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Engine oil specifications

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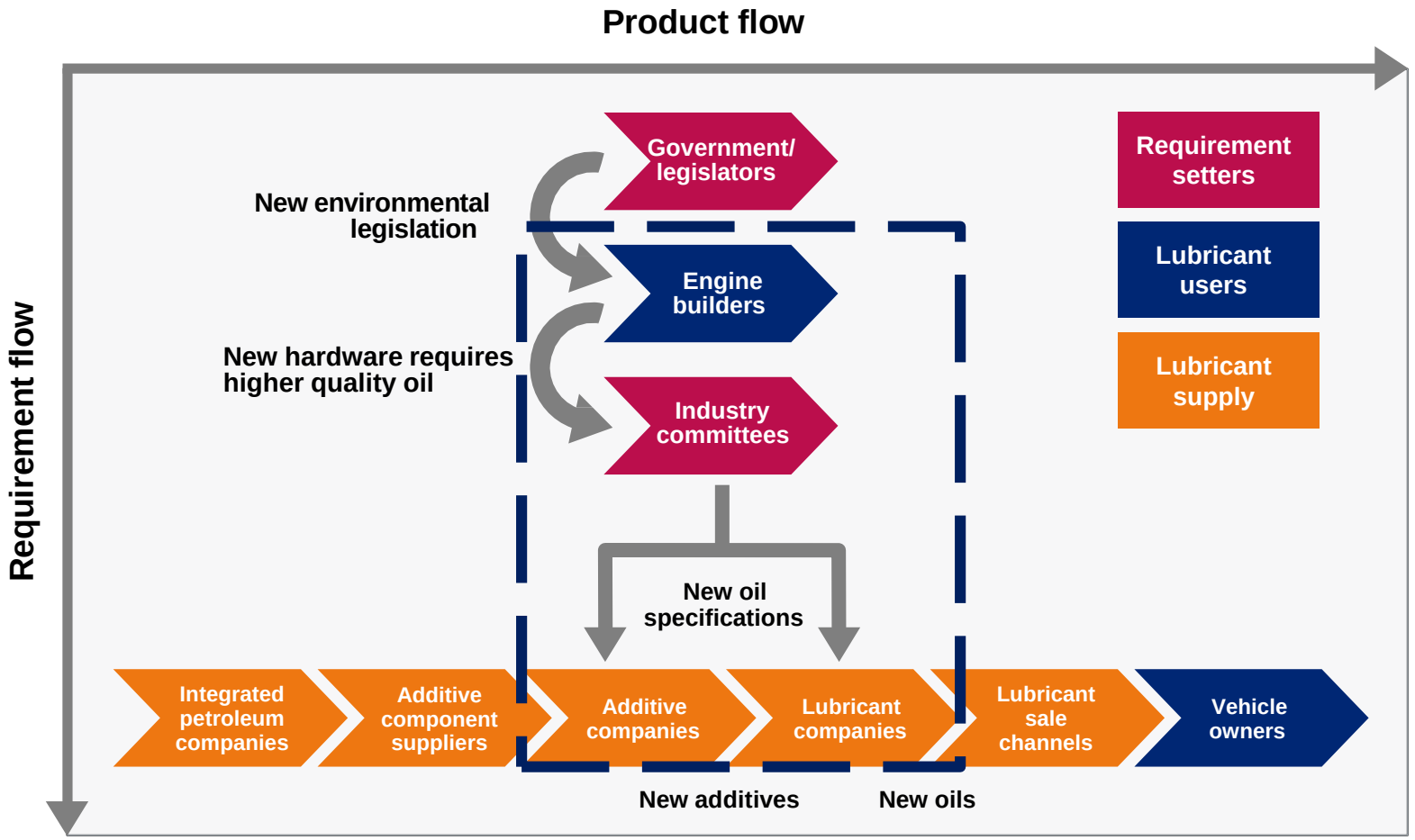
Outline

- Main drivers for specifications
- Industry committees and responsibilities
- Specification overview - heavy duty diesel and passenger car engine oils
- API Engine Oil Licensing and Certification System (EOLCS)
- ACC code of practice
- European specification system

Oil and additive industry value chain

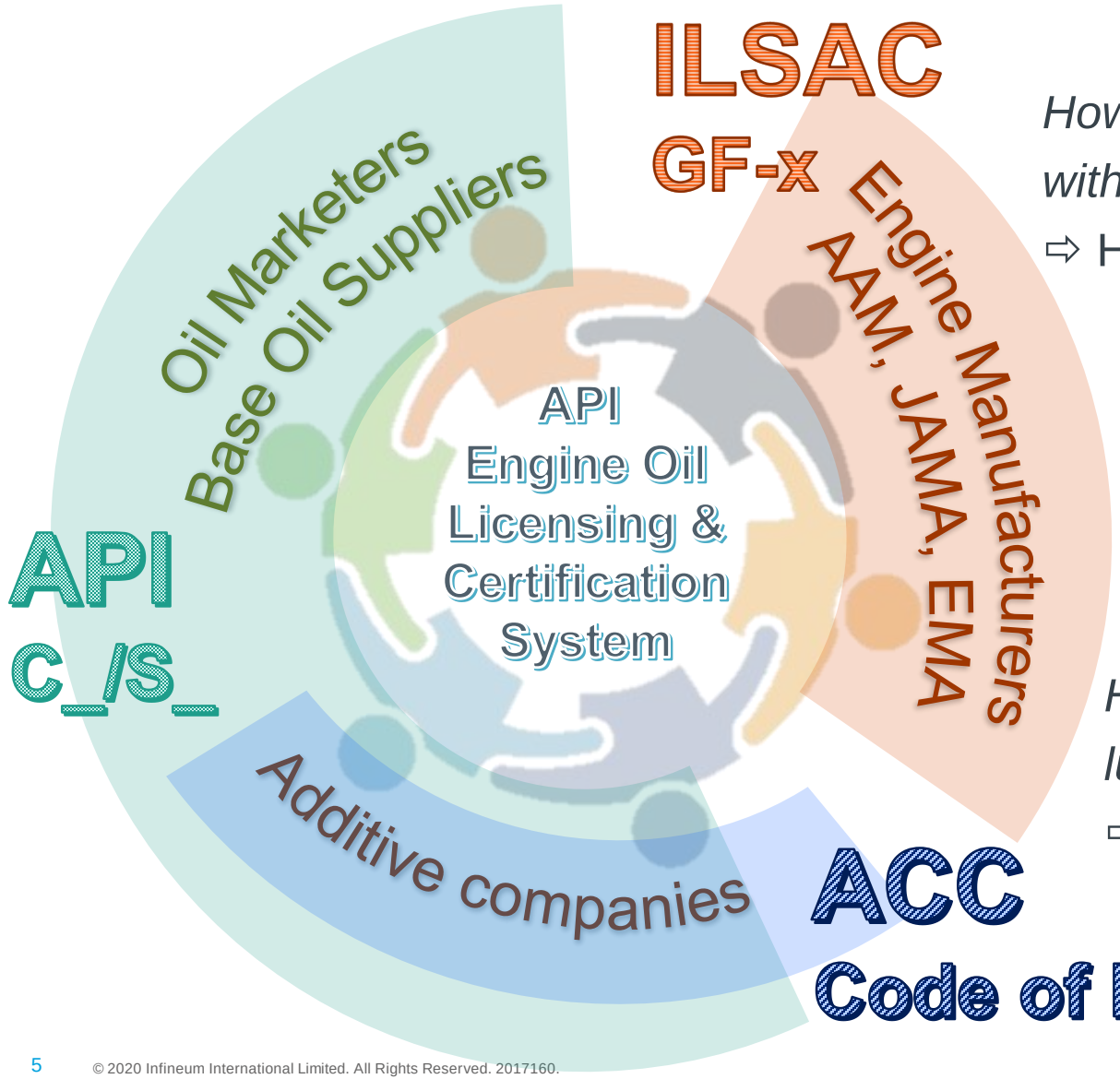


Organizations classifying engine performance

- Industry associations
  - API → American Petroleum Institute
  - ILSAC → International Lubricant Standardization and Approval Committee
  - ACEA → European Automobile Manufacturers Association
  - JASO → Japanese Standard Organization

