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Principles for establishing base stock interchange guidelines

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Interchange extends back to the beginning of engine oil licensing

- Formal guidance established in early 1990's

- Practical flexibility for oil qualification without compromising system integrity

- API base stock grouping: a framework for establishing interchange guidance

The American Petroleum Institute Engine Oil Licensing & Certification System

FINAL DRAFT

APRIL 20, 1992

Base Stock Categories

All base stocks are divided into three general categories as follows:

GROUP I < 90% saturates, and/or > 0.03% sulfur, and ≥ 80 viscosity index using analytical test methods defined in requirement IV.

GROUP II ≥ 90% saturates, and ≤ 0.03% sulfur, and ≥ 80 viscosity index using the methods of requirement IV.

GROUP III All other base stocks, including synthetics, not covered in Group I or II.

Two basic types of base stock interchange

Within a Base Stock Slate

Viscosity Grade Read-Across (VGRA)

| EHC 45 |
| EHC 50 |
| EHC 65 |
| EHC 110 |

10W-30 Engine oil

| EHC 45 |
| EHC 50 |
| EHC 65 |
| EHC 110 |

| EHC 45 |
| EHC 50 |
| EHC 65 |
| EHC 110 |

5W-30 Engine oil

10W-40 Engine oil
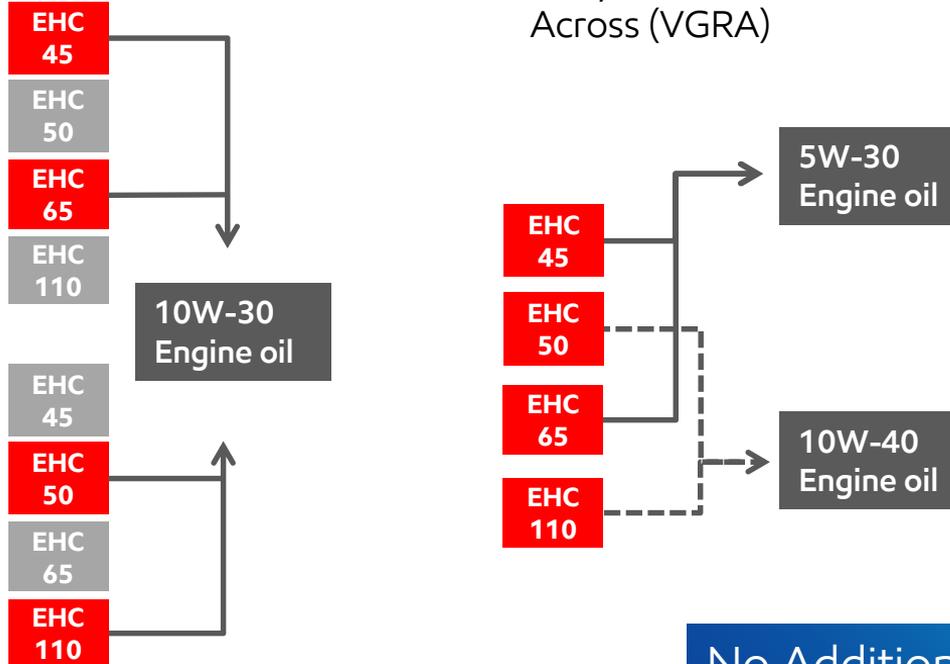
Between Base Stock Slates

Base Oil Interchange (BOI)

| EHC 45 |
| EHC 65 |

10W-30 Engine oil

| Group II Slate LN |
| Group II Slate MN |
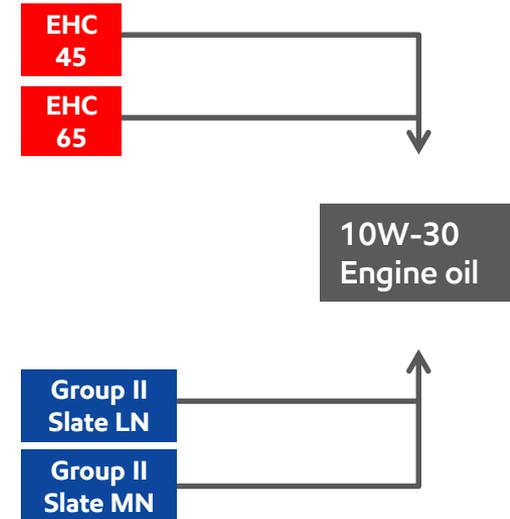
No Additional Engine Testing Required

