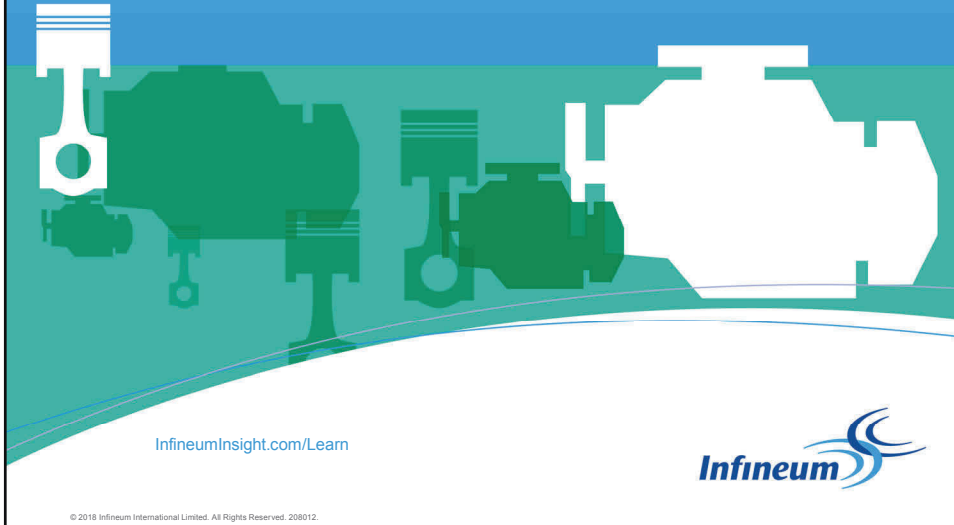


Engine oil specifications



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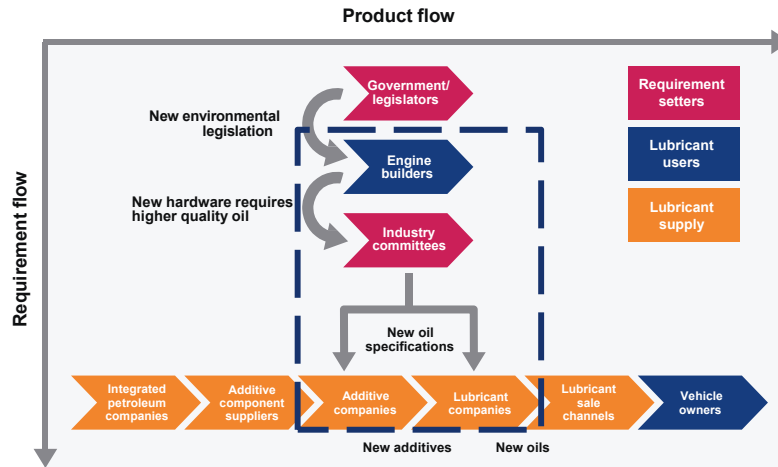
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Outline

