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WORLDWIDE HEAVY-DUTY AND OFF-ROAD EMISSION STANDARDS

- ON-ROAD HEAVY-DUTY VEHICLES AND ENGINES
- OFF-ROAD / NON-ROAD VEHICLES, ENGINES AND EQUIPMENT

2024/2025

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INTRODUCTION

This booklet is a pocket-sized summary of the ever-changing worldwide emissions standards for Heavy-Duty (HD) on-road vehicles and engines, and off-road / non-road mobile vehicles, engines and equipment.

The booklet covers pollutant emissions (oxides of nitrogen, hydrocarbons, carbon monoxide, particulate matter and others) for all engine, vehicle and equipment types. Additionally, it covers fuel consumption, greenhouse gas emissions (CO_2) and zero-emission vehicle standards for on-road vehicles and engines.

Emissions standards are composed of limit values, standard test cycles, testing conditions and references to the relevant fuel standards.

Complementing the emission standards, the booklet also provides an overview of on-board diagnostics and monitoring of emissions, and standards for reference fuels.

CONTENTS

GLOSSARY

ABT	Averaging Banking and Trading
CI	Compression-Ignition
COP	Conformity of Production
De-NOx	NOx aftertreatment system
DF	Deterioration Factor
EEV	Enhanced Environmentally friendly Vehicle
EGR	Exhaust Gas Recirculation
EOBD	European On-Board Diagnostics
Evap	Evaporative Emissions
FC	Fuel Consumption
FE	Fuel Economy
FEL	Family Emission Limits
FR	First Registration, entry into service
FTP	Federal Test Procedure
FUL / IUL	Full useful life / Intermediate useful life
GCW	Gross combination weight
GTR	Global Technical Regulation (UN-ECE)
GVW	Gross Vehicle Weight
GVWR	Gross Vehicle Weight Rating
HHDDE	Heavy Heavy-Duty Diesel Engine
ISC	In-Service Conformity
IUPR	In-use Performance Ratio
LDT	Light-Duty Truck
LDV	Light-Duty Vehicle
LEV	Low Emission Vehicle (CARB LEV I to LEV IV)
LHDDE	Light Heavy-Duty Diesel Engine
LPG	Liquified Petroleum Gas
MDV	Medium-Duty Vehicle
MHDDE	Medium Heavy-Duty Diesel Engine
MY	Model Year
NG	Natural Gas
NMHC	Non-Methane Hydrocarbons
NMOG	Non-Methane Organic Gases
MTBE	Methyl Tertiary Butyl Ether
NRMM	Non-Road Mobile Machinery
NR	New registrations
NTE	Not-To-Exceed
OBD	On-Board Diagnostic
OCE	Off-Cycle Emission
OMHCE	Organic Material Hydrocarbon Equivalent
OTL	OBD Threshold Limit
PEMS	Portable Emissions Measuring System
PI	Positive Ignition (=spark-ignition)
PM	Particulate Matter
PMP	Particulate Measurement Program
PN	Particulate Number
RDE	Real Driving Emissions
SCR	Selective Catalytic Reduction
SHED	Sealed Housing for Evaporative Determination
SI	Spark-Ignition = positive ignition
SORE	Small Off-Road Engine
SULEV	Super Ultra Low Emission Vehicle
TA	Type Approval
THCE	Total Hydrocarbon Equivalent
ULEV	Ultra-Low Emission Vehicle
WNTE	World Harmonized Not-To-Exceed
WWHD	World Harmonized Heavy-Duty
WWH-OBD	Worldwide Harmonized On-board Diagnostics
ZEV	Zero-Emissions Vehicle

GLOSSARY

Test cycles

CHTC	China Heavy-Duty Commercial Vehicle Test Cycle
C-WTVC	China-World Transient Vehicle Cycle
ELR	European Load Response Test
ESC	European Steady-state Cycle
ETC	European Transient Cycle
HDDTC	Heavy-Duty Diesel Transient Cycle
NRSC	Non-Road Steady-state Cycle
NRTC	Non-Road Transient Cycle
HDGTC	Heavy-Duty Gasoline Transient Cycle
SET	Steady-state Emissions Test
WHSC	Worldwide Harmonized Steady-State Cycle
WHTC	Worldwide Harmonized Transient Cycle
WHVC	World Harmonized Vehicle Cycle

Responsible regulatory agencies

European Union	European Commission
United States	Environmental Protection Agency (EPA) National Highway Transport Safety Administration (NHTSA)
California	California Air Resources Board (CARB)
Japan	Ministry of Economy, Trade and Industry (METI)
China	Ministry of Ecology and Environment (MEE)
Korea	Ministry of Environment
India	Automotive Research Association of India (ARAI)
United Nations	Economic Commission for Europe (ECE)

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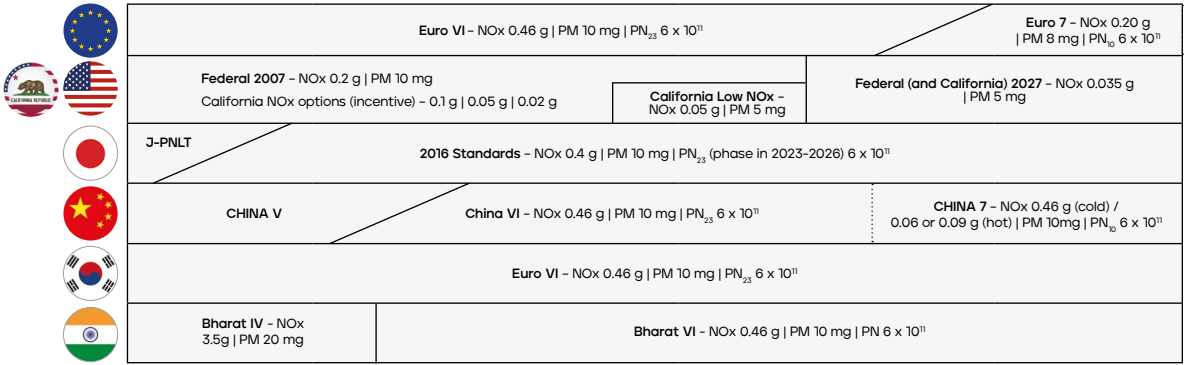
ON-ROAD POLLUTANT EMISSIONS STANDARDS

ROAD MAP FOR HEAVY-DUTY CI ENGINE POLLUTANT EMISSION STANDARDS

All units per kWh except US/California where per bhp-hr is used



All limits shown are on transient cycles.
Diagonal lines indicate phase-in of the new standard over different vehicle classes or by new types / new vehicles.
Dotted line means standard and introduction date to be confirmed.

VEHICLE CATEGORIES

Classes

Category	Description	Sub-Category	Number Of Seats	Mass Limit
M	Transport of passengers Minimum 4 wheels	M_1[a]	No more than 8 plus driver	N/A
		M_2	More than 8 plus driver	GVW ≤ 5,000 kg
		M_3		GVW > 5,000 kg
M & N	Transport of goods Minimum 4 wheels	N_1[a]	N/A	GVW[b] ≤ 3,500 kg
		N_2		3,500 < GVW ≤ 12,000 kg
		N_3		GVW > 12,000kg

Sub-Classes

EU Heavy-Duty Category	Capacity	Class	Mass Limit
M_2 & M_3	Capacity exceeding 22 passengers	Class I	Only standing passengers
		Class II	Principally for seated passengers Standing passengers possibly in the gangway
		Class III	Only seated passengers
	Capacity not exceeding 22 passengers	Class A	Only standing passengers
		Class B	Only seated passengers

Footnotes:

[a] LDV regulations apply, except under certain circumstances (see page 11), when requested by the manufacturer.

[b] GVW: Gross Vehicle Weight

Light-Duty
Medium-Duty
Heavy-Duty

HEAVY-DUTY VEHICLE ENGINE EXHAUST EMISSION STANDARDS – CHRONOLOGICAL OVERVIEW

	Introduction Date ALL	Test Cycle	Emissions Limits Steady-State / Emissions Limits Transient (g/kWh)										WNTE	
			CO	NMHC	HC	CH_4	NOx	NH_3	PM	Smoke Opacity Value (per m)	PNx10^{11} (#/kWh)	N_2O	OCE Engine Limits (g/kWh)	RDE Vehicle Limits
Euro I	Oct 1993	ECE R-49	4.5 / -	-	1.1 / -	-	8 / -	-	0.36 - 0.612[d] / -	-	-	-	-	-
Euro II	Oct 1996		4 / -	-		-	7 / -	-	0.25 - 0.15[d] / -	-	-	-	-	-
Euro III	Oct 2000	ESC[a] & ELR[a] & ETC	2.1 / 5.45	- / 0.78	0.66 / -	- / 1.6	5 / 5	-	0.10 / 0.16[c]	0.8 / -	-	-	-	-
Euro IV	Oct 2006		1.5 / 4	- / 0.55	0.46 / -	- / 1.1	3.5 / 3.5	-	0.02 / 0.03	0.5 / -	-	-	-	-
Euro V	Oct 2009		1.5 / 4	- / 0.55	0.46 / -	- / 1.1	2.0 / 2.0	-	0.02 / 0.03	0.5 / -	-	-	-	-
Euro VI	Jan 2013	WHSC[a] / WHTC	1.5 / 4	- / 0.16	0.13 /-	- / 0.5	0.4 / 0.46	10 / 10 (ppm)	0.01 / 0.01	-	8 / 6	-	NOx: 0.6 THC: 0.22 CO: 2 PM: 0.016	CF NOx: 1.5 CF PN: 1.63 From Jan 2022, cold start included (Coolant temperature 30°C)
Euro 7[b]	May 2029	WHSC[a] & WHTC	1.5	NMOG = 0.08	-	0.5	0.2	0.06	0.008	-	6	0.2	Not defined in Euro 7	See below
		RDE	1.95	NMOG = 0.105	-	0.65	0.26	0.085	-	-	9	0.26		Cold start included (Coolant temperature 30°C)

Footnotes:

[a] Only for CI engine

[b] Only one limit for both Transient and Steady-State tests

[c] For engines of swept volume less than 0.75 dm^3 per cylinder and a rated power speed of more than 3000 rev/min

[d] 2nd limit is for engine with Maximum Power ≤ 85 kW

EURO VI ENGINE EXHAUST EMISSIONS STANDARDS (CURRENTLY IN FORCE)

(Reg (EC) N° 595/2009 and implementing regulations (EU) N° 582/2011 and 64/2012)

Heavy-duty vehicle engine limit values (also shown in table on page 10)

	CO	THC	NMHC	CH_4	NOx	PM	NH_3	PN
	mg/kWh						ppm	#/kWh
WHSC (CI)	1,500	130	-	-	400	10	10	8×10^{11}
WHTC (CI)	4,000	160	-	-	460	10	10	6×10^{11}
WHTC (PI)	4,000	-	160	500	460	10	10	6×10^{11}

Footnotes:

- Scope : M_1 & N_1 with reference mass (RM) > 2,610 kg and all M_2, M_3, N_2 & N_3, with the following exceptions:
  - At the request of the manufacturer, type approval of vehicles granted under Euro VI shall be extended to its variants and versions with a reference mass between 2,380kg and 2,610kg
  - At the request of the manufacturer, type approval granted under Euro 6 (light duty may be extended to vehicles within the scope above with reference mass between 2,610kg and 2,840kg
- Application dates: new types 31st December 2012 / new vehicles 31st December 2013 (see page 14 for different stages)
- Global Test Procedure from UN-ECE GTR-4 & GTR-10
- Only worldwide harmonized driving cycles (WHTC, WHSC - page 16 & 17) are applicable
- World-Harmonized Not-to-Exceed (WNTE) procedures applied with off-cycle emission (OCE) test (page 18) and on-road test with portable emissions measurement systems (PEMS)
- Reference fuel specifications - see pages 182-187
- Extended documentation package required – alternative emission system (AES) documentation (to validate off-cycle emissions strategies), complementing the base-emission strategy (BES)
- On-board diagnostics (OBD) and in-use performance ratio (IUPR - see OBD section)
- Access to vehicle OBD, vehicle repair and maintenance information
- In-service conformity (ISC) testing performed on a sample of in-use vehicles, using conformity factor multiplier (next page) to determine target under in-service conditions

EURO VI ENGINE EXHAUST EMISSIONS STANDARDS (CURRENTLY IN FORCE)

Durability of pollution control devices, in-service conformity

All emissions levels should be respected for the normal useful life period defined in the legislation, according to vehicle category (see table).

