other base stocks not included in Group I, II, III, or IV.

Table E-1—Analytical Methods for Base Stock

Property	Test Method
Saturates	ASTM D2007
Viscosity index	ASTM D2270
Sulfur (use one listed method)	ASTM D1552 ASTM D2622 ASTM D3120 ASTM D4294 ASTM D4927

Note: The most recent version of each of the listed standards shall be used.

E.2 INTERCHANGE FOR PASSENGER CAR MOTOR OILS

E.2.1 GUIDELINES

E.2.1.1 Based on existing engine test data submitted to API, passing engine tests specified in Section E.2 are required for interchanging the base stock in an original API-licensed PCMO.

E.2.1.2 In any case where base stocks of more than one group are interchanged simultaneously, the most severe testing requirement applies.

E.2.1.3 Engine testing is not required when a single interchange base stock that meets the definition of Group I, Group II, Group III, or Group IV is used at less than or equal to 10 mass percent of the blended PCMO formulation. In some cases, higher percentages of Group III or Group IV may be substituted without further engine testing as specified in this annex or in the ACC Code (Appendix I, Guideline 5). The ACC Code should be followed for Group V.

E.2.1.4 The PCMO blended with the interchange base stock shall meet all physical and chemical specifications and bench test requirements for the appropriate API Service Category and/or ILSAC specification.

E.2.1.5 Base stocks approved under the provisions of these Guidelines may be commingled without further testing, consistent with provisions of Annex F.

E.2.1.6 Acceptable test methods for base stock and base oil blend properties are listed in Table E-1. It is understood that when comparing properties, the precision of the methods is taken into consideration. In the following tables, BOV refers to the Base Oil Blend Viscosity measured by ASTM D445.

E.2.1.7 For engine oils licensed by API against the ILSAC GF-5 standard, the licensee shall ensure that the ROBO or IIIGA data supporting the final formulation was produced in a formulation containing the pour point depressant and base stock(s) used in the licensed formulation.

E.2.2 REQUIREMENTS

E.2.2.1 API recognizes the importance of the Multiple Test Evaluation Procedures. Engine testing to support base oil interchangeability shall be in accordance with Annex N. These Guidelines shall be used in conjunction with the ACC Code.

E.2.2.2 Complete performance documentation is required for the original Passenger Car Motor Oils (PCMO). The detergent inhibitor (DI) and/or viscosity modifier (VM) remain unchanged when interchange base oils are tested, except as provided by the ACC Code. A base oil interchange obtained under these guidelines applies to a single PCMO formulation. In the event of a change in the DI and/or VM outside the ACC Code, these Guidelines shall be reapplied.

E.2.2.3 For the passenger car tests listed in Table E-2, these Guidelines may allow some testing relief. Check the Guidelines for each specific test before establishing the test program requirements for a specific oil formulation.

Table E-2—Tests for API S Category Base Oil Interchange

Test Name	ASTM	Annex E Reference	SH	SJ	SL	SM	SN	Energy Conserving	Resource Conserving	ILSAC GF-5
Sequence IID	D 5244	E.4.6	X	X						
Sequence IIIE	D 5533	E.2.2.4.1	X	X						
Sequence IIIF	D 6984	E.2.2.4.1	X	X	X					
Sequence IIIG/IIIGA/IIIGB	D 7320	E.2.2.4.1			X	X	X		X	X
Sequence IVA	D 6891	E.2.2.4.2	X	X	X	X	X			X
Sequence VE	D 5302	E.2.2.4.3	X	X	X					
Sequence VG	D 6593	E.2.2.4.3	X	X	X	X	X			X
Sequence VIA	D 6202	E.2.2.4.4						X		
Sequence VIB	D 6837	E.2.2.4.4						X		
Sequence VID		E.2.2.4.5							X	X
CRC L-38	D 5119	E.2.2.4.6	X	X						
Sequence VIII	D 6709	E.2.2.4.6	X	X	X	X	X			X
Ball Rust Test	D 6557	E.4.6	X	X	X	X	X			X
EOFT	D 6795	E.4.4	X	X	X	X	X			X
Filterability - EOWTT	D 6794	E.4.5		X	X	X	X			X
Homogeneity & Miscibility	D 6922	E.4.4	X	X	X	X	X			X
TEOST 33/33C	D 6335	E.4.2		X						X
TEOST MHT	D 7097	E.4.3			X	X	X			X
Aged Oil Low Temp. Vis. ROBO	D 7528	E.2.1.7					X			X
Elastomer Compatibility Std. Ref. Elastomers	D 7216	E.4.13							X	X

Note: X = Test methods where BOI is defined. Testing requirements can be found in API 1509 Annexes G and Q and/or ASTM D 4485.

E.2.2.4 Passenger car engine tests required for interchanging the base stock are given in E.2.2.4.1 through E.2.2.4.5. The BOI Guidelines vary according to the API base oil group and amount of the base stocks used in the original test oil and the candidate oil formulations. All percentages are mass percent of the total formulation unless otherwise noted. The data set used to establish the BOI Guidelines involving Group III base oil is based on a base oil VI range up to 126 VI, within the precision of the test.

E.2.2.4.1 For Sequence IIIE, IIIF, IIIFHD, IIIG and IIIGA tests required for interchanging the base stock, specific requirements are given in Table E-3. Single Technology Matrix (STM) is an alternate approach to BOI for Sequence IIIF, IIIFHD, IIIG, and IIIGA (see Annex R).

Additionally, once five passing IIIGB tests have been demonstrated on a unique technology (a Unique Technology is a single additive package (DI) at a constant treat rate), then no additional sequence IIIGB testing is required for that unique technology.

Table E-3—Sequence IIIE, IIIF, IIIFHD, IIIG, IIIGA and IIIGB Tests Required for Interchanging the Base Stock

Base Stock in Original Test Oil	Interchange Base Stock				
	Group I	Group II	Group III	Group IV	Group V
Group I	Required	Required	≤ 30% Not Required ----- > 30% Required	≤ 30% Not Required ----- > 30% Required	Required
Group II	Required	Required	≤ 30% Not Required ----- > 30% Required	≤ 30% Not Required **-----** > 30% Required	Required
Group III	Required	Required	Required	≤ 30% Not Required ----- > 30% Required	Required
Group IV	Required	Required	≤ 30% Not Required ----- > 30% Required	Not Required provided the interchange Group IV meets the original manufacturer's specifications in all physical and chemical properties	Required
Group V	Required	Required	Required	Required	Required

E.2.2.4.2 For Sequence IVA tests required for interchanging the base stock, specific requirements are given in Table E-4.

Table E-4—Sequence IVA Tests Required for Interchanging the Base Stock

Base Stock in Original Test Oil	Interchange Base Stock				
	Group I	Group II	Group III	Group IV	Group V
Group I	Not Required if BOV @ 100°C ≥ original	Not Required if BOV @ 100°C ≥ original	≤30% Not Required ----- > 30% Not Required if BOV @ 100°C ≥ original	≤30% Not Required ----- > 30% and ≤ 50% Not Required if BOV @ 100°C ≥ original ----- > 50% Required	Required
Group II	Not Required if BOV @ 100°C ≥ original	Not Required if BOV @ 100°C ≥ original	≤30% Not Required ----- > 30% Not Required if BOV @ 100°C ≥ original	≤30% Not Required ----- > 30% and ≤ 50% Not Required if BOV @ 100°C ≥ original ----- > 50% Required	Required
Group III	Not Required if BOV @ 100°C ≥ original	Not Required if BOV @ 100°C ≥ original	Not Required if BOV @ 100°C ≥ original	≤ 30% Not Required if BOV @ 100°C ≥ original ----- > 30% Required	Required
Group IV	Required	Required	≤ 30% Not Required ----- > 30%Required	Not Required provided the interchange Group IV meets the original manufacturer's specifications in all physical and chemical properties	Required
Group V	Required	Required	Required	Required	Required

Note: BOV refers to the base oil blend viscosity measured by ASTM D445.

E.2.2.4.3 For Sequence VE/VG tests required for interchanging the base stock, specific requirements are given in Table E-5.

Table E-5—Sequence VE/VG Tests Required for Interchanging the Base Stock

Base Stock in Original Test Oil	Interchange Base Stock				
	Group I	Group II	Group III	Group IV	Group V
Group I	Not Required if sulfur ≤ and saturates ≥ original	Not Required	Not Required	≤50% Not Required ----- > 50% Required	Required
Group II	Required	Not Required if saturates ≥ original	Not Required	≤50% Not Required ----- > 50% Required	Required
Group III	Required	Required	Not Required	Required	Required
Group IV	Required	Required	Required	Not Required provided the interchange Group IV meets the original manufacturer's specifications in all physical and chemical properties	Required
Group V	Required	Required	Required	Required	Required

E.2.2.4.4 For Sequence VIA/VIB tests required for interchanging the base stock, specific requirements are given in Table E-6.