- 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

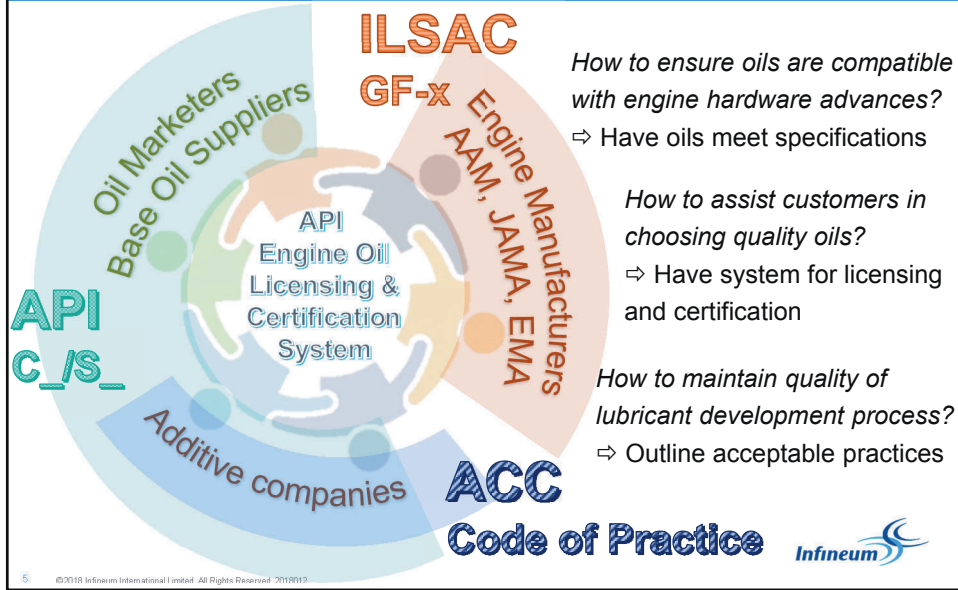


Organisations classifying engine performance

- 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



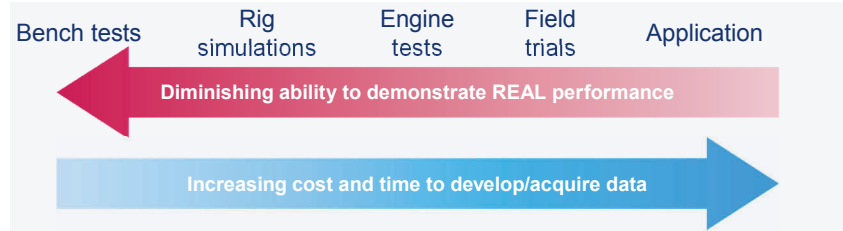
Industry trade organizations and responsibilities (North America)



Industry trade organizations and responsibilities (Global)

Description	North America	Europe	Japan
Engine builders (passenger car)	AAM, JAMA	ACEA	JAMA
Engine builders (commercial)	EMA	ACEA	JAMA
Oil marketers base oil suppliers	API	ATIEL	JASO
Additive companies	API, ACC	ATC	
Specifications	API, ILSAC	ACEA	JASO
Test procedures	ASTM	CEC	JASO
Approvals	API		

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



Heavy-duty specifications



API diesel specifications

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



API diesel specifications

API Category	Status	API recommendations
CI-4	Current	<p>Introduced in 2002</p> <p>To meet 2004 exhaust emission standards (implemented in 2002)</p> <p>For engines with EGR using up to 0.5% sulfur in fuel</p> <p>Can be used in CD, CE, CF-4, CG-4 and CH-4 applications</p> <p>Some may qualify for CI-4+ designation</p>
CH-4	Current	<p>Introduced in 1998</p> <p>To meet 1998 exhaust emission standards</p> <p>Up to 0.5% sulfur in fuel</p> <p>Can be used in CD, CE, CF-4 and CG-4 applications</p>
CA, CB, CC, CD, CD-II*, CE, CF, CF-2*, CF-4, CG-4	Obsolete	Not recommended for modern diesel engines

* Specifications for two-stroke diesel engines



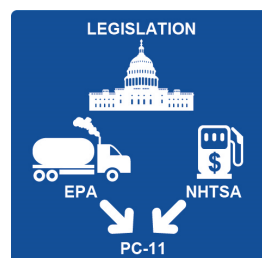
API CJ-4: overview

- API CJ-4 developed as a result of changes in North American emissions regulation:
 - ten-fold reduction in NO_x and particulate matter vs. October 2002 limits
 - exhaust after treatment (DPF, SCR) required for virtually all engines, and on-highway diesel sulfur reduced from 500 ppm to 15 ppm
- API CJ-4 specification highlights:
 - imposes chemical limits to reduce emissions and prevent interference with emission control systems:
 - Phosphorus $\leq 0.12\%$ (m)
 - Sulfur $\leq 0.4\%$ (m)
 - SASH (sulfated ash) $\leq 1.0\%$ (m)
 - introduced four (4) new tests to ensure adequate protection of new technology
- API licensing started October 15, 2006