Heavy-duty vehicle engine useful life periods

Vehicle Category	Normal useful life period (for ISC testing - maximum durability)	Minimum service accumulation period for DF determination
M_1, N_1, M_2	160,000 km or 5 years (whichever is the sooner)	160,000 km
N_2, N_3 with a maximum technically permissible mass ≤ 16t. M_3 Class I, Class II and Class A. M_3 Class B with a maximum technically permissible mass ≤ 7.5t.	300,000 km or 6 years (whichever is the sooner)	188,000 km
N_3 with a maximum technically permissible mass > 16t. M_3 Class III and M_3 Class B with a maximum technically permissible mass > 7.5t.	700,000 km or 7 years (whichever is the sooner)	233,000 km

Maximum allowed conformity factors for in-service conformity emission testing

Pollutant	Maximum Allowed Conformity Factor
CO	1.50
THC	1.50
NMHC	1.50
CH_4	1.50
NOx	1.50
PM number (PN)	1.63

EURO VI ENGINE EXHAUST EMISSIONS STANDARDS (CURRENTLY IN FORCE)

Conformity of Production (COP) and Deterioration Factors (DF) determination

COP tests are performed on an engine test bench. During the test, the engines must comply with the respective emission limits for each pollutant, as given on page 10, after the application of deterioration factors to the test results.

Deterioration Factor determination

Minimum service accumulation distances are used to determine the evolution of the different pollutants over mileage (engine bench procedure – UNECE Regulation 49 (UN R49) Annex 7).

For each pollutant, a linear regression is made using pollutant measurement on WHTC or WHSC at several steps in the procedure until reaching the targeted distance.

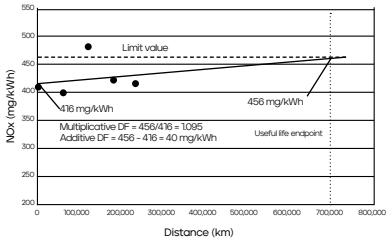
For each pollutant, a multiplicative DF (min 1.0) or additive DF (min 0.00) can then be determined by comparing the pollutant value at the beginning of the process and at the end of the normal useful life period (extrapolated value), resulting in a ratio or a difference, depending on the manufacturer's choice.

Manufacturers may develop DFs using an assigned accumulation schedule. Mixing of multiplicative and additive DFs within one set of pollutants is not permitted.

Alternatively, the assigned multiplicative deterioration factors in the table below can be applied:

Test Cycle	CO	THC[a]	NMHC[b]	CH_4[b]	NOx	NH_3	PM	PN
WHTC	1.3	1.3	1.4	1.4	1.15	1.0	1.05	1.0
WHSC								

[a] CI engines
[b] PI (SI) engines



EURO VI STAGES

Specifications of stages A to E of Euro VI

Stage	Type Approval (New Type / All Vehicles)	OCE NTE (g/kWh)	Cold Start included in PEMS Test	Power Threshold (minimum average power for a valid window)[f]	Maximum Allowed CF (PEMS)	
					NOx, CO, THC, NMHC, CH_4	PN
A/B/C[a]	From Jan 2013 to August 2019	NOx: 0.60 THC: 0.22 CO: 2.0 PM: 0.016	No[b]	20%	1.5[d]	-
D	1 Sept 2018 / 1 Sept 2019			10%		
E	1 Jan 2021 / 1 Jan 2022		Yes[c]			1.63[e]

Footnotes:

[a] Stages were introduced with amendments to conditions other than those included in this table
[b] Evaluation starts when Coolant Temperature has reached 70°C
[c] Evaluation starts when Coolant Temperature is no higher than 30°C
[d] THC only for CI / NMHC & CH_4 only for PI
[e] PN CF for PI engines + Type 1A and 1B dual fuel engines in dual fuel mode is applied in 01.2023 for New Type / 01.2024 for All Vehicles
[f] 6% for Euro 7

EURO 7* ENGINE EXHAUST EMISSIONS STANDARDS

(Regulation (EU) 2024/1257, adopted April 2024)

Scope: Heavy-duty (M_2, N_2 , M_3 & N_3)

Application dates: new types May 2028 – all new vehicles May 2029

	CO	N_2O	NMOG	CH_4	NOx	PM	NH_3	PN10
	mg/kWh							#/kWh
WHSC (CI)	1500	200	80	80	500	200	80	6 x 10^{11}
WHTC (CI & PI)								
RDE	1950	260	105	650	260	-	85	9 x 10^{11}

Euro 7 legislation is based on Euro VI:

- Emissions Procedures are equivalent to Euro VI and based on UN R49
- Real driving emission (RDE) procedure also follows UN R49 with two exceptions:
  - Annex 8 – Appendix 1: the minimum average power to determine the validity of a window is reduced from 10% (Euro VI) to 6% of the maximum engine power
  - Instead of CF application, RDE has specific limits
- RDE is applied during certification and ISC
- Reference fuel as specified for Euro VI (eFuel not included yet)
- AES / BES documentation and Anti-Tampering documentation package required
- On-board diagnostic (OBD) and on-board monitoring (OBM) - page 98ff
- On-board fuel consumption monitoring (OBFCM) for certification, conformity of production (COP) and in-service conformity (ISC) - not defined yet
- Environmental Vehicle Passport required

Durability of pollution control devices, in-service conformity

Euro 7 introduced new normal useful life periods:

Vehicle Category	Normal Useful Life Period (for ISC testing – maximum durability)	Additional Lifetime
M_1, N_1, M_2	160,000 km or 8 years (whichever is the sooner)	200,000 km or 10 years (whichever is the sooner)
N_2, N_3 with a maximum technically permissible mass ≤ 16t, M_3 Class I, Class II and Class A, M_3 Class B with a maximum technically permissible mass ≤ 7.5t	300,000 km or 8 years (whichever is the sooner)	375,000 km or 10 years (whichever is the sooner)
N_3 with a maximum technically permissible mass > 16t M_3 Class III, M_3 Class B with a maximum technically permissible mass > 7.5t	700,000 km or 12 years (whichever is the sooner)	875,000 km or 15 years (whichever is the sooner)

For the additional lifetime, a durability multiplier should be applied – it will be determined by the EU Commission once the durability fleet is analyzed.

Concerning DF, the procedure should be unchanged from Euro VI (including assigned values and minimum service accumulation period).

* The use of Roman numerals, as applied to previous heavy-duty Euro standards, has not (yet) been adopted.

EURO VI AND 7 ENGINE TEST CYCLES

WHDC - Worldwide Harmonized Heavy-Duty Certification Procedure:

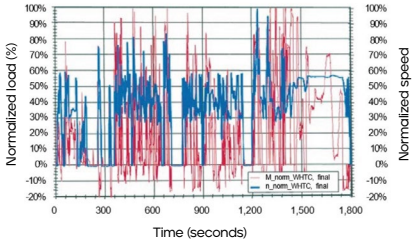
Global Technical Regulation Nr 4 (GTR 4) introduces two representative test cycles, created to cover typical driving conditions in the European Union, USA, Japan and Australia:

- WHTC: World Harmonized Transient Test Cycle
- WHSC: World Harmonized Steady-State Test Cycle
- Additionally, GTR-10 introduces WNTE (World-harmonized-Not-To-Exceed) methodology including off-cycle emissions (OCE) tests and in-service conformity (ISC) test with Real Driving test with PEMS (Portable Emission Measurement System)

WHTC - World Harmonized Heavy-Duty Transient Cycle

The WHTC is a transient test cycle (WHTC) of 1800s duration, with both cold and hot start requirements – "Soak time" between cold and hot cycle 10 +/- 1 min. Normalized engine speed and torque values over the WHTC cycle are described in the regulation.

For the final calculation, the cold start test is taken into account with a weighting factor of 14%, the hot start with a weighting factor of 86%.



EURO VI AND 7 ENGINE TEST CYCLES

WHSC - World Harmonized Heavy-duty Steady-state Cycle

The WHSC is a ramped steady-state test cycle, with a sequence of steady-state engine test modes with defined speed and torque criteria at each mode and defined ramps between these modes.

The WHSC is run from a hot start, following engine preconditioning at mode 9 for 10 minutes.

Notes:

- Engine speed and load must be changed linearly (ramped) within 20 ± 1 seconds.
- The test is run with a hot start. The engine must be preconditioned and the test sequence started within 5 minutes of shut-down.

Mode	Normalized Speed (%)	Normalized Load (%)	Mode Length*
0	Motoring	-	-
1	0	0	210
2	55	100	50
3	55	25	250
4	55	70	75
5	35	100	50
6	25	25	200
7	45	70	75
8	45	25	150
9	55	50	125
10	75	100	50
11	35	50	200
12	35	25	250
13	0	0	210

* Including 20s ramp

EURO VI AND 7 ENGINE TEST CYCLES

WNTE - World Harmonized Not-To-Exceed:

Global Technical Regulation Nr 10 (GTR 10)

Two tests were introduced:

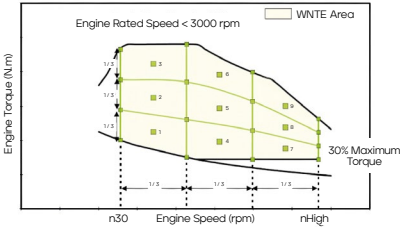
- For Engines, OCE (Off-Cycle Emissions) in a stationary engine test cycle with the measurement of 15 random modes – not applicable for spark-ignition engines
- For Vehicles, during certification and any in-service conformity procedure, RDE (Real Driving Emissions) test, using PEMS

OCE (Off-Cycle Emissions) Procedure (not defined in Euro 7: superseded by RDE testing):

Random 15 modes during stationary engine test with hot engine

Performed during the Type Approval Procedure

- The engine map is divided into a grid. The number of zones depends on the engine rated speed (If greater than 3000rpm, the number of zones is higher)
- For the test, 3 zones are randomly selected and emissions are measured for 5 modes into each selected grid
- This test can be conducted over a wide range of ambient conditions:
  - 70°C < Engine coolant temperature < 100 °C
  - Atmospheric pressure (A.p.) ≥ 82.5 kPa
  - Air temperature (K) ≤ -0.4514 x (101.3 – A.p. (kPa)) + 311 [-29 °C ≤ Ambient air temperature ≤ ~38 °C]
- Using the same principle as WHSC (2 minutes of steady points for each point including 20s maximum for transition between modes) a test sequence is created, and emissions are measured during the complete sequence and compared to OCE NTE limits



EURO VI AND 7 ENGINE TEST CONDITIONS

RDE (Real Driving Emissions) procedure:

Testing is conducted on a vehicle equipped with a PEMS (Portable Emission Measurement System) over a mix of urban, rural and motorway conditions.