- Vehicle or Original Engine Manufacturers (OEMs), such as:
  - General Motors (GM)
  - Volkswagen (VW)
  - Daimler
  - Volvo
  - Scania

Industry trade organizations and responsibilities (North America)



How to ensure oils are compatible with engine hardware advances?

⇨ Have oils meet specifications

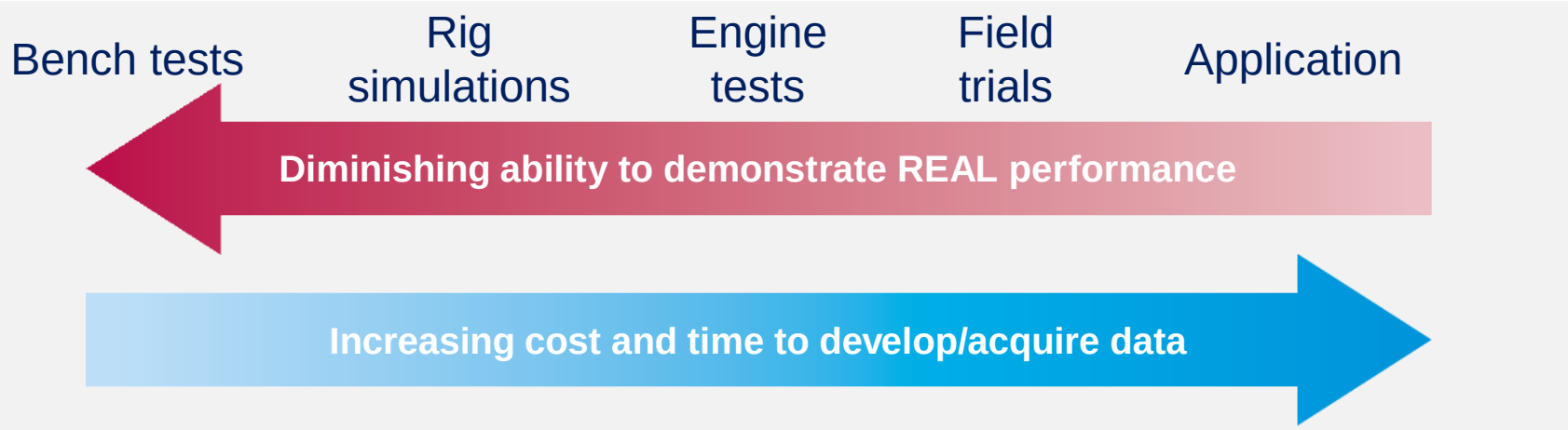
How to assist customers in choosing quality oils?

⇨ Have system for licensing and certification

How to maintain quality of lubricant development process?