Table E-6—Sequence VIA/VIB Tests Required for Interchanging the Base Stock

Base Stock in Original Test Oil	Interchange Base Stock				
	Group I	Group II	Group III	Group IV	Group V
Group I	Not Required if CCS viscosity and HTHS viscosity of candidate ≤ corresponding original test oil values	Not Required if CCS viscosity and HTHS viscosity of candidate ≤ corresponding original test oil values	Required	Required	Required
Group II	Not Required if CCS viscosity and HTHS viscosity of candidate ≤ corresponding original test oil values	Not Required if CCS viscosity and HTHS viscosity of candidate ≤ corresponding original test oil values	Required	Required	Required
Group III	Not Required if CCS viscosity and HTHS viscosity of candidate ≤ corresponding original test oil values	Not Required if CCS viscosity and HTHS viscosity of candidate ≤ corresponding original test oil values	Not Required if CCS viscosity, HTHS viscosity and base oil blend VI of candidate ≤ corresponding original test oil values	Required	Required
Group IV	Required	Required	Required	Not Required provided the interchange Group IV meets the original manufacturer's specifications in all physical and chemical properties	Required
Group V	Required	Required	Required	Required	Required

E.2.2.4.5 For Sequence VID tests required for interchanging the base stock, specific requirements are given in Table E-7.

Table E-7—Sequence VID Tests Required for Interchanging the Base Stock

Base Stock in Original Test Oil	Interchange Base Stock				
	Group I	Group II	Group III	Group IV	Group V
Group I	Required	Required	Required	Required	Required
Group II	Required	Not Required if HTHS@100°C (D6616) ≤ original. If HTHS@100°C > the original, see Equations E 1.0		Required	Required
Group III	Required			Required	Required
Group IV	Required	Required	Required	Not Required provided the interchange Group IV meets the original manufacturer's specification in all physical and chemical properties E.1.3.d	Required
Group V	Required	Required	Required	Required	Required

Equation E.1.0

If the HTHS@100°C of the candidate oil is > the HTHS@100°C of the original passing oil, testing is not required if both equations are true:

$H_{Candidate} \leq H_{Original} + \{(FEIsum_{Limit} - FEIsum_{Original}) / -0.485\} + (H_{Original} * R)$

$H_{Candidate} \leq H_{Original} + \{(FEI2_{Limit} - FEI2_{Original}) / -0.227\} + (H_{Original} * R)$

Where:

$H_{Candidate}$ is the HTHS@100°C of the candidate oil as measured by ASTM D6616
$H_{Original}$ is the HTHS@100°C of the original tested oil as measured by ASTM D6616
$FEIsum_{Limit}$ is the FEI sum passing limit for the original tested viscosity grade
$FEIsum_{Original}$ is the FEIsum ($FEI1_{Orginal} + FEI2_{Orginal}$) result of the original tested oil
-0.485 is the FEIsum coefficient from the Seq. VID industry matrix model
$FEI2_{Limit}$ is the FEI2 passing limit for the original tested viscosity grade
$FEI2_{Original}$ is the FEI2 result of the original tested oil
-0.227 is the FEI2 coefficient from the Seq. VID industry matrix model
R is the reproducibility as reported in the most recent version of ASTM D6616.

Note:

R = 0.035 (3.5%) for ASTM D6616-07
The range of HTHS@100°C used to develop the Seq. VID industry matrix model was 5.44 to 7.68 cP.

E.2.2.4.6 For CRC L-38/Sequence VIII tests required for interchanging the base stock, specific requirements are given in Table E-8.

Note: These BOI Guidelines apply only to bearing weight loss.

Table E-8—CRC L-38/Sequence VIII Tests Required for Interchanging the Base Stock

Base Stock in Original Test Oil	Interchange Base Stock				
	Group I	Group II	Group III	Group IV	Group V
Group I	Not Required	Not Required	Not Required	Not Required	Required
Group II	Not Required	Not Required	Not Required	Not Required	Required
Group III	Not Required	Not Required	Not Required	≤ 30% Not Required ----- > 30% Required	Required
Group IV	Required	Required	≤ 30% Not Required ----- > 30% Required	Not Required provided the interchange Group IV meets the original manufacturer's specifications in all physical and chemical properties	Required
Group V	Required	Required	Required	Required	Required

E.2.3 EXAMPLES

E.2.3.1 General

The API Base Oil Interchangeability Guidelines must be used in conjunction with the API Guidelines for SAE Viscosity-Grade Engine Testing (see Annex F). When the original approved grade contains less than or equal to 10 mass percent of the interchange base stock, the higher grade must be tested if it contains greater than 10 percent of the interchange base stock in the formulation.

E.2.3.2 Example 1

In this example, a marketer wants to replace the Group I, 200N base stock in the marketer's SAE 5W-30 and 10W-30 grades with a new Group I, 200N base stock from another manufacturer. The SAE 5W-30 grade is a fully approved API SJ product made with a Group I base oil mix of 10 percent or less 200N and 90 percent or more 100N. The SAE 10W-30 grade is an approved API SJ product by viscosity grade read-across made with a Group I base oil mix of 65 percent 200N and 35 percent 100N. Both grades use the same Group I base stock slate.

The marketer needs to take the following steps:

a. Check the API Guidelines for SAE Viscosity-Grade Engine Testing. An SAE 5W-30 grade may be read across to an SAE 10W-30 grade when the same base stock slate is used in both grades.
b. Check the API Base Oil Interchangeability Guidelines. Since the SAE 5W-30 product contains less than or equal to 10 percent 200N base stock in the base oil and the interchange base stock is from the same group, no engine testing is required for the interchange. However, testing is required on the SAE 10W-30 product (the higher viscosity grade with a higher level of 200N). According to the API Base Oil Interchangeability Guidelines, the marketer must obtain a passing Sequence IIIE to interchange one Group I, 200N base stock with another. The marketer may also need to obtain a passing Sequence VE if the requirements of Table E-5 are not met.

E.2.3.3 Example 2

In this example, a marketer wants to replace the Group I, 100N and 200N base stocks in its approved SAE 5W-30 and 10W-30 grades with Group I 100N and 200N base stocks from another source. The SAE 5W-30 grade is a fully approved API SJ product made with a Group I base oil mix of 10 percent or less 200N and 90 percent or

more 100N. The SAE 10W-30 grade is an approved API SJ product by viscosity read-across made with a Group I base oil mix of 65 percent 200N and 35 percent 100N. Both grades use the same base stock slate.

The marketer needs to take the following steps:

a. Check the API Guidelines for SAE Viscosity-Grade Engine Testing. As in the previous example, an SAE 5W-30 grade may be read across to an SAE 10W-30 grade when the same base stock slate is used.
b. Check the API Base Oil Interchangeability Guidelines. If the marketer viewed the grades independently, the SAE 5W-30 product would require testing because of the level of 100N base oil, and the 10W-30 product would require testing because of the level of 200N. However, because the API Guidelines for SAE Viscosity-Grade Engine Testing permit read across from the tested SAE 5W-30 grade to the SAE 10W-30 grade when the same base stock slate is used in both grades, only the SAE 5W-30 grade would need to be tested. As in Example 1, the marketer must run a Sequence IIIE and may have to run a Sequence VE in the new base stocks.

E.2.3.4 Example 3

In this example, a marketer wants to interchange the source (brand) of Group I bright stock in an SAE 30 grade. This interchange involves a fully approved API SJ SAE 5W-30 grade made with a Group I base oil mix of 90 percent 100N and 10 percent 200N. The SAE 30 grade is a fully approved API SJ product by viscosity read-across made with a Group I base oil mix of 90 percent 200N and 10 percent bright stock. Both grades use the same base stock slate.

The marketer needs to take the following steps:

a. Check the API Guidelines for SAE Viscosity-Grade Engine Testing. An SAE 5W-30 API SJ product may be read across to an SAE 30 grade if the same base stock slate is used.
b. Check the API Base Oil Interchangeability Guidelines. Base stock slate sources at 10 percent or less of the formulation may be interchanged with other base stock sources without further testing.

E.2.3.5 Example 4

In this example, a marketer wants to interchange the source (brand) of Group I bright stock in an SAE 30 grade. The SAE 30 grade is a fully approved API SJ product by viscosity read-across from an SAE 5W-30 grade. The SAE 30 contains 15 percent bright stock in the finished formulation. Both grades use the same base stock slate.