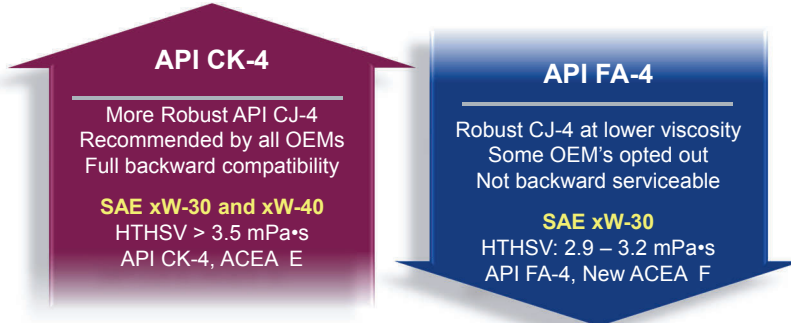


API CK-4 & FA-4: Oxidation & Fuel Economy

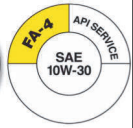
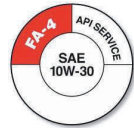
- New fuel economy and greenhouse gas rules began phased implementation in 2014 with full effect in 2018
 - Reduce CO₂ by 270 million tons and save 530 million barrels of oil
- At the June 2011 ASTM meeting, the EMA issued a formal request for a new API performance category to help meet these new regulations
- 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



API CK-4 & FA-4: Why 2 API oil categories?



API CK-4 has the same durability requirements as API FA-4 to minimize risks associated with the new lower viscosity fuel economy grades



Note: Upper left hemisphere can be any contrasting color.



API CK-4 & FA-4: Test requirements

- Combination of New and Carry forward tests from API CJ-4

	Test	Performance Parameters	Fuel Sulfur
Legacy Tests	Caterpillar C13	Piston Deposits, Oil Consumption	15 ppm
	Caterpillar 1N	Aluminum Piston Deposits, Oil Consumption	500 ppm
	Cummins ISB	Valve Train Wear	15 ppm
	Cummins ISM	Valve Train Wear, Filter Plugging, Sludge	500 ppm
	Roller Follower Wear Test	Roller Follower Pin Wear	500 ppm
	Mack T-11	Soot Induced Viscosity Increase	500 ppm
	Mack T-11A	Sooted Oil Low Temperature Pumpability	500 ppm
	Mack T-12	Ring/Liner Wear parameters only	15 ppm
	Kurt Orphan 90 cycle	Shear Stability Bench Test	No Fuel Used
New	Volvo T-13	Oxidation	15 ppm
	Caterpillar C13 Oil Aeration Test (COAT)	Oil Aeration	15 ppm

- Add OM 501LA, OM 646LA and Volvo D12D (or their replacements), and the DD13 Scuff test for OEM specifications



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



OEM heavy-duty diesel specifications (2)

OEM	Specification	Base Industry Specification	Differences
Mack	EO-N	CI-4	Enhanced Mack T-10, T-8E, Cummins M11-EGR & Seq. IIIF requirements
	EO-N Premium Plus '03	CI-4 PLUS	Enhanced Mack T-11, T-10, Cummins M11-EGR & Seq. IIIF requirements
	EO-O Premium Plus	CJ-4	Enhanced Cummins ISM, ISB & Mack T-12 performance; + Volvo D12D; + Seq. IIIG
	EOS-4.5	CK-4	Enhanced Cummins ISM, ISB, Mack T-12 & Volvo T-13 performance; + Volvo D12D



OEM heavy-duty diesel specifications (3)

OEM	Specification	Base Industry Specification	Differences
Cummins	CES 20078	CI-4PLUS	+ Seq. IIIF wear; + Mitsubishi 4D34T4; + min TBN
	CES 20081	CJ-4	Enhanced Cummins ISM, ISB & Mack T-12 performance
	CES 20086	CK-4	Enhanced Cummins ISM, ISB, Mack T-12 & Volvo T-13 performance
	CES 20087	FA-4	Enhanced Cummins ISM, ISB, Mack T-12 & Volvo T-13 performance



Passenger car engine oils specifications



API and ILSAC gasoline specifications

ILSAC Category	Status	ILSAC Service Recommendations
GF-5	Current	Introduced in October 2010 for 2011 and older vehicles, designed to provide improved high temperature deposit protection for pistons and turbochargers, more stringent sludge control, improved fuel economy, enhanced emission control system compatibility, seal compatibility and protection of engines operating on ethanol containing fuels up to E85.
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	Current	For 2010 and older automotive engines.
SL	Current	For 2004 and older automotive engines.
SJ	Current	For 2001 and 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