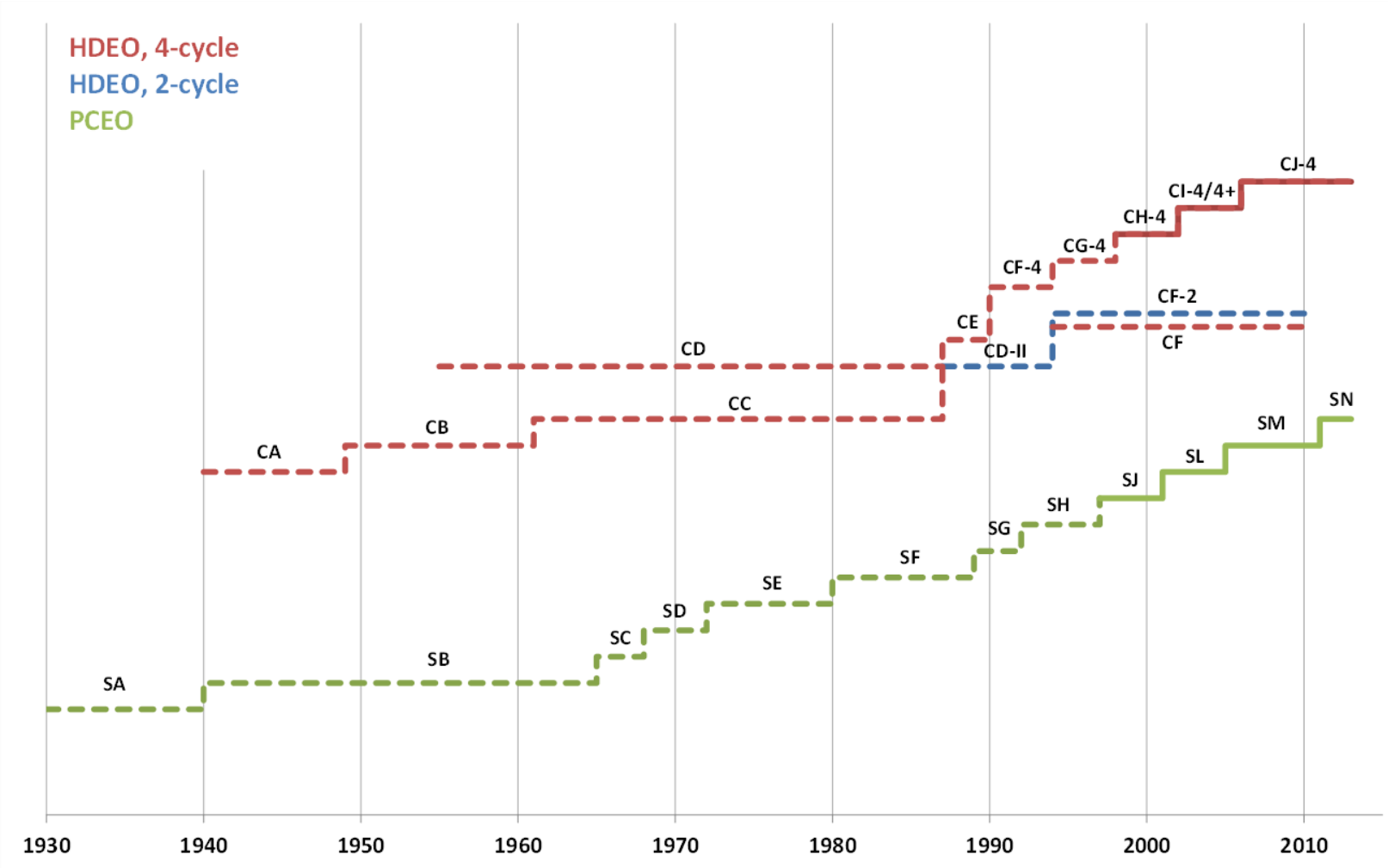
⇨ Outline acceptable practices

Engine tests are the basis of specifications

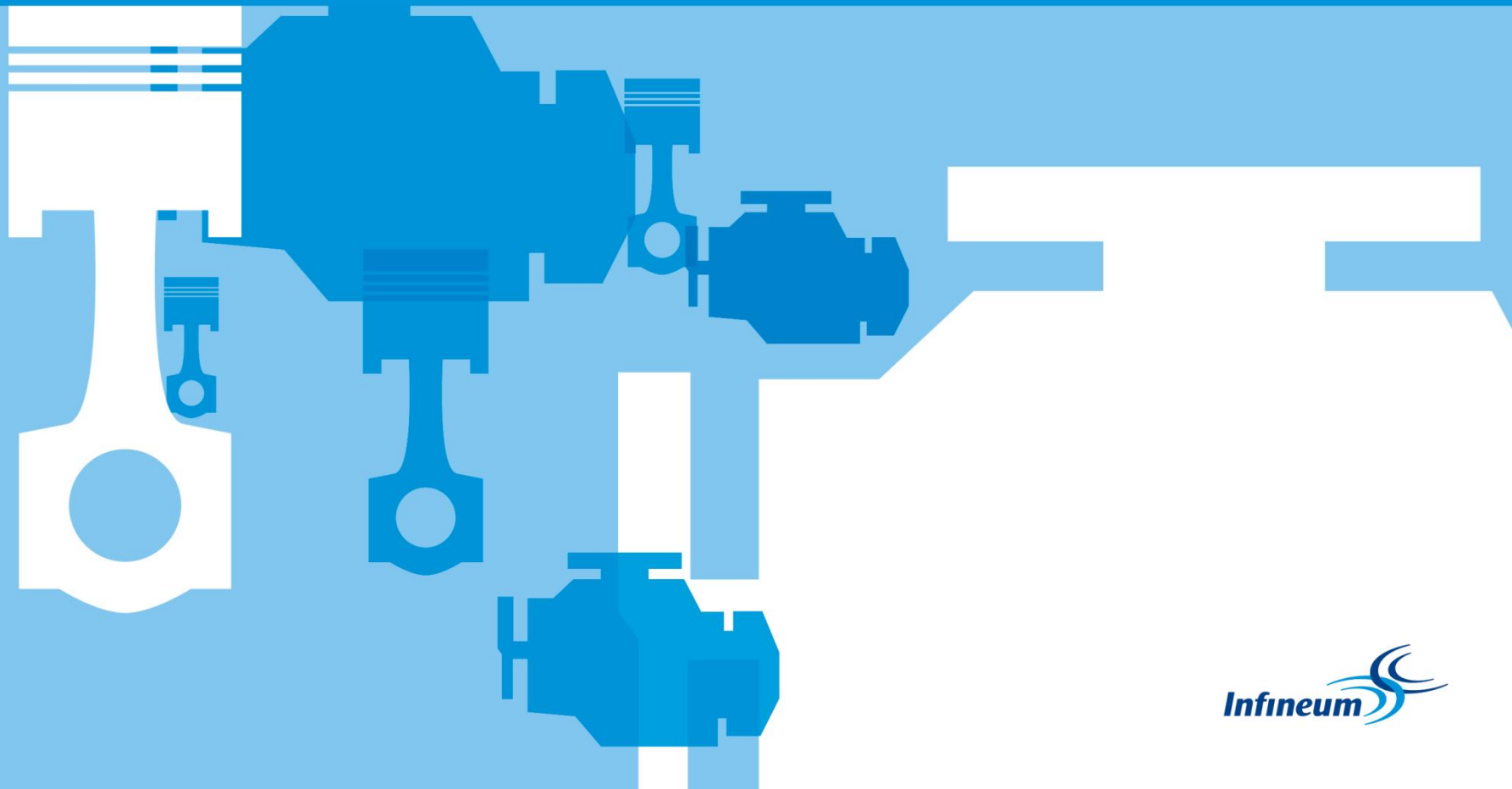


- Developed by individual OEMs or industry groups to target specific performance parameters of concern
- Assessed relative to reference oil of known field performance
- Development should consider:
  - parts availability and quality
  - test conditions and duration
  - parameters of interest and pass/fail limits
  - qualification of test facilities
- Monitored continually by industry
- Specifications derived from compilation of engine tests and limits

Evolution of API Engine Oil Specifications



Heavy-duty specifications



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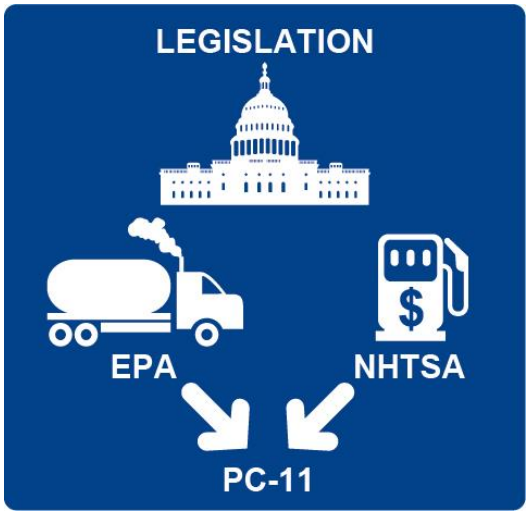
API diesel specifications

API Category	Status	API recommendations
CK-4	**Current**	Introduced in 2016 To meet 2017 model year on-highway exhaust emission standards Sulfur content up to 500 ppm (0.05% by weight) > 15 ppm (0.0015% by weight) may impact exhaust aftertreatment system durability and/or drain interval (Consult engine manufacturer) Effective at sustaining durability of emission control system (particulate filters and other advanced aftertreatment systems) Can be used in CH-4, CI-4, CI-4+, CJ-4 applications
FA-4	**Current**	Similar to CK-4, but for lower HTHS oils
CJ-4	**Current**	Introduced in 2006 To meet 2010 model year on-highway exhaust emission standards Sulfur content up to 500 ppm (0.05% by weight) > 15 ppm (0.0015% by weight) may impact exhaust aftertreatment system durability and/or drain interval (Consult engine manufacturer) Can be used in CF-4, CG-4, CH-4, CI-4, CI-4+ applications

API CK-4 & FA-4: oxidation and fuel economy

- New fuel economy and greenhouse gas rules began phased implementation in 2014 with full effect in 2018
  - Reduce CO2 by 270 million tons and save 530 million barrels of oil
- At the June 2011 ASTM meeting, the EMA issued a formal request for a new API performance category to help meet these new regulations
- Areas requested for improvement versus API CJ-4
  - Shear stability
  - Oxidation
  - Aeration
  - Bio-diesel compatibility (eventually dropped)
  - New lower viscosity oils to help deliver fuel economy performance
- API first license date was December 1, 2016



OEM heavy-duty diesel specifications (1)