The exact trip composition depends on the vehicle category:

- M_1 & N_1: 34% urban / 33% rural / 33% motorway
- M_2 & M_3 & N_2: 45% urban / 25% rural / 30% motorway
- M_2 & M_3 (Class I, II, A): 70% urban / 30% rural
- N_3: 30% urban / 25% rural / 45% motorway

The total test should represent between 4 and 8 times the reference work made during a WHTC.

Test conditions:

Ambient and vehicle parameters:

- Atmospheric pressure (pb) ≥ 82.5 kPa
- Ambient air temperature T (K) range:
  $266 (-7\ °C) \leq T \leq -0.4514 \times (101.3 - pb) + 311$
- Engine coolant temperature no higher than 30 °C
- Payload between 10% and 100%

The compliance evaluation uses the MAW (Moving Average Window) method: the mass emissions are not calculated for the complete test, but for overlapping "windows" of data starting at one-second intervals over the complete data set. The window size is defined by the work, represented by CO_2 emissions, over the window, which is equal to the work done in a WHTC.

Only valid windows are taken into account, i.e. the ones whose average power exceeds the limits defined in the Table on page 14.

To validate the RDE test, the percentage of valid windows shall be equal to or greater than 50%.

A measured conformity factor for each pollutant and each window is calculated from the measured emission value divided by the emission limit.

A conformity factor for the RDE test is calculated as shown below for each pollutant:

- $CF_{final} = 0.14 \times CF_{cold} + 0.86 \times CF_{warm}$
- CF_{cold} = the highest conformity factor of all windows measured during the period of cold operation of the test (below 70 °C coolant temperature)
- CF_{warm} = the 90th cumulative percentile of the conformity factors after the coolant temperature has reached (70 °C)
- CF_{final} for each pollutant may not exceed the maximum allowed conformity factor for that pollutant set out in the table on page 12.

EURO III ENGINE TEST CONDITIONS AND LIMIT VALUES

(Euro III – Directive 88/77/EC as amended by Dir 1999/96/EC 2001/27/EC)

Test conditions

- Diesel engines are tested on ESC and ELR cycles (see pages 21 & 22). NOx can be tested on ETC cycle (page 22 with limit 6.5 g/kWh) if required by the national type approval authority.
- Diesel engines fitted with aftertreatment devices (PM filters, De-NOx) are tested on ESC, ELR and ETC cycles
- Natural gas engines are tested only on ETC cycle

EEV = Enhanced Environmentally friendly Vehicle
= Type of vehicle propelled by an engine complying with the emission target values shown in the EEV columns

Specific requirements for diesel from Euro III:

- NOx is measured at the random check points within the control area of the ESC test and must not exceed by more than 10% the values interpolated from the adjacent test modes
- Smoke on the random test speed of ELR must not exceed the highest smoke value of the two adjacent test speeds by more than 20% or by more than 5% of the limit value
- Defeat devices and irrational emission control strategies are prohibited from Euro III

Limit Values

Emissions TA: 10/2000 – FR: 10/2001		Euro III		Euro III – EEV	
	Unit	ESC/ELR	ETC	ESC/ELR	ETC
		Diesel Only	Diesel / Natural Gas	Diesel Only	Diesel / Natural Gas
CO	g/kWh	2.1	5.45	1.5	3.0
HC		0.66	–	0.25	–
NMHC		–	0.78	–	0.40
CH_4 [b]		–	1.6	–	0.65
NOx		5.0	5.0	2.0	2.0
PM		0.1/0.13[a]	0.16/0.21[a,c]	0.02	0.02[c]
Smoke opacity value	per m	0.8	–	0.15	–

Footnotes:

[a] For engines having a swept volume of less than 0.75 dm^3 per cylinder and a rated power speed of more than 3,000 min^{-1}

[b] For natural gas engines only

[c] Not applicable for gas engines – Euro III stage

EURO V AND EARLIER ENGINE TEST CYCLES

Three cycles are applied:

1) European Steady-State Cycle - ESC

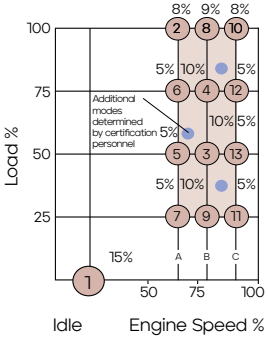
The test cycle consists of a number of speed and load points which cover the typical operating range of diesel engines.

It is determined by 13 fixed and 3 random test points.

Emission values are obtained with the weighted mean of emissions on each of the 13 fixed points. The 3 random points are tested in a control area.

In this random test, only NOx emissions are measured. They must not exceed the interpolated value of the 4 nearest fixed modes plus 10%.

This NOx control check ensures the effectiveness of the emission control of the engine within the typical engine operation range.



Mode	Engine Speed	Load (%)	Weight Factor (%)	Duration (min)
1	Low Idle	0	15	4
2	A	100	8	2
3	B	50	10	2
4	B	75	10	2
5	A	50	5	2
6	A	75	5	2
7	A	25	5	2
8	B	100	9	2
9	B	25	10	2
10	C	100	8	2
11	C	25	5	2
12	C	75	5	2
13	C	50	5	2

Speed A = n_{lo} + 25% (n_{hi} - n_{lo})
Speed B = n_{lo} + 50% (n_{hi} - n_{lo})
Speed C = n_{lo} + 75% (n_{hi} - n_{lo})

n_{hi} = speed at 70% of the declared maximum net power
n_{lo} = speed at 50% of the declared maximum net power

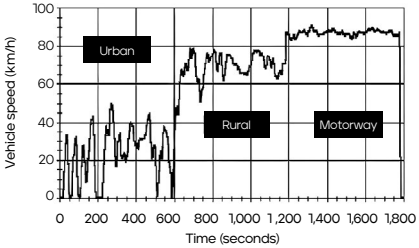
EURO V AND EARLIER ENGINE TEST CYCLES

2) European Transient Cycle - ETC

This drive cycle consists of a second-by-second sequence of transient modes.

It is based on on-road type-specific driving patterns of HD engines installed in trucks and buses.

It is divided into 3 parts: 1/3 urban roads, 1/3 rural roads, 1/3 motorways.

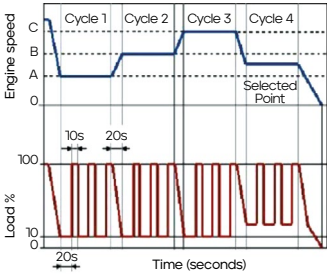


3) European Load Response - ELR

Only diesel smoke is measured. The ELR cycles 1 to 3 are defined by fixed-speed and variable-load sampling.

The random sampling (cycle 4) is represented by a random speed and random initial load.

Smoke measurements during the sampling must not exceed 20% of the highest value of speeds or more than 5% of the limit value. The largest value is selected.



EURO IV AND V ENGINE EXHAUST EMISSION LIMIT VALUES

Euro IV – Dir 88/77/EC as amended by Dir 1999/96/EC, Dir 2005/55/EC, Dir 2005/78/EC and Dir 2006/51/EC

Emissions TA: Oct 05 – FR: Oct 06		Euro IV		Euro IV – EEV	
	Unit	ESC/ELR	ETC	ESC/ELR	ETC
		Diesel Only	Diesel / Natural Gas	Diesel Only	Diesel / Natural Gas
CO	g/kWh	1.5	4.0	1.5	3.0
HC		0.46	–	0.25	–
NMHC		–	0.55	–	0.40
CH_4[a]		–	1.1	–	0.65
NOx		3.5	3.5	2.0	2.0
PM		0.02	0.03[b]	0.02	0.02[b]
Smoke opacity value	per m	0.5	–	0.15	–

· Diesel engines are tested on ESC, ELR and ETC cycles if required (see pages 21 & 22)
· Gas engines are tested on ETC cycle

Euro V – Dir 2005/55/EC + Dir 2005/78/EC amended by Dir 2006/51/EC and Dir 2008/74/EC

Emissions TA: 1st Oct 08 – FR: 1st Oct 09		Euro V		Euro V – EEV	
	Unit	ESC/ELR	ETC	ESC/ELR	ETC
		Diesel Only	Diesel / Natural Gas	Diesel Only	Diesel / Natural Gas
CO	g/kWh	1.5	4.00	1.5	3.0
HC		0.46	–	0.25	–
NMHC		–	0.55	–	0.40
CH_4[a]		–	1.1	–	0.65
NOx		2.0	2.0	2.0	2.0
PM		0.02	0.03[b]	0.02	0.02[b]
Smoke opacity value	per m	0.5	–	0.15	–

For TA and for EEV's, ETC and ESC/ELR tests are applicable (see pages 21 & 22)

Footnotes:

[a] For natural gas engines only

[b] Not applicable for gas fueled engines – Euro IV Stage

EURO IV AND V TEST CONDITIONS

Durability of emission control systems

Vehicles and engines have to confirm the correct operation of the emission control devices during the normal life of the vehicle or engine:

· from 1st Oct 2005 for new type approvals

· from 1st Oct 2006 for all type approvals

Vehicle Category	Useful Life
N_1 - M_2	100,000 km or 5 yrs
N_2, N_3 < 16 tons - M_3 < 7.5 tons	200,000 km or 6 yrs
N_3 ≥ 16 tons - M_3 ≥ 7.5 tons	500,000 km or 7 yrs

Deterioration Factors

Manufacturers can choose to apply DFs foreseen into the directive or DFs developed over a specific service accumulation schedule

1) DFs based on service accumulation schedule

DFs are developed from the selected engines based on a distance and service accumulation procedure that includes periodic testing for gaseous and PM emissions over the ESC or ETC tests.

The principle is the same as that used in Euro VI (Page 13) except that the cycles used are not the same.