The marketer needs to check the API Base Oil Interchangeability Guidelines. Since the bright stock is present at greater than 10 percent, the Sequence IIIE and possibly the Sequence VE must be run in the SAE 30 grade with the new bright stock.

E.2.3.6 Example 5

In this example, a marketer wants to interchange the source (brand) of Group II, 200N base stock used in a fully approved API SJ SAE 10W-30 grade. The product is made with a Group II base oil mix of 80 percent 100N and 20 percent 200N. The base oil mix meets the Group II requirements of less than or equal to 0.03 percent sulfur and greater than or equal to 90 percent saturates.

The marketer needs to check the API Base Oil Interchangeability Guidelines. The 200N oil is present at greater than 10 percent in the original formulation, so testing is required. To make the interchange, the marketer must run a Sequence IIIE and may have to run a VE.

E.2.3.7 Example 6

In this example, a marketer wants to make an SAE 40 grade from the same base stock slate used in a fully approved API SJ SAE 5W-30 grade. The SAE 5W-30 grade is made with a Group I base oil mix of 90 percent 100N and 10 percent 200N and is formulated with a nondispersant viscosity modifier. The SAE 40 grade contains 80 percent 300N and 20 percent bright stock in the base oil.

The marketer needs to take the following steps:

a. Check the API Guidelines for SAE Viscosity-Grade Engine Testing. A non-Energy Conserving API SJ SAE 5W-30 product may be read across to an SAE 40 grade without further testing (note that if the SAE 5W-30 were formulated with a dispersant viscosity modifier, a Sequence VE test would be required).
b. Check the API Base Oil Interchangeability Guidelines. Since the SAE 40 grade has the same source (brand) base oils, no interchange is taking place. No further testing is required.

E.2.3.8 Example 7

In this example, a marketer wants to exchange the Group II, 100N base stock in the base oil mix of a fully approved API SL SAE 5W-30 grade for a Group I, 100N base stock. The SAE 5W-30 grade is made with a base oil mix of 50 percent Group II, 100N, and 50 percent Group I, 150N.

The marketer needs to check the API Base Oil Interchangeability Guidelines. To exchange a Group II for a Group I oil, the marketer needs to run the Sequence VG, IIIF (or Sequence IIIG per ASTM D 4485) and IVA tests and, if Energy Conserving is desired for API Service Category SL, the Sequence VIB test. Check Table E-6 to see if read-across is allowed.

Note: If both the 100N and 150N base stocks were interchanged for new Group I base stocks, the most severe testing requirements [namely, Sequence VG, IIIF (or Sequence IIIG per ASTM D4485] and IVA tests and, if Energy Conserving is desired for API Service Category SL, the Sequence VIB test) would apply.

E.2.3.9 Example 8

In this example, a marketer wants to change from a full Group IV and Group V slate of base stocks to a partly Group IV (PAO) slate for a PCMO. The marketer has two products involved in this interchange: a fully approved API SL SAE 10W-30 grade with a Group IV and Group V base oil mix (Group IV/V) that contains PAO and ester fluids and a fully approved SAE 10W-30 grade with a Group I base oil mix that contains 60 percent 100N and 40 percent 250N. Both oils contain the same DI additive treat and VM.

The marketer needs to check the API Base Oil Interchangeability Guidelines. Exchange between a full Group IV/V and Group I requires full approval testing. This has been done for the Group I and the Group IV/V products. Since both the Group I stocks and the full Group IV/V blend are approved, mixtures of the two can be used without further testing.

E.2.3.10 Example 9

In this example, a marketer wants to change one PAO (Group IV) in a PAO-plus-ester SAE 5W-30 grade. The fully-approved API SL/Energy Conserving/ILSAC GF-3 SAE 5W-30 grade is made with a mix of Group IV and Group V base oils consisting of 4-centistoke PAO and ester fluids.

No testing is required for the substitute 4-centistoke PAO, provided it meets the same physical and chemical specifications as the original 4-centistoke PAO.

E.2.3.11 Example 10

In this example, a marketer wants to add 15 percent more Group IV base stock to a licensed API SJ SAE multi-viscosity grade made with a mix of 15 percent Group IV base stock, 65 percent Group II base stock, and 20 percent DI/VM additive treat. The new formulation contains 30 percent Group IV base stock, 50 percent Group II base stock, and 20 percent DI/VM additive treat.

No engine testing (except for the Sequence VIA if the oil is energy conserving) is required for the new formulation since the BOI tables allow up to 30 percent maximum of Group IV base stock in the finished oil formulation without further testing.

E.2.3.12 Example 11

In this example, a marketer wants to add 30 percent more Group IV base stock to a licensed API SL/Energy Conserving SAE multi-viscosity grade made with a mix of 20 percent Group IV base stock, 60 percent Group II base stock, and 20 percent DI/VM additive treat. The new formulation contains 50 percent Group IV base stock, 30 percent Group II base stock, and 20 percent DI/VM additive treat.

According to the tables, Sequence IIIF and VIB engine testing is required when the total Group IV content is increased to 50 percent. If the total Group IV content were increased to above 50 percent, complete engine testing except for the Sequence VIII would be required for the new formulation.

E.2.3.13 Example 12

In this example, a marketer wants to know how much more Group IV base stock can be added to an API SJ- or SL-licensed SAE multi-viscosity grade made with a mix of 24 percent Group IV base stock, 56 percent Group II base stock, and 20 percent DI/VM additive treat without further engine testing.

Since the tables allow up to 30 percent maximum of Group IV base stock in the finished oil formulation without further testing when interchanging Group II with Group IV, the marketer could add 6 percent more Group IV base stock without further engine testing. The new formulation would contain 30 percent Group IV base stock, 50 percent Group II base stock, and 20 percent DI/VM additive treat.

E.2.3.14 Example 13

For Sequence VID BOI (Table and Equation) the following example is applicable.

A passing oil using any combination of API Group II and/or III base stocks is being read to a candidate formulation of equivalent or lower HTHS using different API Group II or III base stocks.

A candidate oil using the same technology (Performance Package and Viscosity Modifier) is formulated to the same viscosity grade using different Group II or Group III base stocks. The candidate oil has an HTHS @100°C of 6.44 cP.

The Base Oil Interchange is allowed to the candidate oil because the HTHS@100°C value of the candidate oil is less than the original tested oil and the base stocks involved are combinations of Group II and Group III.

E.2.3.15 Example 14

For Sequence VID BOI (Table and Equation) the following example is applicable.

A passing oil using any combination of API Group II and/or III base stocks is being read to a candidate formulation of higher HTHS using different API Group II, III base stocks.

The original formulated oil using a Group II or Group III base stock(s) (or mixture) is run in the Sequence VID and achieves a passing FEIsum and FEI2. The oil has an HTHS @100°C of 6.52 cP. The passing result is 0.40 above the passing specification for FEIsum (i.e. FEIsumLimit – FEIsumOriginal = -0.40) and 0.16 above the passing specification for FEI2. (i.e. FEI2Limit – FEI2Original = -0.16)

A candidate oil using the same technology (Performance Package and Viscosity Modifier) is formulated to the same viscosity grade using different Group II or Group III base stocks. The candidate oil has an HTHS @100°C of 7.40 cP. The reproducibility (R) for D6616-07 is 0.035 (3.5%).

The allowable Base Oil Interchange is assessed using Equations E 1.0 as follows:

A = FEIsum HTHS = 6.52 + (-0.40/-0.485) + 6.52 x 0.035 = 7.57 cP
B = FEI2 HTHS = 6.52 + (-0.16/-0.227) + 6.52 x 0.035 = 7.45 cP

The Base Oil Interchange is limited by the lesser of A and B which is 7.45 cP. The candidate oil HTHS@100 °C is 7.40 and is less than 7.45. Therefore, the Base Oil Interchange is allowed.
No further allowance for precision of HTHS measurement is permitted.

E.2.3.16 Example 15

For Sequence VID BOI (Table and Equation) the following example is applicable.