OEM	Specification	Base Industry Specification	Differences
Caterpillar	ECF-1-a	CH-4	+ Caterpillar 1P; SASH restrictions
	ECF-2	CI-4/CI-4 PLUS	+ Caterpillar C13; SASH restrictions
	ECF-3	CJ-4	None
Detroit Diesel	DFS 93K215	CH-4	+ Mitsubishi 4D34T4; - Mack T-9; + Mack T-10; + OM501LA
	DFS 93K214	CI-4 PLUS	+ OM501LA
	DFS 93K218	CJ-4	+ OM501LA; + OM646LA
	DFS 93K222	CK-4	+ OM501LA; + OM646LA; +DD13 Scuff
	DFS 93K223	FA-4	+ OM501LA; + OM646LA; +DD13 Scuff

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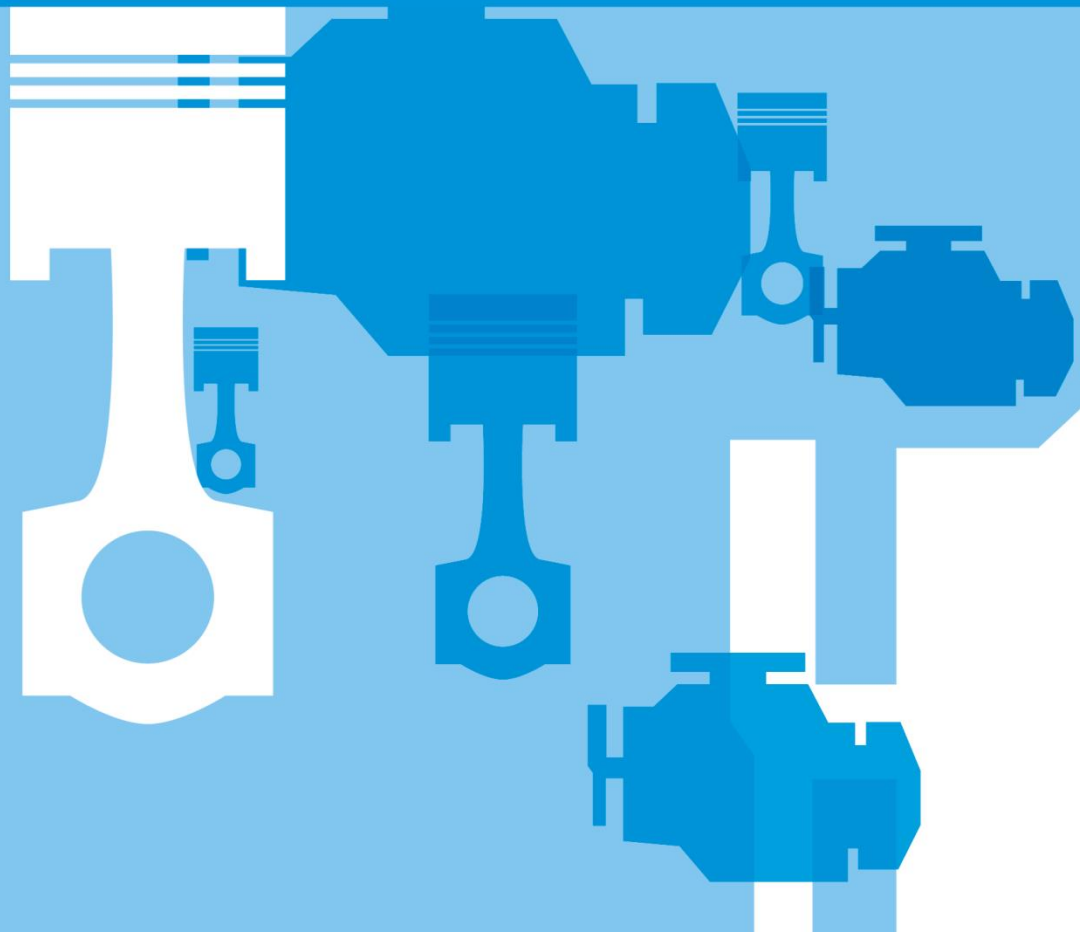
Passenger car engine oils specifications



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API and ILSAC gasoline specifications

ILSAC Category	Status	ILSAC Service Recommendations
GF-6A and GF-6B	**Current**	Meant to be introduced in 2016, but has been delayed due to the introduction of 7 new and replacement engine tests. Designed to provide improved Fuel Economy, LSPI protection for modern turbocharged engines, improved deposits protection for pistons and new improved cam chain wear performance. GF-6A designed to be backwards compatible and GF-6B to accommodate new 0W-16 viscosity grade.
GF-5	**Current but older**	Introduced in October 2010 for 2011 and older vehicles.
GF-4, GF-3, GF-2, GF-1	Obsolete	Use GF-5 where GF-4, GF-3, GF-2 or GF-1 is recommended.
API Category	**Status**	**API Recommendations**
SN, SN with Resource Conserving	**Current**	For 2011 and older vehicles, designed to provide improved high temperature deposit protection for pistons, more stringent sludge control and seal compatibility. API SN with Resource Conserving matches ILSAC GF-5 by combining API SN performance with improved fuel economy, turbocharger protection, emission control system compatibility and protection of engines operating on ethanol containing fuels up to E85.
SM - SJ	**Current but older**	For older automotive engines.
SH, SG, SF, SE, SD, SC, SB, SA	Obsolete	Not recommended for modern gasoline engines.

ILSAC

What is ILSAC?

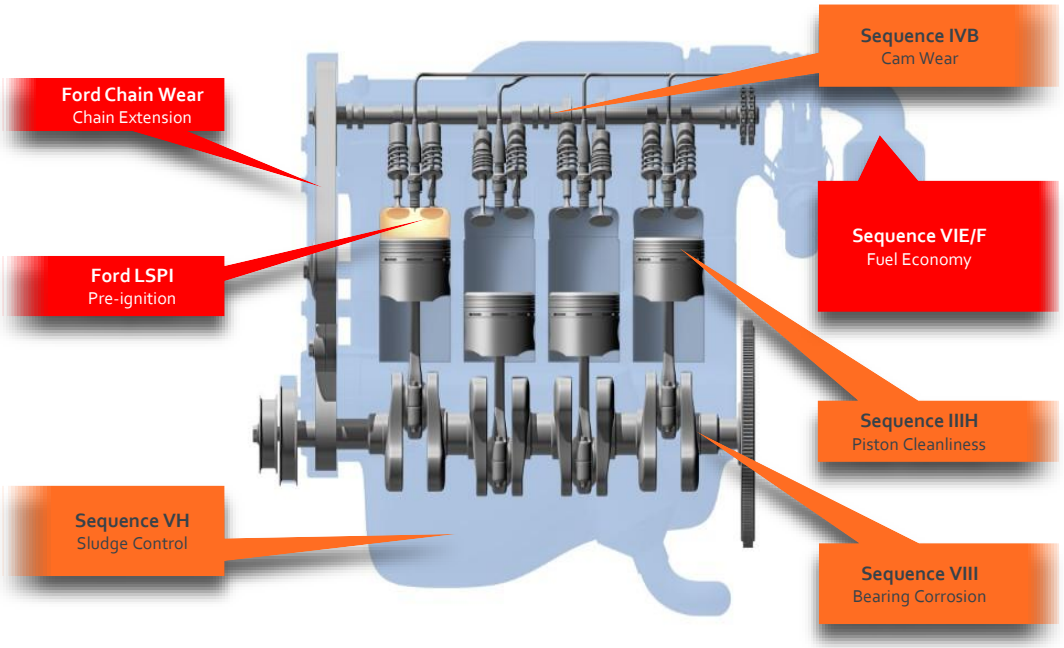
- International Lubricant Standardization and Approval Committee
- A committee consisting of major US vehicle manufacturers and JAMA formed in 1992
- Chrysler, General Motors (GM), and Ford
- Honda, Isuzu, Mazda, Mitsubishi, Nissan, Subaru, and Toyota

What does ILSAC do?