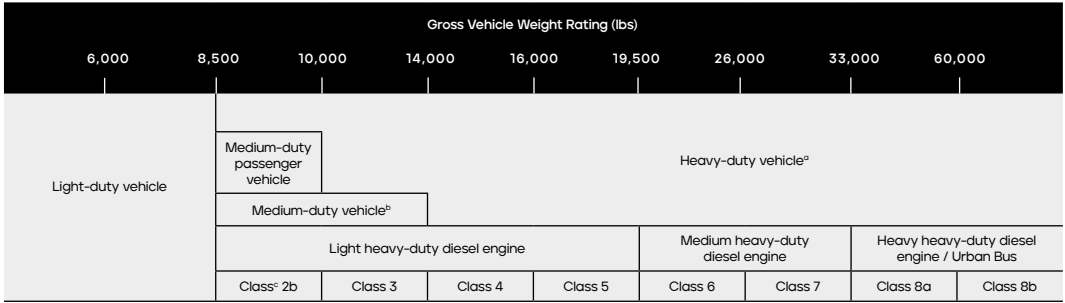
Vehicle Category	Minimum Service Accumulation Period
N_1	100,000 km
N_2	125,000 km
N_3 with permissible mass ≤ 16 tons	125,000 km
N_3 with permissible mass > 16 tons	167,000 km
M_2	100,000 km
M_3 with permissible mass ≤ 7.5 tons	125,000 km
M_3 with permissible mass > 7.5 tons	167,000 km

2) Alternative: DFs defined in Directive 2005/78/EC

Engine Type	Test Cycle	CO	HC	NMHC	CH4	NOx	PM
Diesel	ESC	1.1	1.05	-	-	1.05	1.1
	ETC	1.1	1.05	-	-	1.05	1.1
Gas	ETC	1.1	1.05	1.05	1.2	1.05	-

VEHICLE CATEGORIES

Vehicle Categories



Acronyms:

LDV	Light-duty vehicle
LDT	Light-duty truck
MDPV	Medium-duty passenger vehicle
MDV	Medium-duty vehicle
HDV	Heavy-duty vehicle
HDE	Heavy-duty engine
LHDDE	Light heavy-duty diesel engine
MHDDE	Medium heavy-duty diesel engine
HHDDE	Heavy heavy-duty diesel engine

Footnotes:

[a] Complete HD vehicles are vehicles < 14,000 lbs that have a primary load-carrying container or device attached

[b] "Medium-duty vehicle" originally only used in California until also adopted in Federal standards in 2024

[c] Truck class is used for many purposes, including vehicle category identification, defining driver's license requirements, fuel consumption standards and California zero-emission vehicles standards

COMPRESSION-IGNITION ENGINE STANDARDS – CHRONOLOGICAL OVERVIEW

Heavy-duty highway engine exhaust emission limit values

	Model Year	HC	NMHC	NMHC + NOx	NOx	PM	CO	Smoke Opacity[c] (%)	Useful Life (hrs / yrs / miles)	Emissions Warranty (hrs / yrs / miles)
		(g/bhp-hr)								
Historical	1974-78	–	–	16	–	–	40	20/15/50	–	–
	1979-84	1.5	–	10	–	–	25	20/15/50	–	–
	1985-87	1.3	–	–	10.7	–	15.5	20/15/50	LHDDE: – / 8 / 110,000 MHDDE: – / 8 / 185,000 HHDDE: – / 8 / 290,000	–
	1985-89	1.3	–	–	10.7	0.6	15.5	20/15/50	1990-97 and 1998+ for HC, CO and PM: LHDDE: – / 8 / 110,000 MHDDE: – / 8/ 185,000 HHDDE: – / 8 / 290,000 1994+ urban buses for PM only: LHDDE: – / 10 / 110,000 MHDDE: – / 10 / 185,000 HHDDE: – / 10 / 290,000	5 / 100,000
	1990	1.3	–	–	6.0	0.6	15.5	20/15/50		
	1991-93	1.3	–	–	5.0	0.25[a]	15.5	20/15/50		
	1994-97	1.3	–	–	5.0	0.1[a]	15.5	20/15/50		
	1998-03	1.3	–	–	4.0	0.1[a]	15.5	20/15/50		
	2004-06	–	–	2.4[b]	–	0.1[a]	15.5	20/15/50	For all pollutants:[cd] LHDDE: –/ 10 / 110,000 MHDDE: –/ 10 / 185,000 HHDDE: 22,000 / 10 / 435,000	LHDDE: 5 / 50,000 M & HHDDE: 5 / 100,000
In force Federal	2007-26	–	0.14	2.4[b]	0.2	0.01	15.5	20/15/50		
In force California	2024-26	–	0.14		0.050 / 0.200[e]	0.005	15.5	20/15/50	LHDDE: – / 10 / 110,000 MHDDE: – / 10 / 185,000 HHDDE: 22,000 / 10 / 435,000	LHDDE: – / 5 / 110,000 MHDDE: – / 5 / 155,000 HHDDE: – / 5 / 350,000
Planned Federal & California	2027+	0.06 / 0.14	–		0.035 / 0.050[e]	0.005	6.0	20/15/50	LHDDE: 13,000 / 15 / 270,000 MHDDE 17,000 / 12 / 350,000 HHDDE: 32,000 / 11 / 650,000	LHDDE: 10,000 / 10 /210,000 MHDDE: 14,000 / 10 / 280,000 HHDDE: 22,000 / 10 / 450,000

SPARK-IGNITION ENGINE STANDARDS – CHRONOLOGICAL OVERVIEW

Heavy-duty highway engine exhaust emission limit values

	Model Year	GVW (lbs)	HC	NMHC	NOx +NMHC	NOx	PM	CO	Useful Life	Emissions Warranty
		(g/bhp-hr)							(hrs / yrs / miles)	(yrs / miles)
Historical	Prior to control	–	12.7	–	6.68	–	–	155	- / 5 / 50,000	–
	1970-73	–	275 ppm	–	–	–	–	1.5%		–
	1974-78	–	–	–	–	16	–	40		–
	1979-84	–	1.5	–	–	10	–	25		–
	1985-86	–	1.9	–	10.6	–	–	37.1		–
	1987	≤ 14,000 > 14,000	1.1 1.9	–	10.6 10.6	–	– –	14.4 37.1		–
	1988-90	≤ 14,000 > 14,000	1.1 1.9	– –	6.0 6.0	–	– –	14.4 37.1		– –
	1990	≤ 14,000 > 14,000	1.1 1.9	–	6.0 6.0	–	– –	14.4 37.1	- / 8 / 110,000[h]	5 / 50,000
	1991-97	≤ 14,000 > 14,000	1.1[f] 1.9[g]	– –	5.0 5.0	–	– –	14.4 37.1		
	1998-2004	≤ 14,000 > 14,000	1.1[f] 1.9[g]	– –	4.0	–	–	14.4 37.1		
	2005-07	≤ 14,000 > 14,000	1.1[f] 1.9[g]	– –	– –	1.0	– –	14.4 37.1	- / 10 / 110,000	
In force federal	2008-2026	All	–	0.14	–	0.20	0.01	14.4		
In force California	2024-2026	> 10,000	–	0.14	–	0.050	0.005	14.4	- / 10 / 110,000	5 / 50,000
Planned Federal & California	2027+	All	0.060	–	–	0.035	0.005	14.4 / 6.0[e]	10,000 / 15 / 200,000	8,000 / 10 / 160,000

COMPLETE VEHICLE STANDARDS – CHRONOLOGICAL OVERVIEW

Complete Light Heavy-Duty and Medium-Duty Vehicles exhaust emission limit values

Standard	Model Year	GVW (lbs)	NMHC[j]	NOx	NOx + NMHC	PM	CO	Formaldehyde	Useful Life (years / miles)	Emissions Warranty (years / miles)
			(g/mi)							
2004 HD rule	2005-2007	8,500-10,000	0.280	0.9	–	–	7.3	–	11 / 120,000	5 / 50,000
		10,000-14,000	0.330	1.0	–	–	8.1	–		
2007 HD rule	2008-2017	8,500-10,000	0.195	0.2	–	0.02	7.3	0.032		
		10,000-14,000	0.230	0.4	–	0.02	8.1	0.040		
EPA Tier 3	2018-2026	8,500-10,000	–	–	0.333 → 0.178[k]	0.008	6.4 → 4.2[l]	0.006	15 / 150,000	EPA 8 / 80,000 CARB 7 / 70,000
CARB LEV III	2015-2025[i]	10,000-14,000	–	–	0.548 → 0.247[k]	0.010	7.3 → 4.2[l]	0.006		
CARB LEV IV	2026+	8,500-10,000	–	–	0.178 → 0.150[k]	0.008	6.4 → 3.2[l]	0.006		
		10,000-14,000	–	–	0.247 → 0.175[k]	0.01	7.3 → 3.7[l]	0.006		
EPA Tier 4	2027+	8,500-14,000	–	–	0.175[k] → 0.075[k]	0.0005[m] (0.5mg)	3.2	0.006		

General notes:

An idle CO standard of 0.5% of gas flow applied to certain heavy-duty vehicles until 2016, with a phase-out in 2005/2007 for engines meeting OBD requirements.

FOOTNOTES TO CHRONOLOGICAL OVERVIEW

Footnotes CI engine standards:

[a] Certification standards for urban buses (g/mi): 1993 0.10 / 1994-95 0.07 / 1996-2007 0.05 (in-use 0.07)

[b] Limit = 2.5 with an NMHC limit of 0.5. NHMC + NOx limit phased out by 2010

[c] Percentages apply to smoke opacity at acceleration/lug/peak modes (see page 43) - not used in vehicle certification, may be used in some state in-use monitoring programs

[d] If the useful life hours interval is reached before the engine reaches 10 years or 100,000 miles, the useful life shall become 10 years or 100,000 miles, whichever occurs first, as required under Clean Air Act section 202(d)

[e] Standards for SET & FTP / LLC respectively for CI and SET / FTP for SI

Footnotes SI engine standards:

[f] 0.9 g/bhp-hr NMHC for natural gas engines

[g] 1.7 g/bhp-hr NMHC for natural gas engines

[h] 10 years for NOx from 1998

Footnotes complete vehicle standards:

[i] Compliance can optionally be shown for NMHC or THC instead of NMOG

[j] EPA Tier 3 (to 2026) and California LEV III (to 2024) are aligned except for adoption of PM standards after MY2024, test fuels (E10 for LEV III and E15 for Tier 3), an additional evaporative test leak for Tier 3 some minor phase-in differences

[k] Bin structure and reducing fleet average limit year-by-year

[l] CO value corresponding to compliant NMOG + NOx bin

[m] Phased in from 2027 to 2031

CURRENTLY IN FORCE STANDARDS (AS OF 2024)

(see also summaries on pages 26-28)

MY 2007+ heavy-duty On-Highway Compression-Ignition Engines exhaust emission limit values

Standard	NOx + NMHC	PM	CO	Smoke Opacity	Useful Life[a]	Emissions Warranty
	(g/bhp-hr)			(%)	(hrs / years / miles)	(years / miles)
2007	2.4[b]	0.01	15.5	20 / 15 / 50	LHDDE - / 10 / 110,000 MHDDE - / 10 / 185,000 HHDDE 22,000 / 10 / 435,000	LHDDE 5 / 50,000 MHDDE 5/ 100,000 HHDDE 5 / 100,000

MY 2008+ heavy-duty On-Highway Spark-Ignition Engines exhaust emission limit values

Standard	NMHC[d]	NOx	PM	CO	Useful Life	Emissions Warranty
	(g/bhp-hr)				(years / miles)	(years / miles)
2008	0.14	0.20	0.01	14.4	10 / 110,000	5 / 50,000

MY 2016+ heavy-duty On-Highway complete vehicle < 14,000lbs chassis dynamometer exhaust emission limit values

Standard	GVW	NOx + NMHC	PM	CO	Formaldehyde	Useful Life	Emissions Warranty
	(lbs)	(g/mi)				(years / miles)	(years / miles)
Tier 3 / LEV III	8,500 - 10,000	0.178 → 0.150	0.008	6.4 → 4.2	0.006	15 / 150,000	EPA 8 / 80,000 CARB 7 / 70,000
	10,000 - 14,000	0.247 → 0.175	0.010	7.3 → 4.2	0.006		

Footnotes:

[a] If the useful life hours interval is reached before engine reaches 10 years or 100,000 miles, the useful life shall become 10 years or 100,000 miles, whichever occurs first

[b] Or 2.5 with a limit of 0.5 on NMHC

[c] Percentages for Acceleration / Lug / Peak Modes

[d] For methanol & alcohol fueled vehicles the standard is for non-methane hydrocarbon equivalent (NMHCE)

TEST PROCEDURES

Emission testing is generally engine-dynamometer-based.