A passing oil using any combination of API Group II and/or III base stocks is being read to a candidate formulation of higher HTHS using different API Group II, III base stocks.
The original formulated oil using a Group II or Group III base stock(s) (or mixture) is run in the Sequence VID and achieves a passing FEIsum and FEI2.. The oil has an HTHS @100°C of 6.52 cP. The passing result is within the lower rounding of passing specification, i.e. -0.04 below the passing specification for FEIsum (i.e. FEIsumLimit – FEIsumOriginal = +0.04) and 0.10 above the passing specification for FEI2. (i.e. FEI2Limit – FEI2Original = -0.10)

A candidate oil using the same technology (Performance Package and Viscosity Modifier) is formulated to the same viscosity grade using different Group II or Group III base stocks. The candidate oil has an HTHS @100°C of 7.02 cP. The reproducibility (R) for D6616-07 is 0.035 (3.5%).

The allowable Base Oil Interchange is assessed using Equations E 1.0 as follows:

A = FEIsum HTHS = 6.52 + (+0.04/-0.485) + 6.52 x 0.035 = 6.67 cP
B = FEI2 HTHS = 6.52 + (-0.10/-0.227) + 6.52 x 0.035 = 7.19 cP

The Base Oil Interchange is limited to the lesser of A or B, which is an HTHS @100°C of 6.67 Cp. The candidate oil HTHS is 7.02 cP and is greater than 6.67 cP so the Base Oil Interchange is NOT allowed.
No further allowance for precision of HTHS measurement is permitted.

E.2.3.17 Additional Examples

Additional examples on applying Base Oil Interchangeability Guidelines may be noted in Annex O.

E.3 INTERCHANGE FOR HEAVY DUTY ENGINE OILS

E.3.1 GUIDELINES

E.3.1.1 Based on existing engine test data submitted to API, passing engine tests specified in Section E.3 are required for interchanging the base stock in an original API-licensed Heavy Duty Engine Oil (HDEO).

E.3.1.2 In any case where base stocks of more than one group are interchanged simultaneously, the most severe testing requirement applies.

E.3.1.3 Engine testing is not required when a single interchange base stock that meets the definition of Group I, Group II, Group III, or Group IV is used at less than or equal to 10 mass percent of the blended HDEO formulation. In some cases, higher percentages of Group III or Group IV may be substituted without further engine testing as specified in this annex or in the ACC Code (Appendix I, Guideline 5). The ACC Code should be followed for Group V.

E.3.1.4 The heavy duty engine oil blended with the interchange base oil shall meet all physical and chemical specifications required for the appropriate API Service Category.

E.3.1.5 Base stocks approved under the provisions of these Guidelines may be commingled without further testing, consistent with Annex F.

E.3.1.6 Acceptable test methods for base stock and base oil blend properties are listed in Table E-1. It is understood that when comparing properties, the precision of the methods is taken into consideration. In the following tables, BOV refers to the Base Oil Blend Viscosity measured by ASTM D445.

E.3.2 REQUIREMENTS

E.3.2.1 API recognizes the importance of the Multiple Test Evaluation Procedures. Engine testing to support base oil interchangeability shall be in accordance with Annex N. These Guidelines shall be used in conjunction with the ACC Code.

E.3.2.2 Complete performance documentation is required for the original HDEOs. The detergent inhibitor (DI) and/or viscosity modifier (VM) remain unchanged when interchange base oils are tested, except as provided by the ACC Code. A base oil interchange obtained under these guidelines applies to a single HDEO formulation. In the event of a change in the DI and/or VM outside the ACC Code, these Guidelines shall be reapplied.

E.3.2.3 When a base stock or slate of base stocks is to be changed in a number of different viscosity grades containing a single Heavy Duty engine oil formulation, these Guidelines shall be used in conjunction with Annex F, except when the recommended grade for testing contains less than or equal to 10 mass percent of the interchange base stock in the formulation. In this case, the next higher viscosity grade shall be tested.

E.3.2.4 For HDEO tests listed in Table E-9, the BOI Guidelines may allow for some testing relief. Check Guidelines for each specific test before establishing the test program requirements for a specific oil formulation.

Table E-9—Tests for API C Category Base Oil Interchange

Test Name	ASTM	Annex E Reference	CF	CF-2	CG-4	CH-4	CI-4	CI-4 w/CI-4 PLUS	CJ-4
Sequence IIIF/IIIFHD	D 6984	E.2.2.4.1			X	X	X	X	X
Sequence IIIG	D 7320	E.2.2.4.1			X	X	X	X	X
CRC L-38	D 5119	E.2.2.4.5	X	X	X				
Sequence VIII	D 6709	E.2.2.4.5	X	X	X				
Caterpillar 1M-PC	D 6618	E.3.2.5.1	X	X					
Caterpillar C13	—	E.3.2.5.16							X
Caterpillar 1K	D 6750 (1K)	E.3.2.5.3				X	X	X	
Caterpillar 1N	D 6750 (1N)	E.3.2.5.4			X		X	X	X
Caterpillar 1P	D 6681	E.3.2.5.6				X	X	X	
Caterpillar 1R	D 6923	E.3.2.5.5					X	X	
Engine Oil Aeration Test	D 6894	E.3.2.5.11			X	X	X	X	X
Cummins ISM	D 7468	E.3.2.5.13					X	X	X
Cummins ISB	D 7484	E.3.2.5.13							X
Cummins M11	D 6838	E.3.2.5.12				X			
Cummins M11 EGR	D 6975	E.3.2.5.12					X	X	
Detroit Diesel 6V92TA	D 5862	E.3.2.5.2		X					
Mack T-8	D 5967	E.3.2.5.8			X				
Mack T-8E	D 5967	E.3.2.5.8				X	X	X	
Mack T-9	D 6483	E.3.2.5.7				X			
Mack T-10	D 6987/ D 6987M	E.3.2.5.9				X	X	X	
Mack T-10A	75 hr. used oil in D 4684	E.4.7					X	X	
Mack T-11	D 7156	E.3.2.5.15						X	X
Mack T-11A	D 6896	E.4.10						X	X

Mack T-12	D 7422	E.3.2.5.14					X	X	X
Roller Follower Wear Test	D 5966	E.3.2.5.10			X	X	X	X	X
Cummins HTCBT	D 6594	E.4.11				X	X	X	X
Elastomer Compatibility CI-4	D 7216	E.4.8					X	X	
Elastomer Compatibility CJ-4	D 7216	E.4.9							X

Note: X = Test methods where BOI is defined. Testing requirements can be found in API 1509 Annexes G and Q and/or ASTM D 4485.

E.3.2.5 Heavy duty engine tests required for interchanging the base stock are given in E.3.2.5.1 through E.3.2.5.16. The BOI guidelines vary according to the API base oil group and amount of the base stocks used in the original test oil and the candidate oil formulations. All percentages are mass percent of the total formulation unless otherwise noted. The data set used to establish the BOI guidelines involving Group III base oil is based on a base oil VI range up to 126 VI, within the precision of the test.

E.3.2.5.1 For Caterpillar 1M-PC tests required for interchanging the base stock, specific requirements are given in Table E-10.

Note: Caterpillar 1M-PC testing is waived if the lubricant meets CH-4, CI-4 and/or CJ-4 interchange requirements.

Table E-10—Caterpillar 1M-PC Tests Required for Interchanging the Base Stock

Base Stock in Original Test Oil	Interchange Base Stock				
	Group I	Group II	Group III	Group IV	Group V
Group I	Required	Required	Required	Required ----- ≤30% Not Required for API CF if original oil also meets API SJ	Required
Group II	Not Required	Not Required	Required	Required ----- ≤30% Not Required for API CF if candidate oil meets API SJ	Required
Group III	Required	Required	Not Required	Required	Required
Group IV	Required	Required	Required	Not Required provided the interchange Group IV meets the original manufacturer's specifications in all physical and chemical properties	Required
Group V	Required	Required	Required	Required	Required

E.3.2.5.2 For Detroit Diesel 6V92TA tests required for interchanging the base stock, the base stock interchange guidelines vary based on original API group tested and the amount of interchange base stock used in the finished oil formulation. Specific requirements are given in Table E-11.

Table E-11—Passing Detroit Diesel 6V92TA Tests Required for Interchanging the Base Stock

Base Stock in Original Test Oil	Interchange Base Stock				
	Group I	Group II	Group III	Group IV	Group V
Group I	Not Required if the base oil viscosity at 100°C is ≥ the base oil viscosity in the originally approved formulation	Not Required if the base oil viscosity at 100°C is ≥ the base oil viscosity in the originally approved formulation	Required	Required	Required
Group II	Not Required if the base oil viscosity at 100°C is ≥ the base oil viscosity in the originally approved formulation	Not required if the base oil viscosity at 100°C is ≥ the base oil viscosity in the originally approved formulation	Required	Required	Required
Group III	Required	Required	Required	Required	Required
Group IV	Required	Required	Required	Not Required provided a) the interchange Group IV meets the original manufacturer's specifications in all physical and chemical properties AND b) the base oil viscosity at 100°C is ≥ the base oil viscosity in the originally approved formulation	Required
Group V	Required	Required	Required	Required	Required

E.3.2.5.3 For Caterpillar 1K tests required for interchanging the base stock, specific requirements are given in Table E-12.