- Sets complimentary specs to API passenger car specs to include fuel efficiency and catalyst protection
- Goes beyond ‘engine protection’ which is the basis for the API specs
  - Protects the catalyst system and adds a fuel efficiency measurement
- During update of ILSAC specifications the previous specification is only valid during a one year transition period
  - API specification become obsolete when no longer required or the tests are unavailable

GF-6: An unprecedented challenge

- AC GF-6 will contain 4 replacement engine tests and 3 new engine tests
  - This is a historic level of change in a category, only the Seq. VIII is unchanged



ILSAC GF-5	
Sequence IIIG	1996 GM 3.8L PFI
Sequence IVA	1994 Nissan 2.4L PFI
Sequence VG	2000 Ford 4.6L PFI
Sequence VID	2009 GM 3.6L PFI
Sequence VIII	CLR Test 0.7L

ILSAC GF-6A/B	
Sequence III**H**	2012 FCA 3.6L PFI
Sequence IV**B**	2010 Toyota 1.5L PFI
Sequence V**H**	2013 Ford 4.6L PFI
Sequence VI**E**	2012 GM 3.6L PFI
Sequence VIII	CLR Test 0.7L
Sequence VIF	**2012 GM 3.6L PFI**
Sequence IX (Ford LSPI)	**2016 Ford 2.0L GDI**
Sequence X (Ford Chain Wear)	**2016 Ford 2.0L GDI**

OEM PCMO specifications

OEM	Specification	Base industry specification	Key differences
Chrysler	MS-6395T	GF-5/6(?)	Enhanced elastomers; + Las Vegas field trial
Ford	WSS-M2C945A/6A	GF-5	
	WSS-M2C945/6/7 B1	API SN PLUS RC	
GM	dexos1™	Gen1: GF-5 Gen2: GF-5/6 Gen 3: GF-6	GMOD instead of IIIH, enhanced VH performance; + M271SL; +GM FE test; + GM Aeration; + GM TC test; + MTM bench wear test
Honda/Acura	HTO-06	GF-5	+ Hot Tube Test

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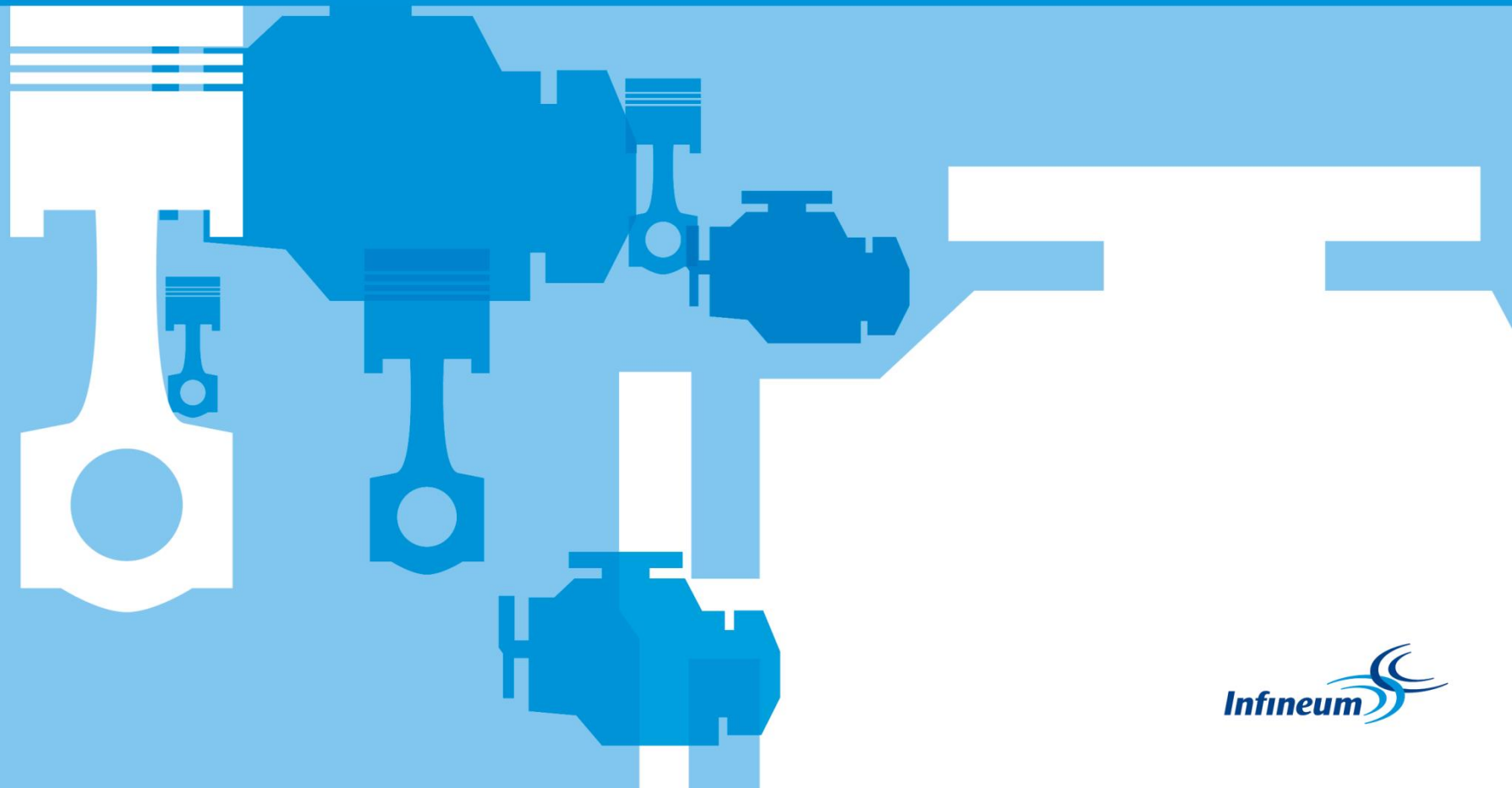
EOLCS and ACC code of practice