Chassis certification is available in place of HD Federal Test Procedure (FTP) Transient cycle.

Incomplete HD vehicles may be certified to either HD engine or HD chassis standards.

CI and SI HD engine testing

- Federal test procedure (FTP – page 41) test to the quoted standard
- Supplemental emission test (SET – page 43), with limits equal to the FTP standards
- Not-to-exceed (NTE – page 44) test with limits of 1.5 × FTP standards

CI and SI HD vehicles < 14,000lbs chassis testing

- From 2018, complete HD vehicles with CI or SI engines < 14,000 lbs GVWR weight must be tested on chassis-based procedures (page 45) to the quoted Tier 3 / LEV III g/mi standards
- Incomplete HD vehicles may be certified to either the HD engine or HD chassis standards

CURRENTLY IN FORCE EVAPORATIVE EMISSION STANDARDS (AS OF 2024)

Heavy-duty On-Highway Compression-Ignition and Spark-Ignition Engines evaporative emission limit values

Engine Type	Model Year	GVWR	Three-Diurnal Test Sequence[a]	Supplemental Two-Diurnal Test Sequence[b]	Spitback[b]	Running Loss[b]	Useful Life[c]
		(lbs)	(g/test)			(gpm)	(years / miles)
SI	2008	8500-14,000	1.4	1.75	1.0	0.05	11 / 110,000
		> 14,000[d]	1.9	2.3	-		
CI	1998	≤ 14,000	3.0	3.5	1.0		LHDDE 8 / 110,000 MHDDE 8 / 185,000 HHDDE 8 / 290,000
		> 14,000[d]	4.0	4.5	-		

Footnotes:

[a] For SI engines, standard applies to gasoline, methanol, natural gas (NG) and liquid petroleum gas (LPG) engines. For CI engines, standard applies to methanol, NG and LPG engines Standard is THCE for methanol engines, HC otherwise

[b] Grams per mile. For SI engines, standard applies to gasoline and methanol engines. For CI engines, standard applies to methanol engines Standard is THCE for methanol engines, HC otherwise

[c] Years or miles, whichever comes first

[d] Vehicles > 26,000 lbs GVWR may demonstrate compliance with engineering design evaluation in lieu of testing

CURRENTLY IN FORCE ENGINE STANDARDS

(see also summaries on pages 26 and 27)

2024 low NOx omnibus program

MY	Engine Category	Test	NOx	NMHC	CO	PM	Useful Life	Emissions Warranty
			(g/bhp-hr)				(miles / years / hours)	(miles / years)
2024-2026	All HD diesel Engines	FTP & RMC	0.050[b, c]	0.14	15.5	0.005	LHDD 110,000 / 10 / - MHDD 185,000 / 10 / - HHDD 435,000 / 10 / 22,000	LHDD 110,000 / 5 MHDD 150,000 / 5 HHDD 350,000 / 5
		LLC	0.200[b, c]	0.14	15.5	0.005		
	HD SI[a]	FTP	0.050	0.14	14.4	0.005	110,000 / 10 / -	50,000 / 5

Off-cycle testing

A 3-bin moving average window methodology is used. The test based on a normal driving day is split into 300-second windows at one-second intervals. Windows are sorted into three bins according to their normalized average CO_2 value (approximating load):

1. < 6% maximum (idle).
2. Between 6% and 20% of maximum (low-load).
3. > 20% of maximum (medium / high load).

All pollutant results from the windows in each bin are averaged and compared to the respective emission limit multiplied by a conformity factor (2.0).

Footnotes:

[a] Standards apply to HD SI engines and SI engines used in incomplete MD Vehicles from 10,000 to 14,000 lbs. SI engines also have a formaldehyde limit of 0.01 g/bhp-hr

[b] Optional low NOx standards of 0.020/0.080 g/bhp-hr for FTP and RMC and 0.010/0.040 g/bhp-hr for LLC

[c] Manufacturers may opt to certify an engine family using one of two phase-in schedules from 2024 to 2026 under certain conditions

[d] Idling Emissions: Diesel engines must either be fitted with an engine shutdown system or optionally meet NOx idling emission requirements of 10 g/h for MY 2024 to MY 2026 or 5 g/h for MY 2027 and later

CURRENTLY IN FORCE EVAPORATIVE EMISSIONS STANDARDS (AS OF 2024)

A manufacturer must certify all vehicles to standards in either Option 1 or Option 2 (fully phased in from MY 2022)

Option 1: Hydrocarbon[a] Emission Standards for MD Vehicles (8501 lbs < GVWR < 14,000 lbs and HD Vehicles (GVWR > 14,000lbs)

Running Loss (g/mile)	Three-Day Diurnal + Hot Soak and Two-Day Diurnal + Hot Soak		Useful Life
	Whole Vehicle (g/test)	Fuel Only[b] (g/test)	(years / miles)
0.05	0.750	0.0	15 / 150,000

Option 2: Hydrocarbon[a] Emission Standards for MD Vehicles (8501 lbs < GVWR < 14,000 lbs and HD Vehicles (GVWR > 14,000lbs)

Running Loss (g/mile)	Highest Whole Vehicle Diurnal + Hot Soak[c,d] (g/test)	Canister Bleed (g/test)	Useful Life (years / miles)
0.05	0.600	0.030	15 / 150,000

Footnotes:
[a] Organic Material HC equivalent for alcohol-fueled vehicles
[b] May demonstrate with alternate test with Executive Officer approval
[c] Highest of Three-Day Diurnal Plus Hot Soak Test and Two-Day Diurnal Plus Hot Soak Test
[d] Fleet averaging compliance options exist

ON-BOARD REFUELING VAPOR RECOVERY (ORVR) STANDARDS

The maximum refueling emissions for applicable vehicles for the useful life (15 years or 150,000 miles, whichever occurs first):

(1) 0.20 g hydrocarbons per gallon of fuel dispensed for vehicles using volatile liquid fuels.

(2) 0.15 g hydrocarbons per gallon of fuel dispensed for liquefied petroleum gas-fueled vehicles and natural gas-fueled vehicles.

In addition, fuel spitback emissions may not exceed 1.0 g hydrocarbons.

Applicability

	Vehicle Category	Model Years Subject to the Standards
California (CARB)	Complete medium-duty vehicles from 8,501 through 14,000 lbs. GVWR	2015 and subsequent
	Complete heavy-duty vehicles greater than 14,000 lbs. GVWR	2022 and subsequent
Federal (EPA)	Complete vehicles with a GVWR of 8,501 to 14,000 lbs.	2004-2006 phase-in
	Complete heavy-duty vehicles over 10,000 lbs. GVWR	2018
	Incomplete heavy-duty vehicles over 14,000 lbs. GVWR	2027[a]
	Incomplete medium-duty vehicles with a GVWR of 8,501 to 14,000 lbs.	2030[a]

Footnotes:

[a] In the alternative phase-in, manufacturers would certify all their incomplete heavy-duty vehicles above and below 14,000 pounds GVWR to the refueling standards, starting with 40% of vehicles in 2026 and 2027, followed by 80% of vehicles in 2028 and 2029 before reaching 100% of vehicles in 2030

2026 AND LATER LEV IV MEDIUM-DUTY VEHICLE CHASSIS DYNAMOMETER EMISSION STANDARDS

Fleet average standard for medium-duty vehicles

Fleet Average Standard[a] for MDVs (NMOG+NOx g/mile)						
MY	2025[b]	2026	2027	2028	2029	2030+
8,501-10,000 lb GVWR	0.178	0.178	0.174	0.166	0.158	0.150
10,001-14,000 lb GVWR	0.247	0.247	0.232	0.212	0.193	0.175

Each vehicle is given a bin category (see next page) according to its NOx + NMOG value. The average of the bin values over all vehicles in an OEM's fleet has to be below the limit for the year in question.

The following tests are applied (see page 45):

- 50°F FTP standards (up to 4,000 miles)
- Supplemental FTP requirements
  - US06 for 8,501 to 10,000 lbs GVWR fleet
  - Hot 1435 UC (Hot 1435 LA92) for 10,001 to 14,000 lbs GVWR fleet
- SC03 attestation to binned standards
- Federal Highway Fuel Economy Test to meet FTP Standards by bin

Useful life and Emissions Warranty periods

Model Year	Periods (miles / years / hours)			
	LHDE	MHDE	HHDE	HDO
Useful Life	270,000 15 years 13,000 hours	350,000 12 years 17,000 hours	650,000 11 years 32,000 hours	200,000 15 years 10,000 hours
Emissions Warranty	210,000 10 years 10,000 hours	280,000 10 years 14,000 hours	450,000 10 years 22,000 hours	160,000 10 years 8,000 hours

Footnotes:

[a] The maximum percentage of ZEVs and emission-adjusted PHEVs included in the fleet average is: 100% in 2025; 60% in 2026; 30% in 2027; 15% in 2028; zero from 2029

[b] Only applicable to manufacturers optionally certifying 2025 model year test groups

2026 AND LATER LEV IV MEDIUM-DUTY VEHICLE CHASSIS DYNAMOMETER EMISSION STANDARDS

Bin standards for medium-duty vehicles 8,501 lbs to 10,000 lbs

MDVs 8,501 to 10,000 lbs GVWR				
Vehicle Emission Category	NMOG+NOx	CO	HCHO	PM
	(g/mile)		(mg/mile)	
ULEV250[a]	0.250	6.4	6	8
ULEV200[a]	0.200	4.2	6	8
SULEV170	0.170	4.2	6	8
SULEV150	0.150	3.2	6	8
SULEV125	0.125	3.2	6	8
SULEV100	0.100	3.2	6	8
SULEV85	0.085	3.2	6	8
SULEV75	0.075	3.2	6	8

Bin standards for medium-duty vehicles 10,001 lbs to 14,000 lbs

MDVs 10,001 to 14,000 lbs GVWR				
Vehicle Emission Category	NMOG+NOx	CO	HCHO	PM
	(g/mile)		(mg/mile)	
ULEV400[a]	0.400	7.3	6	10
ULEV270[a]	0.270	4.2	6	10
SULEV230	0.230	4.2	6	10
SULEV200	0.200	3.7	6	10
SULEV175	0.175	3.7	6	10
SULEV150	0.150	3.7	6	10
SULEV125	0.125	3.7	6	10
SULEV100	0.100	3.7	6	10

Footnotes:
[a] Only applicable for model years 2026 through 2028

2027 AND LATER TIER 4 MEDIUM-DUTY VEHICLE CHASSIS DYNAMOMETER EMISSION STANDARDS

Classes 2b and 3

In April 2023, the EPA issued a notice of proposed rules for multipollutant emission standards for light- and medium- duty vehicles (MDVs, < 14,000 lbs). With some amendments, the final rule was published on March 14th 2024.