Table E-12—Caterpillar 1K Tests Required for Interchanging the Base Stock

Base Stock in Original Test Oil	Interchange Base Stock				
	Group I	Group II	Group III	Group IV	Group V
Group I	Not Required	Not Required	≤30% Not Required ----- >30% Required	≤30% Not Required ----- >30% Required	Required
Group II	Not Required	Not Required	≤30% Not Required ----- >30% Required	≤30% Not Required ----- >30% Required	Required
Group III	Required	Required	Required	Required	Required
Group IV	Required	Required	Required	Not Required provided the interchange Group IV meets the original manufacturer's specifications in all physical and chemical properties	Required
Group V	Required	Required	Required	Required	Required

E.3.2.5.4 For Caterpillar 1N tests required for interchanging the base stock, specific requirements are given in Table E-13.

Table E-13—Caterpillar 1N Tests Required for Interchanging the Base Stock

Base Stock in Original Test Oil	Interchange Base Stock				
	Group I	Group II	Group III	Group IV	Group V
Group I	Not Required	Not Required	Required	Required	Required
Group II	Not Required	Not Required	Required	Required	Required
Group III	Required	Required	Required	Required	Required
Group IV	Required	Required	Required	Not Required provided the interchange Group IV meets the original manufacturer's specifications in all physical and chemical properties	Required
Group V	Required	Required	Required	Required	Required

E.3.2.5.5 For Caterpillar 1R tests required for interchanging the base stock, specific requirements are given in Table E-14.

Table E-14—Caterpillar 1R Tests Required for Interchanging the Base Stock

Base Stock in Original Test Oil	Interchange Base Stock				
	Group I	Group II	Group III	Group IV	Group V
Group I	Not Required	Not Required	Required	Required	Required
Group II	Required	Not Required	Required	Required	Required
Group III	Required	Required	Required	Required	Required
Group IV	Required	Required	Required	Not Required provided the interchange Group IV meets the original manufacturer's specifications in all physical and chemical properties	Required
Group V	Required	Required	Required	Required	Required

E.3.2.5.6 For Caterpillar 1P tests required for interchanging the base stock, specific requirements are given in Table E-15.

Table E-15—Caterpillar 1P Tests Required for Interchanging the Base Stock

Base Stock in Original Test Oil	Interchange Base Stock				
	Group I	Group II	Group III	Group IV	Group V
Group I	Not Required	Required in only one Group II base stock for CH-4/Not Required for CI-4	Required	Required	Required
Group II	Not Required	Not Required	Required	Required	Required
Group III	Required	Required	Required	Required	Required
Group IV	Required	Required	Required	Not Required provided the interchange Group IV meets the original manufacturer's specifications in all physical and chemical properties	Required
Group V	Required	Required	Required	Required	Required

E.3.2.5.7 For Mack T-9 tests required for interchanging the base stock, specific requirements are given in Table E-16.

Table E-16—Mack T-9 Tests Required for Interchanging the Base Stock

Base Stock in Original Test Oil	Interchange Base Stock				
	Group I	Group II	Group III	Group IV	Group V
Group I	Not Required if sulfur ≤ and saturates ≥ original	Not Required	≤30% Not Required ----- >30% Required	≤30% Not Required ----- >30% Required	Required
Group II	Required	Not Required if saturates ≥ original	≤30% Not Required ----- >30% Required	≤30% Not Required ----- >30% Required	Required
Group III	Required	Required	Required	Required	Required
Group IV	Required	Required	Required	Not Required provided the interchange Group IV meets the original manufacturer's specifications in all physical and chemical properties	Required
Group V	Required	Required	Required	Required	Required

E.3.2.5.8 For Mack T-8 and T-8E tests required for interchanging the base stock, specific requirements are given in Table E-17.

Table E-17—Mack T-8/T-8E Tests Required for Interchanging the Base Stock

Base Stock in Original Test Oil	Interchange Base Stock				
	Group I	Group II	Group III	Group IV	Group V
Group I	Not Required if either of the following is met: 1. Saturates of original oil is ≥ 80% and interchange base oil saturates is ≥ the original oil 2. Saturates of original oil is <80% and interchange base oil saturates is ≥ the original oil saturates at the 95% confidence level (see example in E.3.3.5)	Not Required	Not Required	Not Required	Required
Group II	Required	Not Required if saturates is ≥ the original oil	Not Required	Not Required	Required
Group III	Required	Required	Required	Required	Required
Group IV	Required	Required	Required	Not Required provided the interchange Group IV meets the original manufacturer's specifications in all physical and chemical properties	Required
Group V	Required	Required	Required	Required	Required

E.3.2.5.9 For Mack T-10 tests required for interchanging the base stock, specific requirements are given in Table E-18.

Table E-18—Mack T-10 Tests Required for Interchanging the Base Stock

Base Stock in Original Test Oil	Interchange Base Stock				
	Group I	Group II	Group III	Group IV	Group V
Group I	Not Required if: saturates ≥ original AND sulfur ≤ original AND BOV at 100°C ≥ BOV at 100°C of original	Not Required if: saturates ≥ original AND BOV at 100°C ≥ BOV at 100°C of original	≤30% Not Required if: saturates ≥ original AND BOV at 100°C ≥ BOV at 100°C of original ----- >30% Required	≤30% Not Required if: saturates ≥ original AND BOV at 100°C ≥ BOV at 100°C of original ----- >30% Required	Required
Group II	Required	Not Required if: saturates ≥ original AND BOV at 100°C ≥ BOV at 100°C of original	≤30% Not Required if: saturates ≥ original AND BOV at 100°C ≥ BOV at 100°C of original ----- >30% Required	≤30% Not Required if: saturates ≥ original AND BOV at 100°C ≥ BOV at 100°C of original ----- >30% Required	Required
Group III	Required	Required	Required	Required	Required
Group IV	Required	Required	Required	Not Required provided the interchange Group IV meets the original manufacturer's specifications in all physical and chemical properties	Required
Group V	Required	Required	Required	Required	Required

E.3.2.5.10 For Roller Follower Wear Test (RFWT) tests required for interchanging the base stock, specific requirements are given in Table E-19.

Table E-19—RFWTs Required for Interchanging the Base Stock

Base Stock in Original Test Oil	Interchange Base Stock				
	Group I	Group II	Group III	Group IV	Group V
Group I	Not Required	Not Required	≤30% Not Required ----- >30% Required	≤30% Not Required ----- >30% Required	Required
Group II	Required in only one Group I base stock	Not Required	≤30% Not Required ----- >30% Required	≤30% Not Required ----- >30% Required	Required
Group III	Required	Required	Required	Required	Required
Group IV	Required	Required	Required	Not Required provided the interchange Group IV meets the original manufacturer's specifications in all physical and chemical properties	Required
Group V	Required	Required	Required	Required	Required

E.3.2.5.11 For Engine Oil Aeration Tests (EOAT) required for interchanging the base stock, specific requirements are given in Table E-20.

Table E-20—EOATs Required for Interchanging the Base Stock

Base Stock in Original Test Oil	Interchange Base Stock				
	Group I	Group II	Group III	Group IV	Group V
Group I	Not Required	Not Required	≤30% Not Required ----- >30% Required	≤30% Not Required ----- >30% Required	Required
Group II	Not Required	Not Required	≤30% Not Required ----- >30% Required	≤30% Not Required ----- >30% Required	Required
Group III	Required	Required	Required	Required	Required
Group IV	Required	Required	Required	Not Required provided the interchange Group IV meets the original manufacturer's specifications in all physical and chemical properties	Required
Group V	Required	Required	Required	Required	Required

E.3.2.5.12 For Cummins M11 and M11 EGR tests required for interchanging the base stock, specific requirements are given in Table E-21.

Table E-21—Cummins M11/M11 EGR Tests Required for Interchanging the Base Stock

Base Stock in Original Test Oil	Interchange Base Stock				
	Group I	Group II	Group III	Group IV	Group V
Group I	Not Required if: saturates ≥ original AND sulfur ≤ original	Not Required	≤30% Not Required ----- >30% Required	≤30% Not Required ----- >30% Required	Required
Group II	Required	Not Required if saturates ≥ original	≤30% Not Required ----- >30% Required	≤30% Not Required ----- >30% Required	Required
Group III	Required	Required	Required	Required	Required
Group IV	Required	Required	Required	Not Required provided the interchange Group IV meets the original manufacturer's specifications in all physical and chemical properties	Required
Group V	Required	Required	Required	Required	Required

E.3.2.5.13 For Cummins ISM and ISB tests required for interchanging the base stock, specific requirements are given below.