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The concept of a slate underpins interchange

- Supports industry wide product integrity

- Single manufacturer responsible for:

  – Ensuring consistent base stock quality

  – Demonstrating interchangeability of base stocks within a slate

API 1509 E.1.2.2

A **base stock slate** is a product line of base stocks that:

- Have different viscosities

- Are in the same base stock grouping

- Are produced by the same manufacturer

- Are technically substitutable (implied by examples)

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Substantiating a slate definition

Volvo T-13 Test
Prototype CK-4 Technology
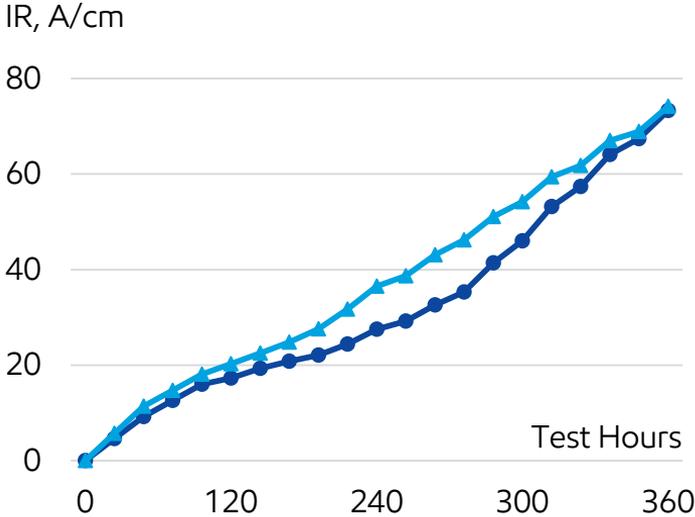
EP6CDT
ACEA A3/B4-16, MB 229.1 Technology
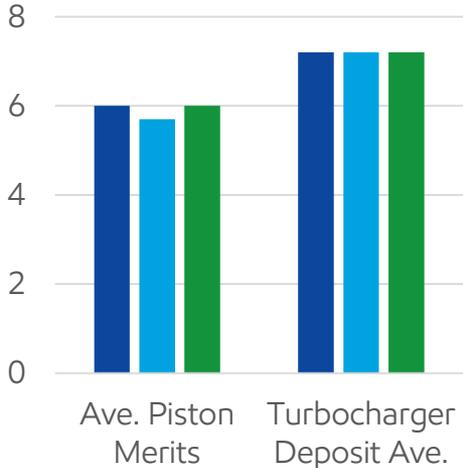
Legend: ■ EHC North America   ■ EHC Asia Pacific   ■ 2019 EHC Europe & Asia (Pre-prod)

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Base stock interchange principles

Clear framework

Consistently applied

Data driven

Science based
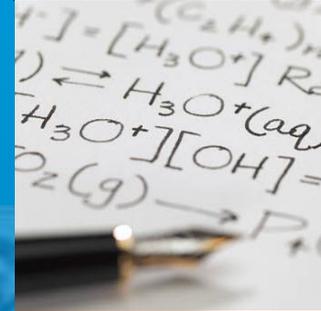
Clear framework, consistently applied

Read guidance should apply for <u>all</u> time, for <u>all</u> base stock slates and <u>all</u> additive technologies

- Risk-based assessment; data reduces, but does not eliminate risk

- Not possible to test all base stock slate/additive technology combinations

- API practice evaluates reads in 3 additive technologies

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Data driven and science based

- To deliver maximum value to the industry, base stock interchange should be evaluated just after test development

  - Integrated with or leveraging the precision matrix is a best practice

- Data to support interchange reads should be generated in a transparent environment