API SN, SN-RC and ILSAC GF-5 overview

- API SN designed to have:
 - Improved deposits control
 - Stringent sludge control
 - Seals compatibility
- API SN-RC (Resource Conserving) and ILSAC GF-5 provide additional benefits, assisting OEMs in meeting regulatory requirements and providing additional benefits to the end-user:
 - Improved fuel economy (Corporate Average Fuel Economy Requirements, CAFE)
 - Emissions system protection (minimum limit on phosphorus retention)
 - Turbocharger protection
 - Engine protection for fuels containing up to 85%(m) ethanol (E85)
- Same engine test requirements as for API SN-RC
- In practice, ILSAC GF-5 finds application only to grades favorable to fuel economy:
 - e.g. 0W-20, 0W-30, 5W-20, 5W-30, 10W-30



API SN & ILSAC GF-5 Phosphorus and Sulfur limits

ILSAC GF-5 has equal or tighter chemical requirements than the API SN category depending on viscosity grade

SAE Grades, if specified	ILSAC GF-5	API SN	
	0W-XX, 5W-XX, 10W-XX	0W-16, 5W-16, 0W-20, 5W-20, 0W-30, 5W-30, 10W-30	Others
Phosphorus, %m			
Min.	0.06	0.06	0.06
Max.	0.08	0.08	-
Sulfur, %m			
Max.	0.5 (0W-XX, 5W-XX) 0.6 (10W-30)	0.5 0.6 (10W-30)	-



Engine tests for API SN, SN-RC and ILSAC GF-5

Test	Performance Parameters
Sequence IIIG or Sequence IIH	Piston deposits and oxidation control
Sequence IIIGA or ROBO#	Viscosity of aged oil (only required for certain viscosity grades)
Sequence IIIGB* or Sequence IIHIB*	Phosphorus retention
Sequence IVA	Wear control
Sequence VG	Sludge and varnish control
Sequence VIII	Bearing corrosion resistance
Sequence VID*	Fuel economy

*Sequence VID and Sequence IIIGB/IIHIB required only for API SN-RC/ILSAC GF-5

ROBO Test (Romaszewski Oil Bench Oxidation test).



API SN PLUS, SN PLUS - RC

- Request from 10 automakers to come up with a supplemental standard to the current API SN gasoline engine oil spec to address low-speed pre-ignition (LSPI) problem in turbocharged direct injection gasoline engines.
- On November 9, 2017, API Lubricants Standards Group approved the adoption of SN PLUS.
- Addition of Sequence IX (Ford LSPI) test to API SN is the only direct change to specification.
- Oils satisfying API SN PLUS, SN PLUS – RC can also effectively lubricate engines calling for API SN, SN-RC or ILSAC GF-5



API SN PLUS, SN PLUS – RC engine tests

Test	Performance Parameters
Sequence IIIG or Sequence IIH	Piston deposits and oxidation control
Sequence IIIGA or ROBO#	Viscosity of aged oil (only required for certain viscosity grades)
Sequence IIIGB* or Sequence IIHIB*	Phosphorus retention
Sequence IVA	Wear control
Sequence VG	Sludge and varnish control
Sequence VIII	Bearing corrosion resistance
Sequence VID*	Fuel economy
Sequence IX	Low speed pre-ignition

*Sequence VID and Sequence IIIGB/IIHIB required only for API SN PLUS - RC

ROBO Test (Romaszewski Oil Bench Oxidation test).



OEM PCMO specifications

OEM	Specification	Base industry specification	Key differences
Chrysler	MS-6395T	GF-5	Enhanced elastomers; + Las Vegas field trial
Ford	WSS-M2C945A/6A	GF-5	
GM	dexos1™	GF-5	Enhanced Seq. IIIG, VG performance; - Seq. IVA; + TU3; + TU5; + M271SL; + M111FE; + GM OP1; + GM Aeration; + OPEL RNT
Honda/Acura	HTO-06	GF-5	+ Hot Tube Test



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:
 - 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



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

Test Run on	Can Be "Read-Across" to:												
	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*	X*	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.
*Read-across permitted if requirements in F.1.3 are met.



ILSAC GF-5 approval cost

Test	Cost
Seq. IIIG	\$59k
Seq. IVA	\$23k
Seq. VG	\$63k
Seq. VIII	\$15k
Seq. VID	\$29k
Bench	\$9k
TOTAL	\$198k

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. IIIG	\$59k
Bench	\$6k
TOTAL	\$935k

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



European specification system



ACEA Sequences

PSA VW Ford Daimler Volvo Scania Etc.