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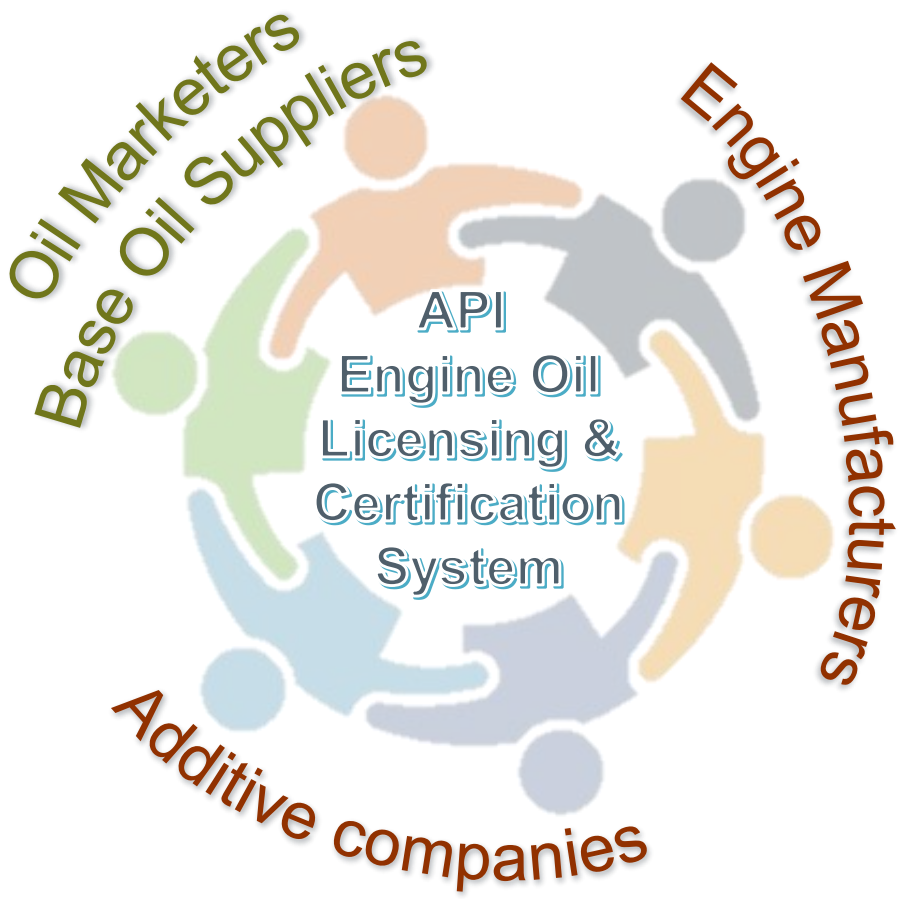
Engine oil licensing and certification system (EOLCS)



- Voluntary licensing and certification program
- Designed to define, certify, and monitor engine oil performance
- Assist customers in identifying products by licensing two (2) marks:
- Ensure compliance by auditing
  - Verifying physical and chemical properties of oil with licensing data on file at API
  - Subjecting a randomized, limited number of products to engine and bench testing
  - World-wide remit

Comparison of licensing marks

API Service Symbol

'donut'

API S_ = service categories for cars, vans, and light trucks with gasoline engines
API C_ = commercial category for heavy-duty trucks and vehicles with diesel engines

API Certification Mark

'starburst'

Current ILSAC performance level

ILSAC GF-6A and GF-6B symbol

API Certification Mark
‘starburst’
ILSAC GF-6A

API Certification Mark
‘shield’
ILSAC GF-6 B

Future ILSAC performance level

EOLCS licensing

- All engine tests must be conducted per the American Chemistry Council (ACC) code of practice
  - Marketer is ultimately responsible for product performance, however they may utilize the following guidelines in lieu of engine testing, when appropriate (fully explained in API 1509 document):
  - API Base Oil Interchange (BOI)
  - API Viscosity Grade Read-Across (VGRA)
- Marketer must disclose:
  - physical and chemical properties
  - bench test data
  - product traceability code
- Marketer must agree to monitoring and enforcement procedures
- Each viscosity grade and brand requires an individual license

ACC code of practice: what is it?

- Officially called the ACC ‘Petroleum Additives Product Approval Code of Practice’
- ACC is the American Chemistry Council, which is involved in a wide spectrum of activity affecting the chemical industry in North America
- For our purposes, the ACC represents the North American lube additive industry
- It’s code of practice is a minimum standard covering lubricant additive validation and reporting
- Maintains consistent quality of the lubricant development process through guidelines for program management
- Code does not . . .
  - Establish needs or develop tests; set limits; deal with labeling or licensing; after market testing

ACC code of practice: main features

- Engine Testing:
  - Test stands are calibrated, referenced & monitored with ASTM Test Monitoring Centre (TMC)
  - Scheduled tests are pre-registered with monitoring agency (TMC) and can only be run in stands meeting acceptance criteria
  - Scheduled tests can be placed at a laboratory of choice, but test stands are randomly assigned
  - Test results are severity adjusted then judged against criteria for averaging results known as MTEP (multiple test evaluation procedures)
- Additive package formulation
  - Minor formulation modifications are controlled against allowed limits and criteria (16 detailed sets of guidelines in Appendix H and I of the ACC code)
- Presentation of results
  - Results are communicated to customer via a Candidate Data Package (CDP)
- Compliance - Annual internal and external audits

Base oil interchange (BOI) guidelines

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.

(API 1509)

- Developed to improve efficiency while maintaining confidence in engine oil performance when interchanging base stocks
- Based on engine test data demonstrating that base stock changes within a defined range have no significant impact on the tests/parameters of interest
- May be quite simple (i.e. no restriction among API groups) or subject to numerous criteria on saturates, sulfur content, viscosity index (VI) and base oil viscosity (BOV)

BOI example – Seq. IVA

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.

Viscosity grade read-across (VGRA) guidelines

In certain situations, data generated from one viscosity grade of a given engine oil formulation may be extrapolated to another viscosity grade that uses the same additive technology by means of a practice commonly referred to as "read-across" (See Tables F-1 through F-13).

These Viscosity-Grade Engine Testing Guidelines can be used to complete a testing program using the most severe viscosity grade for each individual test for the grades being licensed. Engine tests shall be registered using the ACC Code. No read-across or substitute data are permitted for physical and chemical analyses or for bench tests (except as allowed in F.1.3 and F.4); that is, all specified physical and chemical analyses must be run on the final formulation. Proposed changes to the read-across tables or F.1.3 should be sent to the Chair of API's Base Oil Interchange (BOI)/Viscosity Grade Read-Across (VGRA) Task Force or API. The proposal must include a justification and supporting data for such change.

(API 1509)

- Similar to BOI, developed to improve efficiency
- General principles of VGRA include read-across from most difficult to less-difficult viscosity grades
  - From high viscosity modifier (VM) treat to low VM treat
  - From high volatility base stock to low volatility base stocks

VGRA example – Seq. IVA

Table F-6—Groups I, II, III and IV Viscosity Read-Across: Sequence IVA Test

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

Notes:

1. X = read-across is permitted for the viscosity grades identified based on data and some applications of the technical principles approved by API BOI/VGRA Task Force and API Lubricants Committee.
2. A dash (—) means that read-across is not permitted; NA = not applicable.
3. New viscosity grades and associated read-across are allowed if the requirements described in F.1.3 are met.
4. Tested formulations containing Group V stocks must contain an equal amount of the same Group V base stock (e.g., ester) in the finished oil blend for application of viscosity grade read-across.

[a]Read-across permitted if requirements in F.1.3 are met.