The rule applies the bin structure approach used by EPA for light-duty vehicles to medium-duty vehicles. Each vehicle is given a bin category according to its NOx + NMOG value. The average of the bin values over all vehicles in an OEM's fleet has to be below the limit for the year in question.

The limits are phased-in from 2027 to 2031 with two options according to the table.

For gasoline vehicles, a -7°C FTP NMOG+NOx limit of 300mg/mi applies.

Bin structure for MDVs

MDV Bin	NMOG+NOx (mg/mi)
Bin 170	170
Bin 150	150
Bin 125	125
Bin 100	100
Bin 85	85
Bin 75	75
Bin 70	70
Bin 65	65
Bin 60	60
Bin 55	55
Bin 50	50
Bin 45	45
Bin 40	40
Bin 35	35
Bin 30	30
Bin 25	25
Bin 20	20
Bin 15	15
Bin 10	10
Bin 5	5
Bin 0	0

Fleet average NMOG

Model Year	NMOG+NOx (mg/mi)
2027	175
2028	160
2029	140
2030	120
2031	100
2032	80
2033 and later	75

MDV phase-in schedule

Model Year	Default	Early
2027	0%	20%
2028	0%	40%
2029	0%	60%
2030	0%	80%
2031	100%	100%

2027 LOW NOx HEAVY-DUTY ENGINE EMISSION STANDARDS

Engine dynamometer testing

- Federal test procedure (FTP) test to the given standards
- Supplemental emission test (SET), with limits equal to the FTP standards
- New low-load cycle (LLC – see page 46) with a separate limit

Useful life and Emissions Warranty

- Increased warranty periods for all vehicle types
- Additional requirement that manufacturers must demonstrate at certification that HHDDE emission controls are durable to 750,000 miles
- Hours added to all classes

California

- In June 2023, CARB and the Truck & Engine Manufacturers Associations (EMA) reached an agreement whereby EMA pledged not to bring any lawsuit against the Advanced Clean Fleets regulation (see page 78), in exchange for CARB adopting EPA's 2027 low NOx rule instead of implementing its 2027 low NOx standard
- California is expected to align with the federal standards, with some modifications
- Formal confirmation of the rule is expected in 2025

MY	Engine Category	Test	NOx	PM	NMHC / HC[b]	CO
			(mg/hp-hr)			(g/hp-hr)
Current	All HD Engines	FTP & SET	200	10	140	15.5
		LLC	No LLC Cycle			
2027+	All HD Engines	FTP & SET	35	5	60	6.0[d]
		LLC[c]	50	5	140	6.0
	MHDDE HHDDE with In-use compliance[a]	FTP & SET	50	-	-	-
		LLC	65	-	-	-

Model Year	Periods (miles / years / hours)			
	LHDDE	MHDDE	HHDDE	HDO
Useful life	270,000 15 years 13,000 hours	350,000 12 years 17,000 hours	650,000 11 years 32,000 hours	200,000 15 years 10,000 hours
Emissions Warranty	210,000 10 years 10,000 hours	280,000 10 years 14,000 hours	450,000 10 years 22,000 hours	160,000 10 years 8,000 hours

Footnotes:

[a] Off-cycle testing also applies to LHDD, MHDD and HHDD with the following limits (mg/bhp-hr): HC 120, PM 7.5 (for NOx see next page), CO 9g/bhp-hr
[b] HC from 2027
[c] Only CI engines
[d] 14.4 for SI engines SET

2027 LOW NOx HEAVY-DUTY ENGINE EMISSION STANDARDS

Off-cycle testing

The 2027 standards use the moving average window based methodology, as described on page 33 (California Low NOx).

Using a 2-bin instead of 3-bin method:

- Bin 1: 300s windows with normalized average CO_2 rate ≤ 6%
- Bin 2: 300s second windows with normalized average CO_2 rate > 6%

The final averages for each bin are compared to the in-use compliance standards.

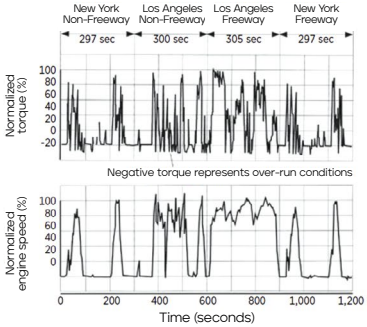
Off-cycle NOx limit values

MY 2027 and later MAW Bin Limits	Engine Category	
	LHDDE MHDDE HHDDE	MHDE HHDE with In-use compliance
Bin 1: Idle (g/hr)	10.0	10.0
Bin 2: Low/Medium/High Load (mg/hp-hr)	58	73

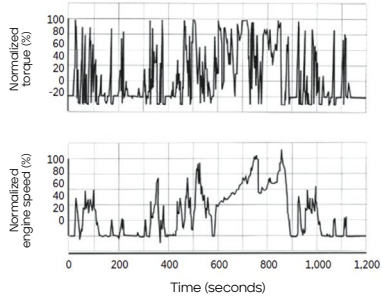
ENGINE TEST CYCLES

Federal test procedure engine dynamometer cycles

Heavy-Duty Diesel Transient Cycle (HDDTC)



Heavy-Duty Gasoline Transient Cycle (HDGTC)



Test cycle comprised of 4 phases representing different driving conditions.
Phases 1 and 4 are the same. Test is a cold start followed by a 20 minute soak and then a repeat of the test cycle.

ENGINE TEST CYCLES

Ramped modal cycle supplemental emissions test (RMC-SET)

Ramped modal cycle involves a single and continuous emission measurement as the engine operates over the test modes in a defined sequence.

It also includes short transition segments between modes.

RMC Mode	Time in Mode (seconds)	Engine Speed	Torque (%)
1a Steady-state	170	Warm Idle	0
1b Transition	20	Linear Transition	Linear Transition
2a Steady-state	173	A	100
2b Transition	20	Linear Transition	Linear Transition
3a Steady-state	219	B	50
3b Transition	20	B	Linear Transition
4a Steady-state	217	B	75
4b Transition	20	Linear Transition	Linear Transition
5a Steady-state	103	A	50
5b Transition	20	A	Linear Transition
6a Steady-state	100	A	75
6b Transition	20	A	Linear Transition
7a Steady-state	103	A	25
7b Transition	20	Linear Transition	Linear Transition
8a Steady-state	194	B	100
8b Transition	20	B	Linear Transition
9a Steady-state	218	B	25
9b Transition	20	Linear Transition	Linear Transition
10a Steady-state	171	C	100
10b Transition	20	C	Linear Transition
11a Steady-state	102	C	25
11b Transition	20	C	Linear Transition
12a Steady-state	100	C	75
12b Transition	20	C	Linear Transition
13a Steady-state	102	C	50
13b Transition	20	Linear Transition	Linear Transition
14 Steady-state	168	Warm Idle	0

Load Response Test (LRT) applicable to HD diesel, MY 2004-2007

This test is conducted on a dynamometer. The purpose is to measure the brake-specific gaseous and particulate emissions from an HD diesel engine as it is suddenly loaded, with its fueling lever, at a given engine operating speed. Results of this test are not compared to emission standards.

FTP TEST CYCLES

Supplemental emission test discrete mode cycle (DMC) up to Model Year (MY) 2009

As a result of the Consent Decree of 1998, most engine manufacturers were required to meet the applicable FTP transient emission standard during the SET schedule (among other requirements).

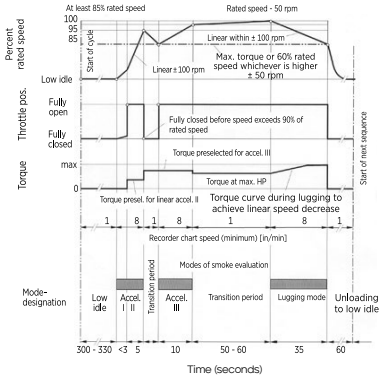
The DMC is based on the EU ESC cycle.

It contains 13 fixed modes and 3 by random selected modes.

The alternate procedure for Steady-State test was permitted through MY 2009.

The ramped modal cycle RMC-SET (Slide 42) is mandatory from MY 2010.

Diesel Smoke



ENGINE TEST CYCLES

NOT-TO-EXCEED TEST (NTE)

As a result of a Consent Decree between the United States and engine manufacturers in 1998, most manufacturers are required to maintain engine emissions below a limit of 1.25 x applicable FTP standards during engine operation in a speed-load zone below the engine's torque curve.

The limit increases to 1.5 x FTP standard in MY 2007.

There is no specific drive cycle.

It is applicable to steady-state AND transient maneuvers at varying ambient temperatures and up to 5,500 ft elevation.

Emissions are measured over intervals with a minimum of 30 seconds in length.

CHASSIS DYNAMOMETER TEST CYCLES

LEV III and Tier 3 chassis testing is performed according to the following procedures:

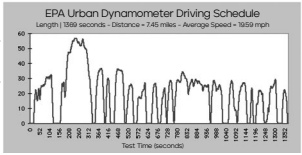
1. Federal Test Procedure (FTP) using the light-duty Urban Dynamometer Driving Schedule (UDDS, right).
2. Heavy-Duty Supplemental Federal Test Procedure (HD-SFTP) = 0.35 x FTP + 0.28 x HDSIM + 0.37 x SC03, where HDSIM is defined:
   - For Class 2b vehicles: the US06 cycle (right)
   - For Class 2b vehicles with a power-to-weight ratio ≤ 0.024 hp/lb certified to optional Tier 3 standards: US06 highway portion
   - For Class 3 vehicles: the Hot LA-92 cycle (right)

A manufacturer may, alternatively, use FTP emission results to substitute for the SC03 value in the above calculation.

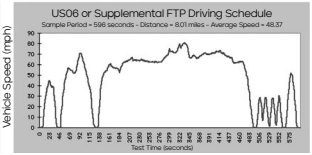
The results of both the FTP and the HD-SFTP are compared to the relevant standard.

Test cycles

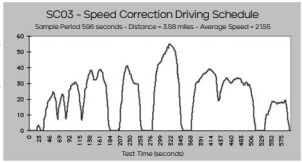
FTP - UDDS



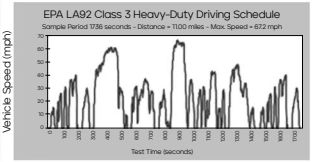
US06



SC03



LA92

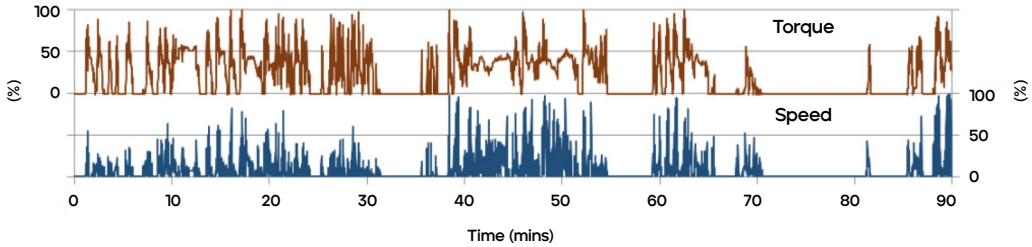


ENGINE TEST CYCLES

LOW LOAD CYCLE (LLC)

California Air Resources Board (CARB) determined that existing certification test cycles do not accurately represent today's traffic conditions, which are characterized by more congestion and more frequent low load operations.