E.3.2.5.13.1 If only one passing Cummins ISM or ISB test is available on a given technology, Table E-22 applies.

Table E-22—Cummins ISM and ISB Tests Required for Base Oil Interchange

Base Stock in Original Test Oil	Interchange Base Stock				
	Group I	Group II	Group III	Group IV	Group V
Group I	Not Required if: saturates ≥ original AND sulfur ≤ original	Not Required	≤30% Not Required ----- >30% Required	≤30% Not Required ----- >30% Required	Required
Group II	Required	Not Required if saturates ≥ original	≤30% Not Required ----- >30% Required	≤30% Not Required ----- >30% Required	Required
Group III	Required	Required	Required	Required	Required
Group IV	Required	Required	Required	Not Required provided the interchange Group IV meets the original manufacturer's specifications in all physical and chemical properties	Required
Group V	Required	Required	Required	Required	Required

E.3.2.5.13.2 If more than one passing Cummins ISM or ISB test is available on a given technology, BOI is allowed if the candidate's base oil blend saturates level, sulfur content, and base oil KV@100°C fall within the range of saturates, sulfur, and base oil KV@100°C of the base oil blends in the original passing oils with a minimum of two tested/two passed and the Group III content of the candidate falls within the range of the Group III content covered by the original passing oils.

E.3.2.5.14 For Mack T-12 tests required for interchanging the base stock, specific requirements are given below.

E.3.2.5.14 .1 If only one passing Mack T-12 test is available on a given technology, Table E-23 applies.

Table E-23—Mack T-12 Tests Required for Base Oil Interchange

Base Stock in Original Test Oil	Interchange Base Stock				
	Group I	Group II	Group III	Group IV	Group V
Group I	Not Required if: saturates ≥ original AND sulfur ≤ original AND BOV at 100°C ≥ BOV at 100°C of original	Not Required if: saturates ≥ original AND BOV at 100°C ≥ BOV at 100°C of original	≤30% Not Required if: saturates ≥ original AND BOV at 100°C ≥ BOV at 100°C of original ----- >30% Required	≤30% Not Required if: saturates ≥ original AND BOV at 100°C ≥ BOV at 100°C of original ----- >30% Required	Required
Group II	Required	Not Required if: saturates ≥ original AND BOV at 100°C ≥ BOV at 100°C of original	≤30% Not Required if: saturates ≥ original AND BOV at 100°C ≥ BOV at 100°C of original ----- >30% Required	≤30% Not Required if: saturates ≥ original AND BOV at 100°C ≥ BOV at 100°C of original ----- >30% Required	Required
Group III	Required	Required	Required	Required	Required
Group IV	Required	Required	Required	Not Required provided the interchange Group IV meets the original manufacturer's specifications in all physical and chemical properties	Required
Group V	Required	Required	Required	Required	Required

E.3.2.5.14.2 If more than one passing Mack T-12 test is available on a given technology, BOI is allowed if the proposed interchange oil's base oil blend saturates level, sulfur content, and base oil KV@100°C fall within the range of saturates, sulfur content, and base oil viscosity at 100°C of the base oil blends in the original oils with a minimum of two tested/two passed and the Group III content of the candidate falls within the range of the Group III content covered by the original oils.

E.3.2.5.15 Base Oil Interchange for all Mack T-11 engine tests associated with API CJ-4 and for Mack T-11 engine tests associated with API CI-4 and CI-4 PLUS started after April 28, 2006, may be determined using the method provided in Tables E-24 or E-25 or Figure E-1. Tables E-24 and E-25 and Figure E-1 all define the minimum saturates content of the candidate oil that can be interchanged from the original test oil.

Table E-24—Mack T-11 BOI Saturates Requirements (within a range)

Tested Oil	Candidate Oil
X ≤ 70.0	80.0 minimum
70.0 < X < 95.0	(0.6*X + 38) minimum
X ≥ 95.0	95.0 minimum

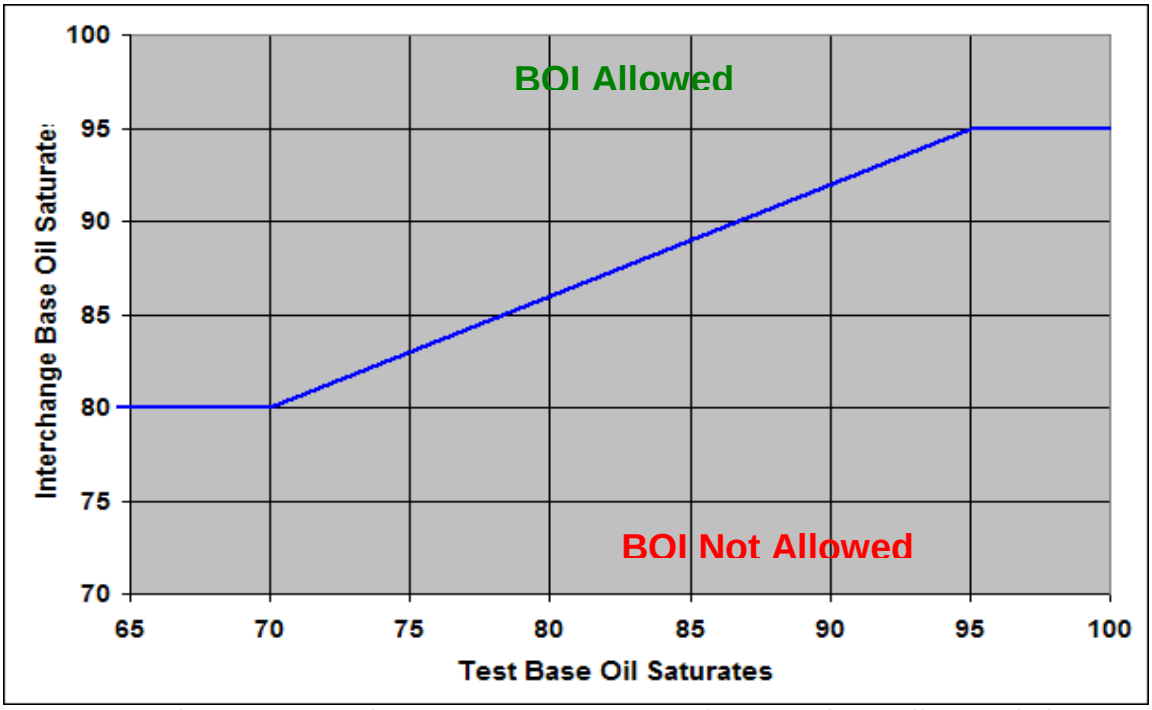

Figure E-1—Mack T-11 BOI Saturates Requirements (according to plot)

Table E-25—Mack T-11 BOI Saturates Requirements (minimum saturates for interchange)

Base Oil Originally Tested for Licensing	Minimum Saturates for Interchange Base Oil
≤70.0	80.0
71.0	80.6
72.0	81.2
73.0	81.8
74.0	82.4
75.0	83.0
76.0	83.6
77.0	84.2
78.0	84.8
79.0	85.4
80.0	86.0
81.0	86.6
82.0	87.2
83.0	87.8
84.0	88.4
85.0	89.0
86.0	89.6
87.0	90.2
88.0	90.8
89.0	91.4
90.0	92.0
91.0	92.6
92.0	93.2
93.0	93.8
94.0	94.4
≥95.0	95.0

E.3.2.5.16 Caterpillar C13 test base oil interchange guidelines within Groups I, II, and III are described in paragraphs E.3.2.5.16.1 and E.3.2.5.16.2 (see notes below). Acceptable test methods for base stock and base oil blend properties are listed in Table E-1. It is understood that when comparing properties, the precision of the methods is taken into consideration.

Notes:
1) The typical viscosity index of the Group III in the candidate must be no more than 6 units higher than the typical viscosity index of the Group III in the passing C13 oil with no allowance for test precision.
2) PAOs (Group IV) can be interchanged in accordance with item d of E.1.3.
3) When Group V base stocks are present, the C13 test must be run.