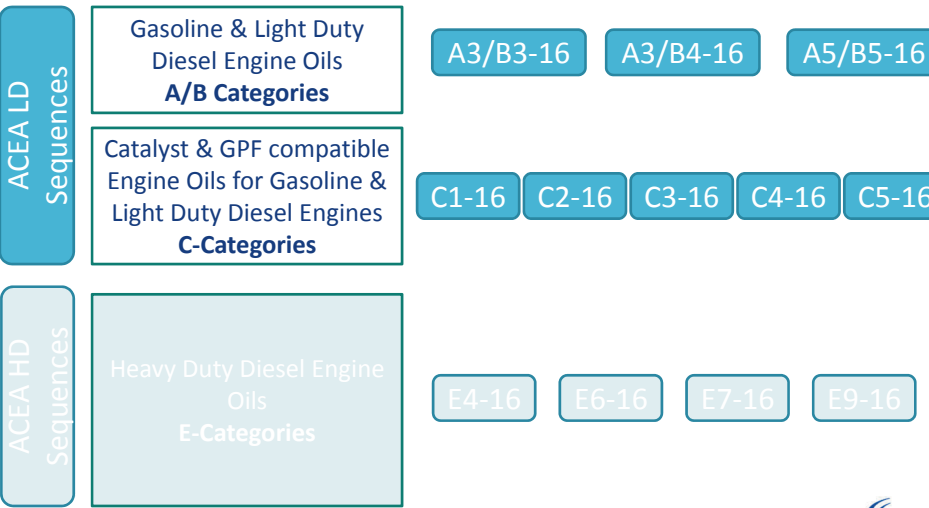
ACEA – Industry body consisting of group of European OEMs

ACEA Light Duty (LD) Sequences ACEA Heavy Duty (HD) Sequences

- Covers lubricants for passenger car diesel and gasoline vehicles
- 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



ACEA 2016 Sequences



Important Bench and Analytical Tests for ACEA A/B and C Categories

Lubricant property	Test	A3/B3	A3/B4	A5/B5	C1	C2	C3	C4	C5
"SAPS" Levels	Sulphated Ash (ASTM D874)	H	H	H	L	M	M	L	M
	Phosphorus (ASTM D5185)	report			L	M	M	M	M
	Sulphur (ASTM D5185)	report			L	M	M	L	M
Total Base Number	TBN (ASTM D2896)	M	H	M	L				
High Temperature Viscosity	HTHS (CEC L-036-90)	H	H	M	M	M	H	H	L
Oxidation with Biodiesel	"L-109" (CEC L-109)	X	X	X	X	X	X	X	X
Elastomer Compatibility	Seals Tests (CEC L-112-16)	X	X	X	X	X	X	X	X

Catalyst-compatible oils



Important Bench and Analytical Tests for ACEA A/B and C Categories

Lubricant property	Test	A3/B3	A3/B4	A5/B5	C1	C2	C3	C4	C5
"SAPS" Levels	Sulphated Ash (ASTM D874)	≥ 0.9 ≤ 1.5	≥ 1.0 ≤ 1.6	≤ 1.6	≤ 0.5	≤ 0.8	≤ 0.8	≤ 0.5	≤ 0.8
	Phosphorus (ASTM D5185)	report			≤ 0.05	≥ 0.07 ≤ 0.09	≥ 0.07 ≤ 0.09	≤ 0.05	≥ 0.07 ≤ 0.09
	Sulphur (ASTM D5185)	report			≤ 0.2	≤ 0.3	≤ 0.3	≤ 0.2	≤ 0.3
Total Base Number	TBN (ASTM D2896)	≥ 8.0	≥ 10.0	≥ 8.0	L				
High Temperature Viscosity	HTHS (CEC L-036-90)	≥ 3.5	≥ 3.5	≥ 2.9 ≤ 3.5	M	M	H	H	L
Oxidation with Biodiesel	"L-109" (CEC L-109)	X	X	X	X	X	X	X	X
Elastomer Compatibility	Seals Tests (CEC L-112-16)	X	X	X	X	X	X	X	X