A new low load certification cycle (LLC) was introduced from MY 2024 to demonstrate that the engine and aftertreatment hardware and controls needed to deal with low load operations are present and functional. The LLC will also be used in the federal standard from 2027.



LOW NOx OMNIBUS ENGINE STANDARDS FOR 2027 (FOR REFERENCE ONLY)

California Low NOx Omnibus standards for 2027 and subsequent model years (for reference) - superseded by federal standards due to agreement with truck and engine manufacturers.

In August 2020, CARB proposed NOx emissions standards for 2024 (see page 33) and further tightened limits for 2027 for heavy-duty CI and SI engines intended for vehicles of GVWR > 10,000 lbs.

In June 2023, CARB and the Truck & Engine Manufacturers Associations (EMA) reached an agreement whereby EMA pledged not to bring any lawsuit against the Advanced Clean Fleets regulation (see page 78), in exchange for CARB adopting EPA's 2027 low NOx rule instead of implementing its 2027 low NOx standard.

MY	Engine Category	Test	NOx IUL[c]	NOx FUL[c]	NMHC	CO	PM
			(g/bhp-hr)				
2027+	LHDDE MHDDE	FTP & RMC	-	0.020[b]	0.14	15.5	0.005
		LLC	-	0.050[b]	0.14	15.5	0.005
	HD SI[a]	FTP	-	0.020	0.14	14.4	0.005
2027-2030	HHDDE	FTP & RMC	0.020[c]	0.035[b]	0.14	15.5	0.005
		LLC	0.050[c]	0.090[b]	0.14	15.5	0.005
2031+		FTP & RMC	0.020[c]	0.040[b]	0.14	15.5	0.005
		LLC	0.050[c]	0.100[b]	0.14	15.5	0.005

Footnotes:

[a] Standards apply to HD SI engines and SI engines used in incomplete MD vehicles from 10,000 to 14,000 lbs. SI engines also have a formaldehyde limit of 0.01 g/bhp-hr

[b] Optional low NOx standards of 0.010 g/bhp-hr for FTP and RMC and 0.025 g/bhp-hr for LLC

[c] Due to the increase in full useful life (FUL) for HHDDE (from 435,000 to 600,000 miles), a separate Intermediate Useful Life (IUL) standard applies for the period of use to 435,000 miles / 8 years / 22,000 hours whichever occurs first

VEHICLE CATEGORIES AND CURRENTLY IN FORCE DIESEL ENGINE EXHAUST EMISSION STANDARDS

Vehicle Categories:

- Original weight category: trucks and buses > 2.5 t gross vehicle weight GVW[a]
- From 2001 standards: gasoline vehicle threshold increased to > 3.5 t GVW
- From 2005 long term standards: diesel vehicles threshold increased to > 3.5 t GVW

Currently In Force Emissions Standards (2016 and later)

Trucks and Buses GVW > 3.5t								
	PM (g/kWh)		NOx (g/kWh)		NMHC (g/kWh)		CO (g/kWh)	
(g/kWh)	Std[b]	Others[c]	Std[b]	Others[c]	Std[b]	Others[c]	Std[b]	Others[c]
Diesel	0.010	0.013	0.4	0.7	0.17	0.23	2.22	2.95
Gas/LPG	0.010	0.013	0.4	0.7	0.23	0.31	16.0	21.3

Implementation date: GVW > 7.5 t (except for tractor): October 2016
GVW > 7.5 t (tractor): October 2017
3.5 t < GVW < 7.5 t: October 2018
Imported vehicles and existing domestic vehicles: 11 months later

Test cycle: WHTC and WHSC mode (Diesel Sulphur content: 10 ppm)

PN standards: phased in between 2023 and 2026 for WHSC (8×10^{11}) and WHTC (6×10^{11})

New Evaporative Emissions (2020 and later)

Conditioning	WLTC (Low, Medium, High, Medium)
Hot Soak Loss (HSL)	1 hr SHED at 27 ± 4°C
Diurnal Breathing Loss (DBL)	2 heat builds in 48 hrs acc. to UN GTR19
Emission standard	HSL + DBL_1stDay + DBL_2ndDay ≤ 2 g/test

Footnotes:

[a] GVW = Curb weight + maximum number of passengers x 55kg + maximum loading capacity
[b] Emission standard at type approval (TA) for type assigned vehicle and vehicle with TA (standard) equipment
[c] Emission standard for the vehicles other than defined in "2" above (including pre-type approval, prototypes, imports)

PREVIOUS ENGINE EXHAUST AND EVAPORATIVE EMISSION STANDARDS

Pre-2003 EMISSIONS limits values for categories in scope

Diesel Engines	GVW	CO (g/kWh)		HC (g/kWh)		NOx (ppm or g/kWh)		PM (g/kWh)		Smoke Opacity Value[c]
		Std[a]	Others[b]	Std[a]	Others[b]	Std[a]	Others[b]	Std[a]	Others[b]	
Japan 88/89 6-Mode test (ppm)	GVW > 2.5t	980		670		520 (DI)		-	-	50%
						350 (IDI)				
Japan 94 13-Mode test (g/kWh)						6.8 (IDI)		0.96		40%
						7.8 (DI)				
Japan 97[c] (g/kWh)		7.4	9.2	2.9	3.8	4.5	5.8	0.25	0.49	25%
Gasoline Engines										
Japan 98 13-Mode test (g/kWh)	GVW > 2.5t	51	68	1.8	2.29	4.5	5.9	-	-	-

Footnotes:

[a] Emission standard at type approval (TA) for type assigned vehicle and vehicle with TA (standard) equipment

[b] Emission standard for the vehicles other than defined in "2" above (including pre-type approval, prototypes, imports)

[c] Smoke measured under 3 full load conditions (at 40, 60 or 100% of rated speed) and under free load acceleration

PREVIOUS ENGINE EXHAUST AND EVAPORATIVE EMISSION STANDARDS

New Short-Term Emission Standards (2001 to 2005)

Diesel Engines	2.5 t < GVW ≤ 12 t	GVW > 12 t
New vehicles	from Oct 3rd to Oct 5th	from Oct 4th to Oct 5th
Existing and Import vehicles	from Sept 4th to Sept 7th	from Sept 5th to Sept 7th

CO (g/kWh)		HC (g/kWh)		NOx (g/kWh)		PM (g/kWh)		Smoke Opacity Value
Std[a]	Others[b]	Std[a]	Others[b]	Std[a]	Others[b]	Std[a]	Others[b]	
2.22	3.46	0.87	1.47	3.38	4.22	0.18	0.35	25%

Gasoline Vehicles: GVW > 3.5 t								
Domestic new vehicles				from Oct 1st				
Existing and Import vehicles				from Sept 3rd				
CO (g/kWh)		NMHC (g/kWh)		NOx (g/kWh)		PM (g/kWh)		Smoke Opacity Value
NMHC	Others[b]	Std[a]	Others[b]	Std[a]	Others[b]	Std[a]	Others[b]	
NOx	26.0	0.58	0.99	1.4	2.03	-	-	-

Test cycle: 13-Mode (see page 53)

[a] TA emissions standards for type assigned vehicle and vehicle with TA (standard) equipment

[b] Emission standard for the vehicles other than defined in "2" above (including pre-type approval, prototypes, imports)

Evaporative Emissions (until 2020)

Conditioning	4 x JC08 cycle
Hot Soak Loss (HSL)	1 hr Sealed House for Evaporative Determination (SHED) at 27 ± 4°C
Diurnal Breathing Loss (DBL)	1 heat build in 24 hrs Cycle from 20°C - 35°C
Emission standard	HSL + DBL ≤ 2 g/test

New Long-Term Emissions Standards (2005 to 2009)

Implementation Dates: GVW > 3.5 t									
Domestic new vehicles						from Oct 5th			
Existing and Import vehicles						from Sept 7th			
	CO (g/kWh)		NMHC (g/kWh)		NOx (g/kWh)		PM (g/kWh)		Smoke Opacity Value
	Std[a]	Others[b]	Std[a]	Others[b]	Std[a]	Others[b]	Std[a]	Others[b]	
Diesel	2.22	2.95	0.17	0.23	2.0	2.7	0.027	0.036	25%
Gasoline	16.0	21.3	0.23	0.31	0.7	0.9	-	-	-

Test cycle: New JE05 transient cycle (see page 52)

[a] TA emissions standards for type assigned vehicle and vehicle with TA (standard) equipment

[b] Emissions standards for the vehicles other than defined above

PREVIOUS ENGINE EXHAUST AND EVAPORATIVE EMISSION LIMIT VALUES

Post New Long-Term (PNLT) Emissions Standards (2009 to 2016)

Trucks and Buses GVW > 3.5t								
	PM (g/kWh)		NOx (g/kWh)		NMHC (g/kWh)		CO (g/kWh)	
(g/kWh)	Std[a]	Others[b]	Std[a]	Others[b]	Std[a]	Others[b]	Std[a]	Others[b]
Diesel	0.010	0.013	0.7	0.9	0.17	0.23	2.22	2.95
Gas/LPG	0.010	0.013	0.7	0.9	0.23	0.31	16.0	21.3

Footnotes:
[a] TA emissions standards for type assigned vehicle and vehicle with TA (standard) equipment
[b] Emission standard for the vehicles other than defined in "2" above (including pre-type approval, prototypes, imports)

PM for diesel vehicle > 12t: 0.5 per m (Opacity meter)

PM for gasoline vehicle applies only to DI vehicles equipped with/ NOx adsorber catalyst

Implementation date: New domestic vehicles
Diesel: HD > 3,500 kg and ≤ 12,000 kg:
1st October 2010
Gasoline: 1st October 2009
Imported vehicles and existing domestic vehicles:
11 months later

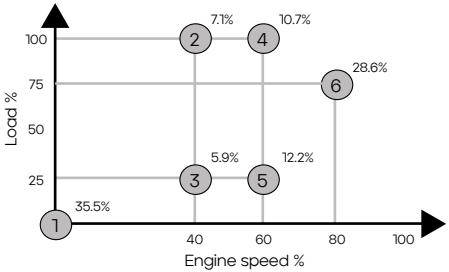
Test cycle: JE05 (Diesel Sulphur content: 10 ppm)

ENGINE TEST CYCLES

6-Mode Cycle (until 2005)

The engine is tested over 6 different speed and load conditions.