E.3.2.5.16.1 If only one passing C13 test is available on a given technology and only Group II and/or Group III base stocks are present in the passing C13 oil and the candidate, then C13 BOI is allowed if the viscosity index (VI) of the base oil blend for the candidate oil is equal to or less than the VI of the base oil blend of the passing C13 oil (see note below). If Group I base stock is present in either the passing C13 oil or the candidate, then C13 BOI is allowed if the base oil blend of the candidate has the same saturates level, the same or less sulfur, and the same or lower VI than the base oil blend of the passing C13 oil. Additional guidelines apply when Group III base stock is present in the C13 passing oil:

a. The candidate oil must have Group III content equal to or less than the passing oil.
b. The typical viscosity index of the Group III in the candidate must be no more than 6 units higher than the typical viscosity index of the Group III in the passing C13 oil with no allowance for test precision.

Worksheets like the ones shown below can be used to determine if a candidate's properties meet the C13 BOI criteria above. Examples follow that show how the worksheets should be used.

Worksheet 1: If only Group II and/or III in both the candidate and passing oils

	Candidate		Passing Oil
Base oil blend VI		< or =	
Group III content, % in oil		< or =	
Group III VI		See b above	

Example w/worksheet 1: If only Group II and/or III in both the candidate and passing oils

	Candidate		Passing Oil
Base oil blend VI	104	< or =	115
Group III content, % in oil	13.5	< or =	40
Group III VI	126	See b above	126

In the example above, the candidate's properties meet the BOI criteria when compared to the passing oil. BOI is allowed for this candidate.

Worksheet 2: If Group I in either the candidate or passing oils

	Candidate		Passing Oil
Base oil blend sats, %		=	
Base oil blend sulfur, ppm		< or =	
Base oil blend VI		< or =	
Group III content, % in oil		< or =	
Group III VI		See b above	

Example w/worksheet 2: If Group I in either the candidate or passing oils

	Candidate		Passing Oil
Base oil blend sats, %	87	=	87
Base oil blend sulfur, ppm	347[a]	< or =	320
Base oil blend VI	93	< or =	99
Group III content, % in oil	0	< or =	15
Group III VI	---	See b above	128

[a]Need to apply the precision of the method.

The candidate's properties meet the BOI criteria when compared to the passing oil. In this case, the precision of the sulfur method shows the sulfur contents to be the same (D2622, 320 ppm +/- 41 ppm covers 347 ppm). BOI is allowed for this candidate.

E.3.2.5.16.2 If more than one passing C13 test is available on a given technology, BOI is allowed if the candidate's base oil blend saturates level, sulfur content, and viscosity index fall within the range of saturates level, sulfur, and VI of the base oil blends in the original passing oils (minimum two tested/two passed oils) and the Group III content of the candidate oil falls within the range of Group III content covered by the original passing oils. Additionally, the typical viscosity index of the Group III in the candidate oil must be no more than 6 units higher than the typical viscosity index of the Group III in the passing C13 oil with no allowance for test precision.

A worksheet like the one shown below can be used to determine if a candidate's properties meet the C13 BOI criteria above. Examples follow that show how the worksheets would be used.

Worksheet 3: If more than one passing C13 test is available on a given technology

	Passing Oil 1	Passing Oil 2	Candidate
Base oil blend sats, %			
Base oil blend sulfur, ppm			
Base oil blend VI			
Group III content, % in oil			
Group III VI (See b above)			
Is C-13 Required?			Yes or no?
Reason			

Example 1 w/worksheet 3: If more than one passing C13 test is available on a given technology

	Passing Oil 1	Passing Oil 2	Candidate
Base oil blend sats, %	87	96	87
Base oil blend sulfur, ppm	347	0	320
Base oil blend VI	93	115	99
Group III content, % in oil	0	40	15
Group III VI (See b above)	--	126	128
Cat C-13	Pass	Pass	
Is C-13 Required?			No
Reason			BOI is allowed. Sats, S, VI, and Group III content fall within matrix ranges. Candidate Group III VI is within the acceptable +6 range.

Example 2 w/worksheet 3: If more than one passing C13 test is available on a given technology

	Passing Oil 1	Passing Oil 2	Candidate
Base oil blend sats, %	87	96	94
Base oil blend sulfur, ppm	347	0	90
Base oil blend VI	93	115	112
Group III content, % in oil	0	40	20
Group III VI (See b above)	--	126	134
Cat C-13	Pass	Pass	
Is C-13 Required?			Yes
Reason			BOI is not allowed. Base oil sats, S, and VI fall within matrix ranges, but Candidate Group III VI is outside the acceptable +6 range.

E.3.3 EXAMPLES

E.3.3.1 General

The API Base Oil Interchangeability Guidelines must be used in conjunction with the API Guidelines for SAE Viscosity-Grade Engine Testing (see Annex F). When the original approved grade contains less than or equal to 10 percent of the interchange base stock, the higher grade must be tested if it contains greater than 10 percent of the interchange base stock in the formulation.

E.3.3.2 Example 1

In this example, a marketer wants to exchange the 600N base stock in a Group I slate of base stocks for API Service Category CF-4 Heavy Duty engine oils. The marketer has two products involved in this interchange: an SAE 15W-40 grade containing a Group I base oil mix of 50 percent 100N and 50 percent 250N that has been approved by viscosity read-across and testing and an SAE 30 grade containing a Group I base oil mix of 35 percent 250N and 65 percent 600N that has also been approved by viscosity read-across and testing.

The marketer needs to take the following steps:

a. Check the API Guidelines for SAE Viscosity-Grade Engine Testing. Some Heavy Duty engine tests can be read across from multigrade to single grade. Others can be read across from single grade to multigrade. Approval testing in original stocks was conducted accordingly.
b. Check the API Base Oil Interchangeability Guidelines. Since the SAE 15W-40 product contains none (that is, less than 10 percent of the formulation) of the Group I 600N interchange stock, no testing is required. Additionally, no testing is required for the SAE 30 product when a 600N Group I base stock from another source is used. Group I for Group I interchanges are permitted for CF-4 oils.

E.3.3.3 Example 2

In this example, a marketer wants to change from a Group II slate of base stocks used in a fully approved API CF-4 SAE 15W-40 Heavy Duty engine oil to a Group I slate and also to a mix of Group I and Group II stocks. The approved SAE 15W-40 grade is made with a Group II base oil mix of 65 percent 100N and 35 percent 240N.

The marketer needs to check the Base Oil Interchangeability Guidelines. No further engine testing is required for either interchange.

E.3.3.4 Additional Examples

Additional examples on applying Base Oil Interchangeability Guidelines may be noted in Annex O.

E.3.3.5 Saturates Calculation Example for Table E-16

The following calculation is utilized to determine if a Mack T-8 or T-8E test can be waived when both the originally tested base oil and the intended interchange base oil are below 80 percent saturates. A Mack T-8 or T-8E test is necessary for base oil interchangeability if the new base oil percent saturates level is not greater than or equal to the percent saturates level in the originally tested base oil at the 95 percent confidence level. This calculation is performed as follows:

Difference between two means (Z value calculation, one-sided assuming normal distribution):

$$X_1 - X_2 \geq 1.645\sqrt{\frac{{\sigma_1}^2}{n_1} + \frac{{\sigma_2}^2}{n_2}}$$

where X = mean of saturate determinations
σ = standard deviation of laboratory performing analyses
n = number of determinations
subscripts 1 and 2 refer to the interchange base oil and original base oil respectively

ASTM D 2007 saturates determinations must be made in a laboratory that has a standard deviation of 1.5 or less with an internal reference oil of less than 80 percent saturates.

If the ASTM D 2007 standard deviation for the laboratory in which both the original 70.0 percent saturates base oil and interchange base oil determinations were run is 1.5 and single saturates determinations were made, the Mack T-8 or Mack T-8E test would be waived for all API Group I Base Oils at least 3.48 percent higher in saturates (73.48 percent saturates minimum).

$$X_1 - X_2 \geq 1.645\sqrt{\frac{(1.5)^2}{1} + \frac{(1.5)^2}{1}}$$
$$X_1 - X_2 \geq (1.645)(1.5)\sqrt{2}$$
$$X_1 - X_2 \geq 3.48$$

If in the above calculation, the ASTM D 2007 laboratory standard deviations were both 0.7 rather than 1.5 and single determinations were made, waiving the Mack T-8 or Mack T-8E Test for all API Group I Base Oils at least 1.63 percent higher (71.63 percent saturates minimum) would be permissible.

E.4 Interchange for Bench Tests

E.4.1 Complete bench testing is required for interchanging a base stock in an API-licensed oil except where noted in the guidelines below.

E.4.2 Based on existing TEOST 33 (ASTM D 6335) bench test data submitted to API, the passing TEOST 33 tests specified in Table E-26 are required for interchanging the base stock.