Catalyst-compatible oils



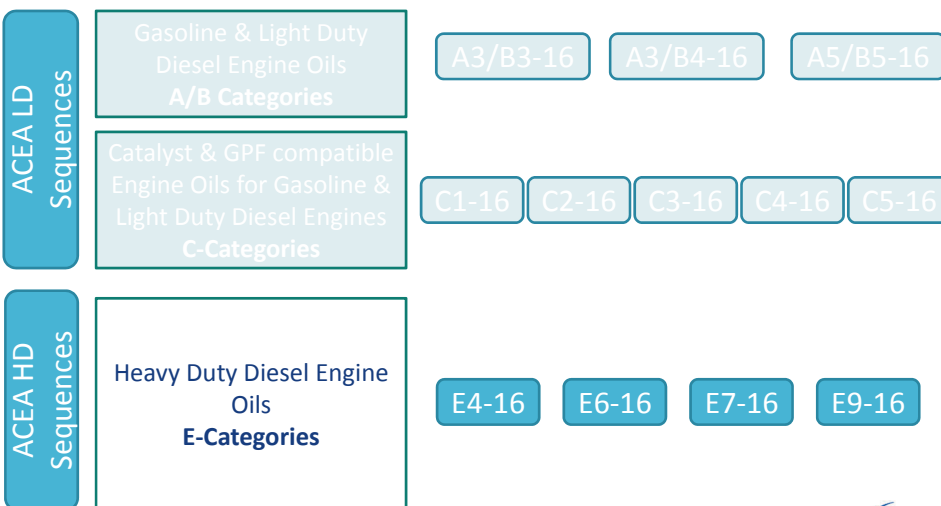
Engine tests for ACEA A/B and C categories

Lubricant property	Test	Engine supplier	A3/B3	A3/B4	A5/B5	C1	C2	C3	C4	C5
Gasoline DI engine cleanliness	CEC L-111-16 (EP6CDT)	Peugeot	X	X	X	X	X	X	X	X
Low temperature sludge	ASTM D6593-00 (Sequence VG)	Ford	X	X	X	X	X	X	X	X
Black sludge	Currently using non-CEC test (M271)	Daimler	X	X	X	X	X	X	X	X
Fuel economy	CEC L-054-96 (M111)	Daimler			X	X	X	X	X	X
Medium temperature oil dispersion	CEC L-106-16 (DV6C)	Peugeot	X	X	X	X	X	X	X	X
Wear	CEC L-099-08 (OM646LA)	Daimler	X	X	X	X	X	X	X	X
DI diesel Piston cleanliness & Ring sticking	CEC L-078-99 (VW TDI)	VW	X	X	X	X	X	X	X	X
Effects of biodiesel	CEC L-104-16 (OM646LA Bio)	Daimler		X	X	X	X	X	X	X

Catalyst-compatible oils



ACEA 2016 Sequences



ACEA E categories: heavy-duty diesel engine oils

ACEA E4

- **Excellent** control of piston cleanliness, wear, soot handling and lubricant stability
- It is recommended for highly rated diesel engines meeting Euro I, Euro II, Euro III, Euro IV and Euro V emission requirements and running under **very** severe conditions
- It is suitable for engines **without** particulate filters, and for **some** EGR engines and **some** engines fitted with SCR NOx reduction systems

ACEA E6

- **Excellent** control of piston cleanliness, wear, soot handling and lubricant stability
- It is recommended for highly rated diesel engines meeting Euro I, Euro II, Euro III, Euro IV, Euro V **and Euro VI** emission requirements and running under **very** severe conditions
- It is suitable for EGR engines, with or without particulate filters, and for engines fitted with SCR NOx reduction systems



ACEA E categories: heavy-duty diesel engine oils

ACEA E7

- **Effective** control with respect to piston cleanliness and bore polishing. It further provides **excellent** wear control, soot handling and lubricant stability
- It is recommended for highly rated diesel engines meeting Euro I, Euro II, Euro III, Euro IV and Euro V emission requirements and running under severe conditions
- It is suitable for engines **without** particulate filters, and for **most** EGR engines, and **most** engines fitted with SCR NOx reduction systems

ACEA E9

- **Effective** control with respect to piston cleanliness and bore polishing. It further provides **excellent** wear control, soot handling and lubricant stability
- Recommended for highly rated diesel engines meeting Euro I, Euro II, Euro III, Euro IV Euro V **and Euro VI** emission requirements and running under severe conditions
- It is suitable for engines with or without particulate filters, and for most EGR engines and for most engines fitted with SCR NOx reduction systems