  - Recent practice to fund interchange evaluation tests collaboratively

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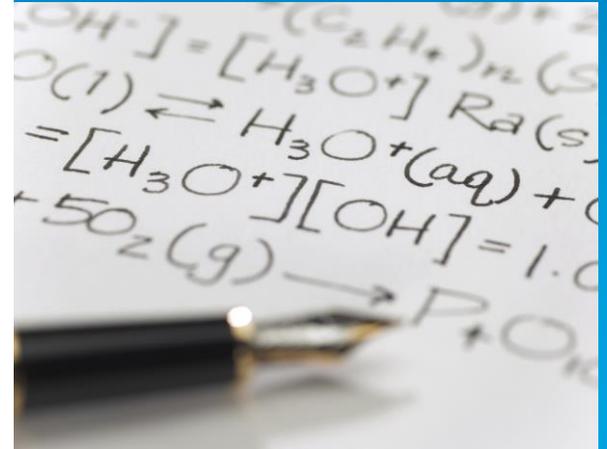
Performance testing is necessary

ATIEL Code of Practice, Issue 19, Section B.1.4:

"The physical and chemical characteristics of base stocks influence their lubrication performance. However, it has not yet proved possible to predict fully the base stock characteristics for a particular engine lubricant application. Practical measurements in engine tests remain the only reliable means of validating the performance of engine lubricants."

Predictability challenges
- Evolving performance standards, involving multiple tests
- Insufficiently precise analytical characterization methods
- Test variability

Performance prediction is challenging

- 100% Group III base oils

- Formulated with GF-4 technology

- Tests differ in duration and temperature

Only a small fraction of the oil contributes to deposits

TEOST MHT-4 deposits, mg

Better

| Oil code: | B | C | D | E | F | G | H |

TEOST 33C deposits, mg

Better

| Oil code: | B | C | D | E | F | G | H |

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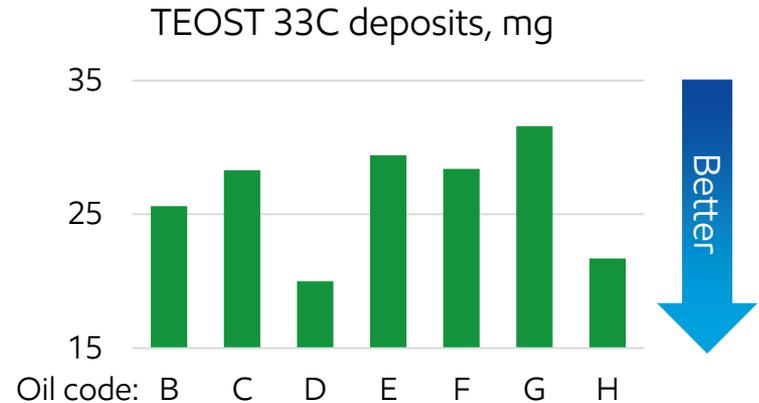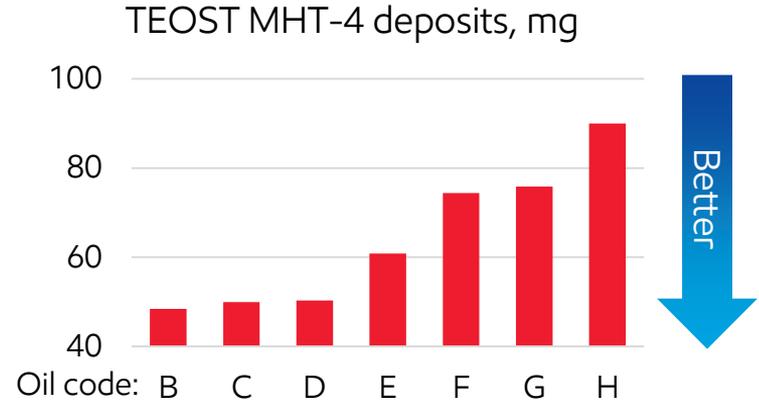
Potential consequences

Inconsistent application of guidelines can result in:

- Oils in the marketplace which do not meet the performance specification

- Competitive imbalance from:
  - Additional testing
  - Additive uptreat

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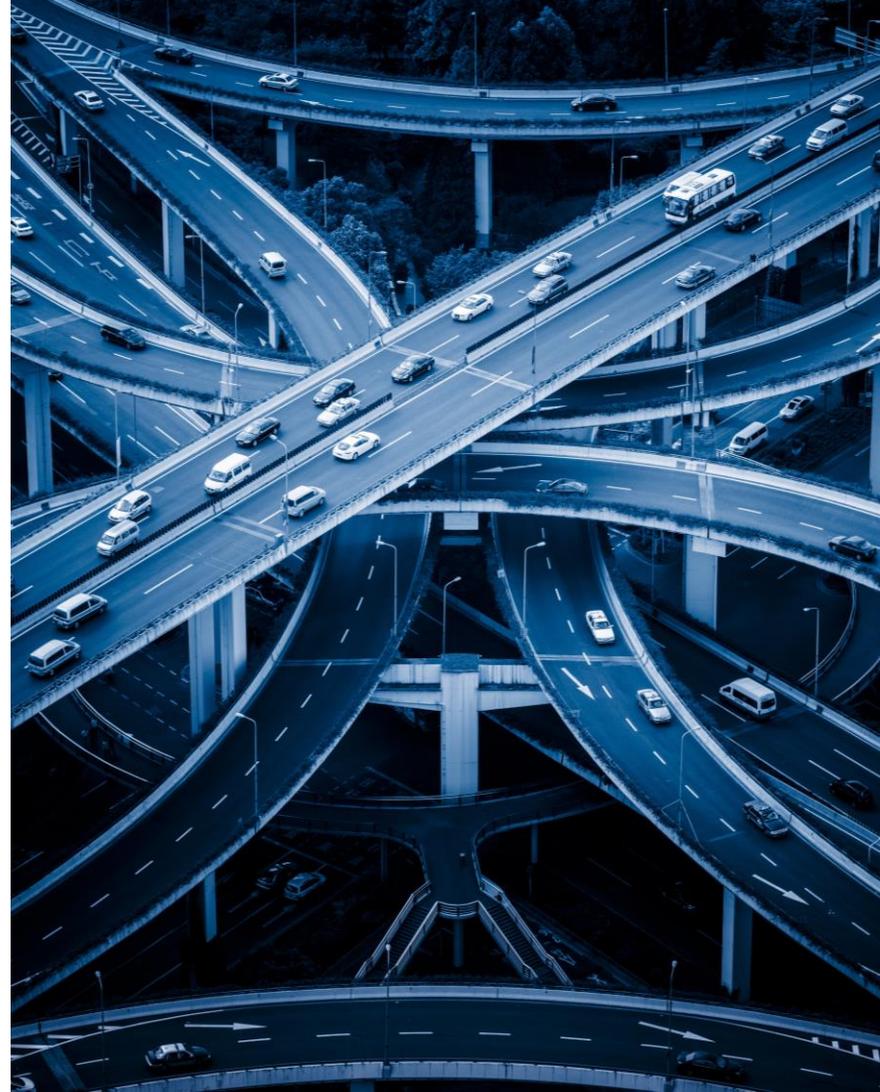
A practical case: real guidance not universally accepted

Table F-3—"Read-Across" for Sequence IIIE Test

Test Run on	Can Be "Read Across" to											
	5W-30	10W	10W-30	10W-40	15W-40	15W-50	20W	20W-40	20W-50	30	40	50
5W-30	—	X	X	X	X	X	X	X	X	X	X	X
10W		—					X			X	X	X
10W-30		X	—	X	X	X	X	X	X	X	X	X
10W-40		X	X	—	X	X	X	X	X	X	X	X
15W-40		X	X	X	—	X	X	X	X	X	X	X
15W-50		X	X	X	X	—	X	X	X	X	X	X
20W							—			X	X	X
20W-40					X	X	X	—	X	X	X	X
20W-50					X	X	X	X	—	X	X	X
30							X			—	X	X
40										X	—	X
50												—

Note: An X means that read-across is permitted; a blank means that read-across is not permitted. This table originally became effective January 1, 1991, and was revised April 27, 1992.