ILSAC GF-6 approval cost

Test	Cost
Seq. IIIH	$59k
Seq. IVB	$57k
Seq. VH	$63k
Seq. VIII	$15k
Seq. VIE	$45k
Seq IX	$19K
Seq X	$48K
Bench	$9k
TOTAL	**$315k**

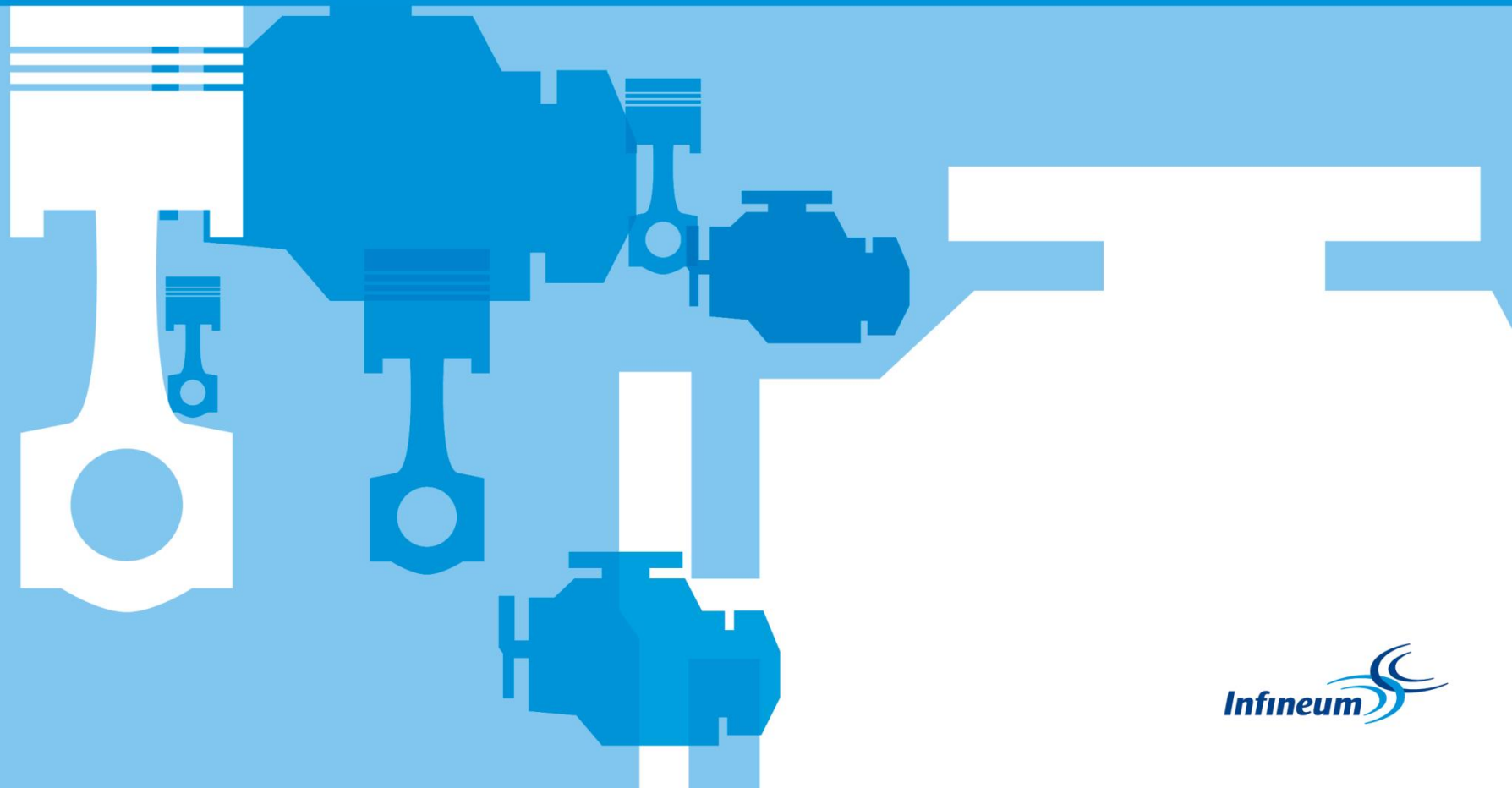
Total cost assumes 1st time passes for each test, and only offers limited viscosity grade and base oil coverage

API CK-4 estimated approval cost

Test	Cost
Caterpillar C13	$185k
Caterpillar 1N	$32k
Cummins ISB	$86k
Cummins ISM	$113k
Roller Follower Wear Test	$13k
Mack T-11	$92k
Mack T-12	$160k
Volvo T-13	$166k
Caterpillar C13 Oil Aeration Test	$23k
Seq. IIIH	$59k
Bench	$6k
TOTAL	**$935k**