Important Bench and Analytical tests for ACEA E Categories

Lubricant property	Test	E4	E6	E7	E9
"SAPS" Levels	Sulphated Ash (ASTM D874)	H	M	H	M
	Phosphorus (ASTM D5185)	-	L	-	M
	Sulphur (ASTM D5185)	-	L	-	M
Total Base Number	TBN (ASTM D2896)	H	L	M	L
High Temperature Viscosity	HTHS (CEC L-036-90)	H	H	H	H
Oxidation with Biodiesel	"L-109" (CEC L-109)	X	X	x	X



Important Bench and Analytical tests for ACEA E Categories

Lubricant property	Test	E4	E6	E7	E9
"SAPS" Levels	Sulphated Ash (ASTM D874)	≤ 2.0	≤ 1.0	≤ 2.0	≤ 1.0
	Phosphorus (ASTM D5185)	-	≤ 0.08	-	≤ 0.12
	Sulphur (ASTM D5185)	-	≤ 0.3	-	≤ 0.4
Total Base Number	TBN (ASTM D2896)	≥ 12	≥ 7	≥ 9	≥ 7
High Temperature Viscosity	HTHS (CEC L-036-90)	≥ 3.5	≥ 3.5	≥ 3.5	≥ 3.5
Oxidation with Biodiesel	"L-109" (CEC L-109)	X	X	x	X



Engine tests for ACEA E Categories

Lubricant property	Test	Engine supplier	E4	E6	E7	E9
Wear	CEC L-099-08 (OM646LA)	Daimler	X	X	x	x
Soot in oil	ASTM D 5967 (Mack T-8E) ¹	Volvo North America	X	X	X	X
Bore polishing Piston Cleanliness	CEC L-101-08 (OM501LA)	Daimler	X	X	X	X
Soot induced wear	ASTM D7468 (Cummins ISM)	Cummins			X	X
Wear (liner-ring-bearings)	ASTM D7422 (Mack T-12)	Volvo North America		X	X	X
Effects of biodiesel	CEC L-104-16 (OM646LA Bio)	Daimler		X		X

¹ E4, E6, E7 and E9 all now use Mack T-8E. However Mack T11 (ASTM D7156) results obtained as part of API CI-4, CI-4 Plus, CJ-4, CK-4 or FA-4 approval program can be used in place of Mack T8E.



ACEA 2016 – what's changed?

- **Light Duty Sequences**
 - A1/B1 removed – Requirements covered by A5/B5 (HTHS 2.9-3.5) and C5 (HTHS 2.6)
 - C5 introduced – New Mid SAPS category with improved FE benefits (HTHS 2.6 vs 2.9-3.5)
- **New Lab Bench Test**
 - HTHS at 100°C report requirement introduced – all LD/HD categories
 - Harmonisation of PDSC requirements – HD only
 - CEC L-109 oxidation test replaces GFC oxidation test in LD categories
 - Introduced as new test for HD
 - CEC L-39 elastomer test replaced by new CEC L-112 elastomer compatibility test – all LD/HD categories



ACEA 2016 – what's changed?

- **New Engine Tests**
 - EP6 (CEC L-111) introduced – LD only
 - GDI TC engine – piston cleanliness (main parameter) and TC deposit (safety parameter)
 - DV4 (CEC L-93) replaced by new DV6 (CEC L-106) – LD only
 - OM646Bio (CEC L-104) with performance limits (LD + HD (E6/E9 only))
- **End of life Engine Tests**
 - TU3 and TU5 have been withdrawn from the ACEA Sequences
- **“State of flux” Engine Tests**
 - Seq VG is predicted to become unavailable soon
 - Seq VH to be introduced once ready (as per ACEA 2016 footnote)
 - The new M271EVO sludge test is still under development by CEC
 - Currently a Daimler version is in use (no CEC number)
 - Mack T8E replaces T11 for HD E9 – T11 still allowable alternative



ACEA 2016

Timetable for ACEA Product Claims:

Sequence issue	First allowable use	Mandatory for new claims	Oils with this claim may be marketed until
2004	1 st November 2004	1 st November 2005	31 st December 2009
2007	1 st February 2007	1 st February 2008	23 rd December 2010
2008	22 nd December 2008	22 nd December 2009	22 nd December 2012
2010	22 nd December 2010	22 nd December 2011	22 nd December 2014
2012	14 th December 2012	14 th December 2013	1 st December 2018
2016	1 st December 2016	1 st December 2017	–

- Products may still claim ACEA 2012 and 2016 as indicated by dates above
- Next planned sequence is ACEA 2018 – still under discussion



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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