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# API practices (PC-11 and GF-6)

- Experimental designs tailored to evaluate desired interchange reads

- Statistically-designed experiments offer highest confidence in oil discrimination at a given cost

- Pairwise comparison data easy to visualize for less complex reads

- Leveraging precision matrix data increases the degree of confidence for establishing interchange guidelines

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# Example Group II BOI matrix analysis – Volvo T-13

Visual comparison supports negligible impact of base stock slate

Source: Infineum presentation to API BOI/VGRA Task Force, Jan., 2015
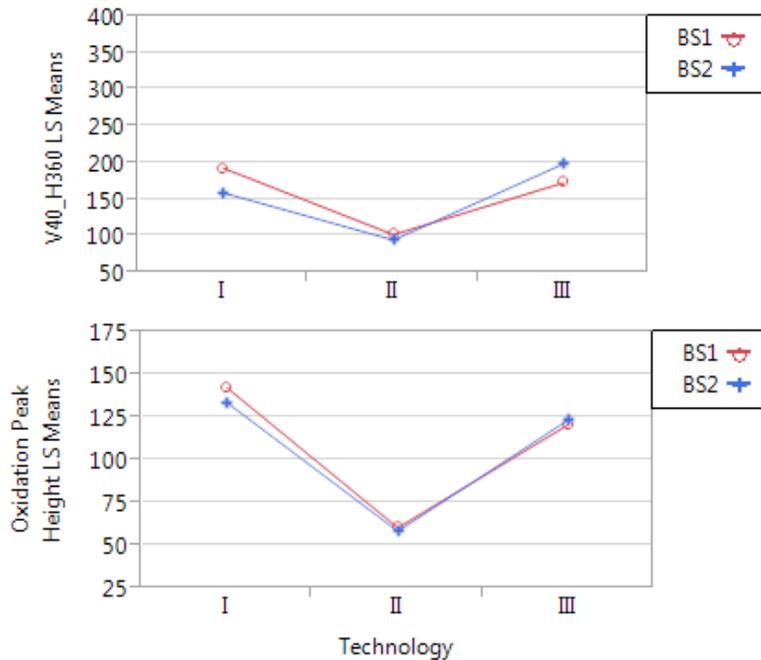
Statistical model confirmed visual interpretation
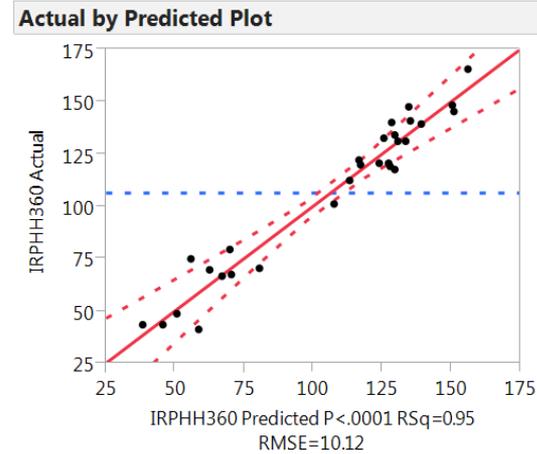
Parameter Estimates

	Estimate	Prob > |t| [1]
Intercept	-148929	0.0045
Base Stock Slate	1.2845	0.5257
Technology 1	31.0517	< 0.001
Technology 2	-48.5984	< 0.001
Serial Date	73.9676	0.0045

(1) Prob < 0.05 statistically significant within 95% confidence

Source: ExxonMobil presentation to API BOI/VGRA Task Force, Feb., 2015

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Key takeaways

- Base stock interchange (BOI and VGRA) is beneficial to the industry and necessary for category delivery timing and cost-efficient oil qualification

- Guidelines should be supported by data generated in the test for which interchange is being developed

- Technical judgment is an important component of data analysis, but does not supplant the need for data

- Data-based interchange guidelines support balanced competition

- Use of interchange guidelines is a risk-based decision; marketers of API licensed oils are not absolved of responsibility for ensuring performance requirements are met (API 1509 Section 4.12)

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