Similar to PCMO, total cost of assumes 1st time passes for each test

European specification system



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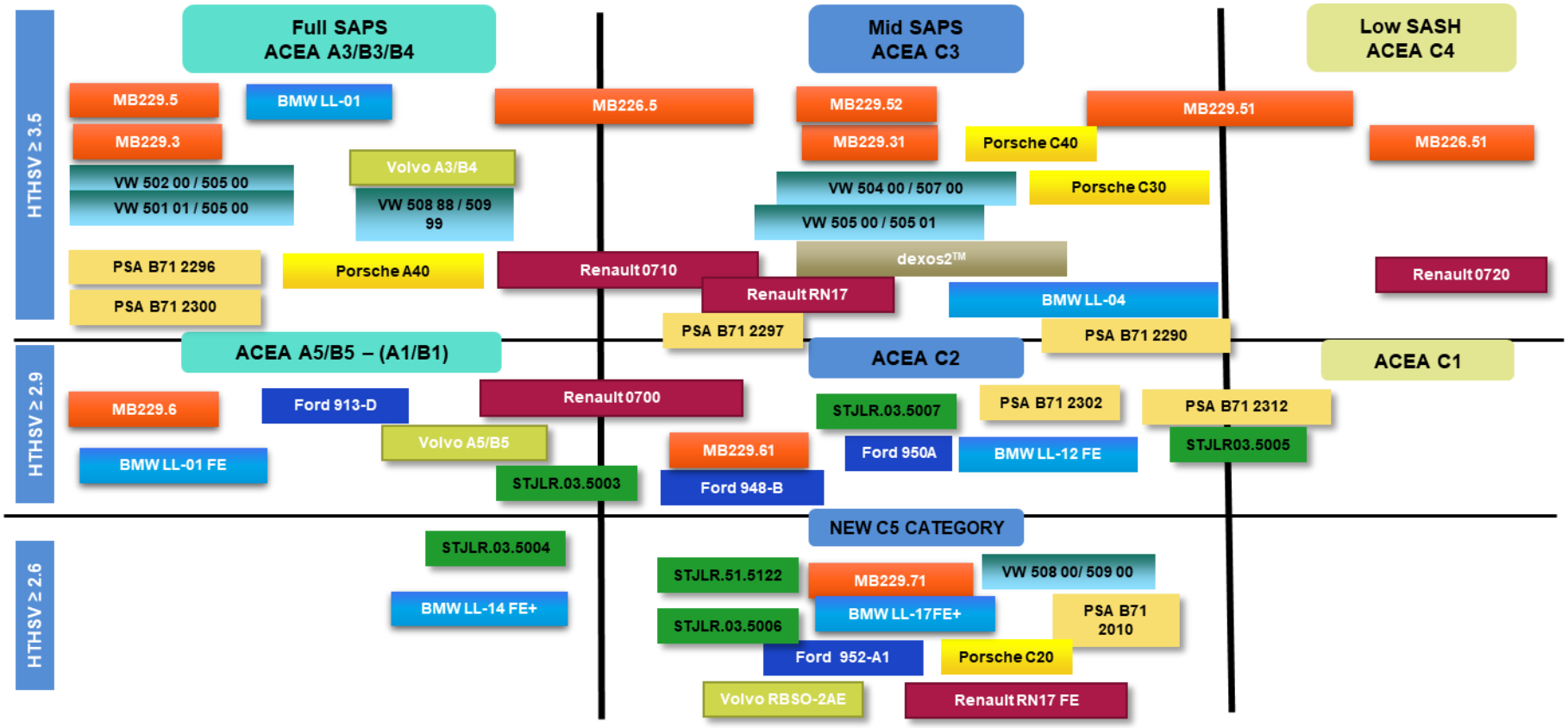
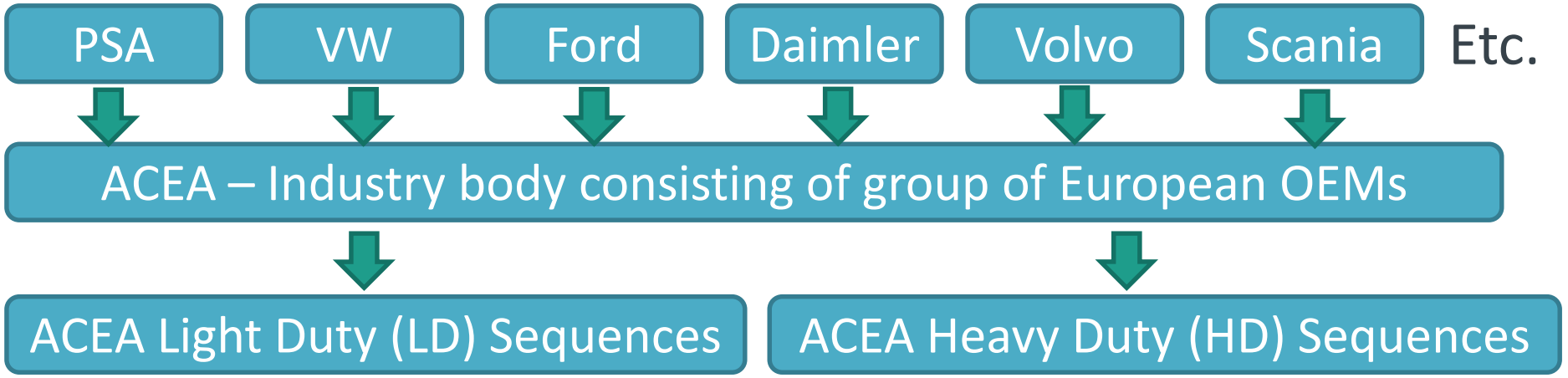
European OEM specifications



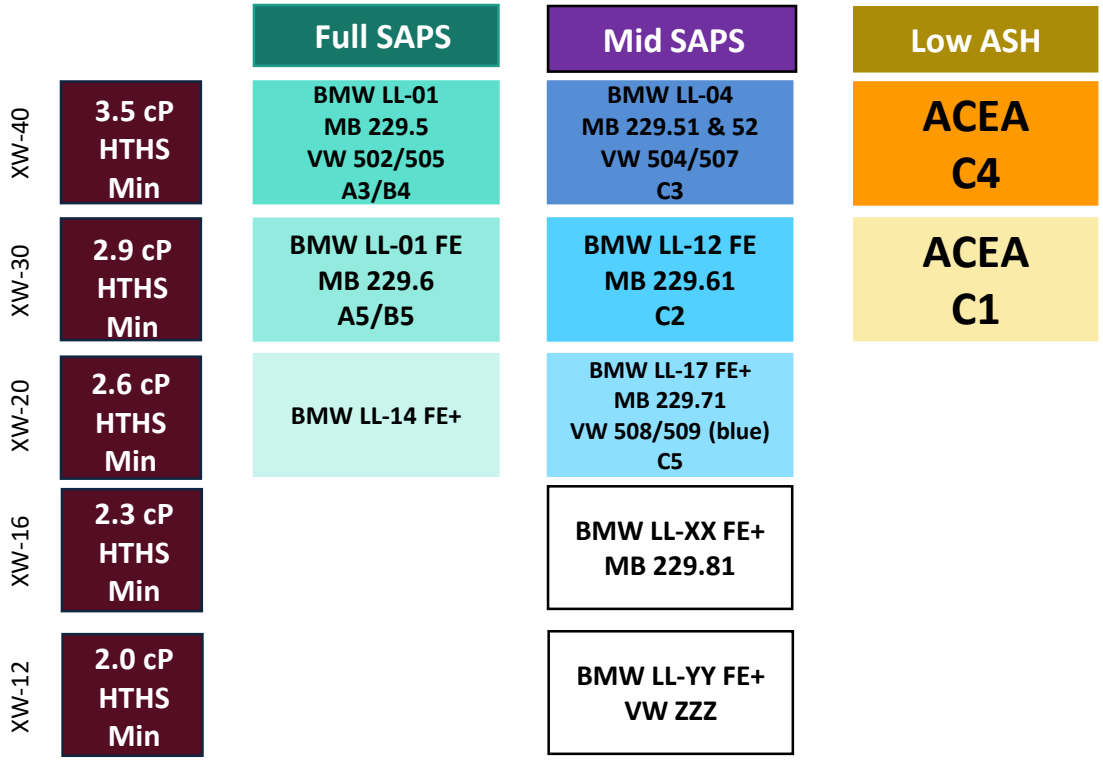
ACEA Sequences



- Covers lubricants for passenger car diesel and gasoline vehicles
- Covers lubricants for heavy duty trucks and buses

- Define a minimum "baseline" quality level for lubricants to be used in ACEA members' engines
- Are self-certified – there is no formal approval body.
  - But oils must conform to a specified quality system (EELQMS)
  - This includes compliance with ATC and ATIEL codes

Market segmentation for German OEM and ACEA specifications



- NA OEM specs are predominately Full SAPs (>1.0% SASH)
- North America gasoline quality a concern by some in move to Mid- SAPS
- Mid SAPS was predominantly used for diesel vehicles but this is changing
- OEMS Future direction towards Mid SAPS and lower viscosity
  - Enables FE goals
  - Emissions Protection (GPF)

ACEA 2016 sequences

ACEA LD Sequences

Gasoline & Light Duty Diesel Engine Oils
A/B Categories

A3/B3-16 | A3/B4-16 | A5/B5-16

Catalyst & GPF compatible Engine Oils for Gasoline & Light Duty Diesel Engines
C-Categories

C1-16 | C2-16 | C3-16 | C4-16 | C5-16

ACEA HD Sequences

Heavy Duty Diesel Engine Oils
E-Categories

E4-16 | E6-16 | E7-16 | E9-16

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Summary

- OEMs continue to challenge the oil and additive industries with increased quality level requirements
- Marketers must offer oils that meet both industry and OEM specifications
- The number and complexity of industry and OEM specifications increase as OEMs introduce new hardware and emission system solutions
- Diversity in specification requirements cause increased fragmentation of products in the marketplace

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