Table E-26—Passing TEOST 33 Tests Required for Interchanging the Base Stock

Base Stock in Original Test Oil	Interchange Base Stock (Applies to SAE 5W-30 and higher viscosity grades only.)				
	Group I	Group II	Group III	Group IV	Group V
Group I	Not Required	Not Required	Required	Required	Required
Group II	Not Required	Not Required	Not Required	Required	Required
Group III	Required	Not Required	Not Required	Required	Required
Group IV	Required	Required	Required	Required	Required
Group V	Required	Required	Required	Required	Required

E.4.3 Based on existing TEOST MHT (ASTM D 7097) bench test data submitted to API, the passing TEOST MHT tests specified in Table E-27 are required for interchanging the base stock.

Table E-27—TEOST MHT Tests Required for Interchanging the Base Stock

Base Stock in Original Test Oil	Interchange Base Stock				
	Group I	Group II	Group III	Group IV	Group V
Group I	Not Required if sulfur ≥ and saturates ≤ original	Required	Required	Required	Required
Group II	Not Required	Not Required	Not Required	Required	Required
Group III	Required	Not Required	Required	Required	Required
Group IV	Required	Required	Required	Required	Required
Group V	Required	Required	Required	Required	Required

E.4.4 Homogeneity and Miscibility (H&M) ASTM D 6922 and Engine Oil Filterability (EOFT) ASTM D 6795 [formerly known as GM 9099P Filterability (Standard Method)] tests are required in one viscosity grade represented in the core data set. Each base oil interchange requires only one H&M and one EOFT test. (See ACC Code for definition of core data set.) Core data sets are typically developed in SAE 5W-30, 10W-30, 10W-40 or 15W-40 viscosity grades.

E.4.5 The Engine Oil Water Tolerance Test (EOWTT) ASTM D 6794 [formerly GM 9099P Filterability (Modified Method for ILSAC GF-2/GF-3)] for each base oil interchange is required only in the viscosity grade with the highest additive (DI/VI) combination.

E.4.6 If there is one passing Ball Rust Test (BRT) ASTM D 6557 in the core data set as defined by the ACC Code, read-across is allowed to all other viscosity grades and base oil slates.

E.4.7 Neither a Mack T-10A nor a Mack T-12A test is required for base oil interchange if the saturates and sulfur content (within the precision of the two analytical tests) of the interchange base oil fall within the range of the saturates and sulfur content of the base oils in the original oils (minimum two oils), and fresh oil MRV-TP1 (ASTM D 4684) @ –20ºC of the interchange is equal to or less than the BOI matrix limit.

The BOI matrix limit is defined as:

$$BOI\ matrix\ limit = 25000 - margin\ of\ safety$$

Margin of safety is defined as:

$$margin\ of\ safety = largest\ of\ Y1 - X1, Y2 - X2, or\ 0$$

where X1 = fresh oil MRV-TP1 @ –20ºC for original oil 1
X2 = fresh oil MRV-TP1 @ –20ºC for original oil 2
Y1 = MRV-TP1 @ –20ºC of 75-hour T-10A or T-12A sample for original oil 1
Y2 = MRV-TP1 @ –20ºC of 75-hour T-10A or T-12A sample for original oil 2

An example of this guideline's application is provided in Table E-28.

Table E-28—Example of T-10A or T-12A BOI Guideline Application[a]

	Matrix Oil 1	Matrix Oil 2	Candidate Oil A	Candidate Oil B	Candidate Oil C
Base Oil Saturates, mass%	99	65	70	80	75
Base Oil Sulfur, mass%	<0.002	0.7	0.5	0.3	0.8
Is base oil saturates within the matrix range (within the precision of the test)?			Yes	Yes	Yes
Is base oil sulfur within the matrix range (within the precision of the test)?			Yes	Yes	No
Fresh Oil MRV-TP1 @ –20°C, cP	12000	15000	16000	20000	Immaterial
T-10A or T-12A MRV-TP1 @ –20°C, cP	18000	16000			
Yield stress, Pa	0	0			
Margin of safety	Largest of (18000–12000) or (16000–15000) or 0 = 6000				
BOI matrix limit	25000–6000 = 19000		19000	19000	19000
Test Required?			No	Yes	Yes
Reason			Fresh oil MRV-TP1 less than BOI matrix limit	Fresh oil MRV-TP1 greater than BOI matrix limit	Base oil sulfur not in matrix range

[a]T-10A = Mack T-10A engine test; T-12A = Mack T-12A engine test.

E.4.8 The CI-4 Elastomer Compatibility Test is not required if the saturates and sulfur content (within the precision of the tests) of the interchange base oil fall within the range of the saturates and sulfur content of the base oils in the original candidate oils (minimum two candidate oils) and the DI package is unchanged. An example of this guideline's application is provided in Table E-29.

Table E-29—Example of CI-4 Elastomer Compatibility BOI Guideline Application

	Matrix Oil 1	Matrix Oil 2	Candidate Oil A	Candidate Oil B
Base Oil Saturates, mass %	99	65	70	80
Base Oil Sulfur, mass %	<0.002	0.7	0.5	0.3
CI-4 Elastomer Compatibility Test	Pass	Pass		
Test Required?			No	No
Reason			Base oil saturates and sulfur fall within matrix ranges	Base oil saturates and sulfur fall within matrix ranges

E.4.9 The CJ-4 Elastomer Compatibility Test is not required if the saturates and sulfur content (within the precision of the tests) of the interchange base oil fall within the range of the saturates and sulfur content of the base oils in the original candidate oils (minimum two candidate oils) and the DI package is unchanged. An example of this guideline's application is provided in Table E-30.

Table E-30—Example of CJ-4 Elastomer Compatibility BOI Guideline Application

	Matrix Oil 1	Matrix Oil 2	Candidate Oil A	Candidate Oil B
Base Oil Saturates, mass %	99	65	70	80
Base Oil Sulfur, mass %	<0.002	0.7	0.5	0.3
CJ-4 Elastomer Compatibility Test	Pass	Pass		
Test Required?			No	No
Reason			Base oil saturates and sulfur fall within matrix ranges	Base oil saturates and sulfur fall within matrix ranges

E.4.10 In addition to the Mack T-11 BOI guidelines being met, for Base Oil Interchange in the Mack T-11A the fresh oil MRV-TP1 (ASTM D 4684) @ –20ºC of the interchange candidate must be less than or equal to 20000 cPs with no yield stress.

E.4.11 If there is one passing High-Temperature Corrosion Bench Test (HTCBT) ASTM D 6594 in the core data set as defined by the ACC Code, read-across is allowed to all other viscosity grades and base oil slates.

E.4.12 For oils formulated with Group II and/or Group III base stocks, the Emulsion Retention ASTM D7563 is required only for the highest additive (DI/VI) concentration. Read across is allowed to all other Group II, Group III and combinations of Group II and Group III base oil/viscosity grade formulations using the same or lower concentration of the identical additive (DI/VI) combination. If the PPD type is changed for the DI/VI combination, testing is required.

E.4.13 A passing GF-5 Elastomer Compatibility Test (ASTM D7216 Annex A2) in the core data set (as defined in the ACC Code) run in Group II or Group III or a mix of Group II and Group III, can be read across to formulations using other Group II or Group III or a mix of Group II and Group III base stocks.

Additionally, there is no viscosity grade restriction if the read across is limited to 0W-20, 0W-30, 5W-20, 5W-30, 10W-30 and 10W-40 viscosity grades.

When reading to a candidate using Group I base stocks, the GF-5 Elastomer Compatibility Test (ASTM D7216 Annex A2) is not required if the base oil saturates and base oil sulfur content (within the precision of the tests) of the interchange base oil fall within the range of the base oil saturates and base oil sulfur content of the base oils in the original candidate oils (minimum two candidate oils) and the DI package is unchanged. An example of this guideline's application is provided in Table E-31.

Table E-31 – Example of GF-5 Elastomer Compatibility Test Including API Group I Base Stocks

	Matrix Oil 1	Matrix Oil 2	Candidate Oil 1	Candidate Oil 2
Base Oil Saturates, mass %	**85**	**99**	**92**	**96**
Base Oil Sulfur, mass%	**0.2**	**0.0**	**0.17**	**0.01**
GF-5 Elastomer Compatibility Test	**Pass**	**Pass**		
Test Required?			**No**	**No**
Reason			**Base oil sulfur and Base oil VI falls within the matrix ranges**	**Base oil sulfur and Base oil VI falls within the matrix ranges**