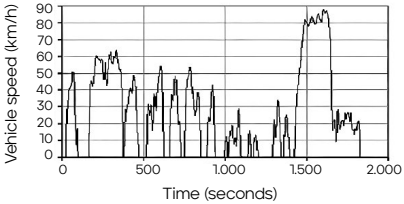
The modes are run in sequence and the duration of each mode is 3 minutes. Measurements are expressed in ppm (volumetric concentration).



Driving Cycle JE05 (also known as ED12)

The JE05 cycle is effective from 2005 for both diesel and gasoline applications. It is based on Tokyo driving conditions. The test cycle is defined through vehicle speed vs. time points, requiring conversion to engine conditions.

Duration: 1,829 s **Average speed: 26.94 km/h**
Maximum speed: ≈88 km/h



ENGINE TEST CYCLES

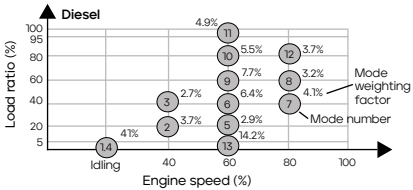
13-Mode Cycle

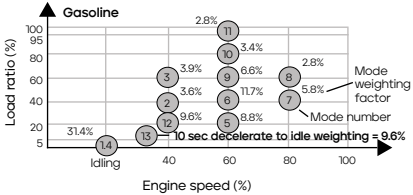
This cycle replaced the 6-Mode cycle. It includes a sequence of 13 steady-state modes. Measurements are expressed in g/kWh. The test represents low-speed driving conditions, specified by low average engine loads and low exhaust temperature.

Mode	Speed (% of nominal)		Load (%)		Weighting Factor	
	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline
1	Idle	Idle	–	–	0.410/2	0.314/2
2	40	40	20	40	0.037	0.036
3	40	40	40	60	0.027	0.039
4	Idle	Idle	–	–	0.410/2	0.314/2
5	60	60	20	20	0.029	0.088
6	60	60	40	40	0.064	0.117
7	80	80	40	40	0.041	0.058
8	80	80	60	60	0.032	0.028
9	60	60	60	60	0.077	0.066
10	60	60	80	80	0.055	0.034
11	60	60	95	95	0.049	0.028
12	80	40	80	20	0.037	0.096
13	60	40[a]	5	20[a]	0.142	0.096

Footnotes:

[a] Deceleration to idle





CURRENTLY IN FORCE CHINA VI ENGINE EXHAUST EMISSION STANDARDS

Applicable Standard GB 17691-2018 (China VI) has been implemented which replaces GB 17691-2005 (China III/IV/V). Key changes are:

- Changed emission test cycles with WHTC (see page 16), WHSC (see page 17) and WNTE (see page 18)
- Introduced particle number limits
- Introduced portable emissions measuring systems (PEMS) for vehicle real road emission
- Introduced emission warranty period requirements

China VI emissions standard is introduced in two phases:

- China VI-a applies to gas (CNG) powered H-DVs from 1st July 2019 and all engines from 1st July 2021
- China VI-b applies to gas (CNG) powered H-DVs from 1st July 2021 and all engines from 1st July 2023

China VI-b introduces more stringent testing requirements and a full-vehicle in-service PEMS test with a PN limit of 1.2 x 10^{12}/kWh.

Key Differences between China VI-a & China VI-b

Technical Requirements	China VI-a	China VI-b
PN requirement in PEMS	No	Yes
Remote Emission data requirement in Tbox	No	Yes
High altitude emission requirement	1700m	2400m
PEMS measurement load range	50-100%	10-100%

China VI Engine emissions limits

China VI	Cycle	THC	CO	CH_4	NMHC	NOx	PM	PN	NH_3
		g/kWh						#/kWh	ppm
CI Engines	WHTC	0.16	4.0	–	–	0.46	0.010	6 x 10^{11}	10
	WHSC	0.13	1.5	–	–	0.40	0.010	8 x 10^{11}	10
PI Engines	WHTC	–	4.0	0.50	0.16	0.46	0.010	6 x 10^{11}	10
All Engines	WNTE	0.22	2.0	–	–	0.60	0.016	–	–

China VI Vehicle on-road emissions limits using PEMS[a]

China VI	CO	THC	NOx	PN[b]
	g/kWh			#/kWh
CI Engines	6.0	-	0.69	1.2 x 10^{12}
PI Engines	6.0	0.24 (LPG) / 0.75 (NG)	0.69	-
All Engines	6.0	1.5*WHTC Limits	0.69	1.2 x 10^{12}

Footnotes:

[a] Measure and Record CO_2 in same test

[b] PN limit start from CNVI-b phase

CURRENTLY IN FORCE CHINA VI ENGINE EXHAUST EMISSION STANDARDS

Emissions Warranty Requirements

Vehicle Category	Shortest Emissions Warranty*	
	Miles (km)	Time in use (year)
M_1, M_2, N_1	80,000	5
M_3, N_2, N_3	160,000	5

* Distance of time in use, whichever occurs first

FUTURE ENGINE EXHAUST EMISSION STANDARDS

Next Applicable Standards GB 17691-20xx (China VII) engine dyno emission:

- Test cycle will be WHTC only, separate cold and hot cycle limits will be considered.
- LLC (Low Load Cycle) to be considered.
- Idle NOx limit will be 5g/h.
- 10nm particle number will be considered.
- New emission pollutants: N_2O, NMOG and HCHO.

Next Applicable Standards GB 17691-20xx vehicle emission with PEMS:

- Test cycle will be CHTC.
- Cold bin emission calculation: $EF_{NOx,\ BinCold} = \frac{\sum_{t=1}^{T_{Cold}} m_{NOx,t}}{W_{WHTC}}$

T_{cold}: cold start bin test duration, $m_{NOx,t}$ = transient NOx emission, W=work

- Hot stable running bin emission calculation (g/kWh):

$$EF_{NOx,\ Bini} = \frac{\sum_{t=1}^{N} m_{NOx,300,windowi}}{\sum_{t=1}^{N} W_{300,windowi}}$$

- Bin number and window number are under discussion.

Next Applicable Standards GB 17691-20xx will be implemented 36 months after regulation published (anticipated 2028).

WHTC Engine Emissions limits (to be confirmed)

Cycle	CO	NMOG	CH_4	NOx	NH_3	N_2O	HCHO	PM	SPN_{10}
	mg/kWh								#/kWh
Cold WHTC	3500	200	700	460	65	160	30	10	6×10^{11}
Hot WHTC	200	50	350	60 / 90[a]	65	200	30	10	6×10^{11}

CHTC Vehicle Emissions (PEMS)

Items	Requirement
Pollutants	NOx, CO, PN_{10}, NH_3, CH_4, N_2O, CO_2
Test boundary	Temperature: -7~40degC, Altitude: 2400m
Test cycle	CHTC Cold start: average vehicle speed ≥ 15km/h; hot stable running: ≥ average vehicle speed of fuel consumption test cycle
Test load	No limitation
Limit mode	Cold Bin + Hot stable running Bin (300s moving average)
Duration	≥ 3 CHTC, Idle Bin > 500 windows

Footnotes:
[a] To be decided

PREVIOUS ENGINE EXHAUST EMISSION STANDARDS (CHINA III TO V)

Applicable Standards GB 17691-2005 (China III, IV & V, equivalent to EU standards).

- Beijing Area implemented China III from 30th Dec 2005; in nationwide, heavy-duty gas engine and diesel engine from 1st July 2008, heavy-duty gasoline engine from 1st July 2010
- Partial areas implemented China IV from 1st July 2013: Beijing, Shanghai, Guangzhou, Shenzhen, Nanjing, Urumqi and Lanzhou etc. In nationwide, China IV was implemented from 1st Jan 2015
- From 1st April 16, HD diesel CN5 vehicles (only city bus, sanitation and postal vehicles) are mandatory for China eastern 11 provinces and cities (Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan). Nationwide, China V was implemented from 1st July 2017

GB 17691-2005 adopts ESC (European Steady Cycle, see Page 21), ETC (European Transient cycle, see Page 22) and ELR (European Load Response test, refer to Page 22).

GB 17691-2005 was replaced by GB17691-2018 on 2nd July 2019.

ESC and ELR Emissions limits

Emission Phase	CO	THC	NOx	PM	Smoke Opacity Value (per m)
	(g/kWh)				
III	2.1	0.66	5.0	0.10 / 0.13[a]	0.8
IV	1.5	0.46	3.5	0.02	0.5
V	1.5	0.46	2.0	0.02	0.5
EEV[b]	1.5	0.25	2.0	0.02	0.15

Footnotes: [a] For engine < 0.75cc/Cyl & rate speed > 3000rpm. [b] Enhanced Environmentally Friendly Vehicle.

ETC Emissions limits

Emission Phase	CO	NMHC	CH_4 [a]	NOx	PM[b]
	(g/kWh)				
III	5.45	0.78	1.6	5.0	0.16 / 0.21[c]
IV	4.0	0.55	1.1	3.5	0.03
V	4.0	0.55	1.1	2.0	0.03
EEV	3.0	0.40	0.65	2.0	0.02

Footnotes: [a] Only for NG engine. [b] Not applicable to gas engines. [c] For engine < 0.75cc/Cyl & rate speed > 3000rpm.

DIESEL VEHICLE EXHAUST EMISSION STANDARDS

Korean emission standards are based on European regulations.

Equivalent to Euro IV until 2009, when the Euro V level was adopted. Since 2014, diesel emissions have been regulated under Euro VI limit values.

Implementation Date for HD Commercial Vehicle	Tail Pipe Emissions (g/kWh)			PM (g/kWh)	Smoke Opacity Value (per m)	PN (#/kWh)	Test Cycle
	CO	NOx	THC				
1st Sept 2009[a]	1.50	2.0	0.46	0.02	K = 0.5	-	ND-13[e] mode
	4.0	2.0	0.55[d]	0.03	-	-	ETC mode
1st Jan 2014[b,c]	1.50	0.40	0.13	0.01	-	8×10^{11}	WHSC
	4.0	0.46	0.16			6×10^{11}	WHTC
1st Oct 2017[b,c]	1.50	0.40	0.13	0.01	-	8×10^{11}	WHSC
	4.0	0.46	0.16			6×10^{11}	WHTC

Footnotes:

[a] Heavy-duty commercial vehicles must satisfy both ND-13 mode and ETC mode. In this case, ND-13 mode measures THC and ETC mode measures NMHC. (From 1st Sept 2009 to 31st Dec 2013)

[b] Heavy-duty commercial vehicles must satisfy both WHSC and WHTC modes (From 1st Jan 2014)

[c] The permissible emission standard for ammonia (NH_3) from heavy-duty commercial vehicles is 10 ppm or less. (From 1st Jan 2014)

[d] Limit is for NMHC

[e] Same as EU ESC (page 21)

GASOLINE VEHICLE EXHAUST EMISSION STANDARDS

In 2009, South Korea adopted CARB's NMOG Fleet Average System (FAS) for gasoline-fueled vehicles. FAS allows car manufacturers to have a range of models with different emissions levels, while each OEM's fleet is required to meet a prescribed level of NMOG average.

Implementation Date for HD Commercial Vehicle	Tailpipe Emissions (g/kWh)			Test Cycle
	CO	NOx	NMHC	
1st Jan 2009	4.0	2.0	0.55	ETC mode
1st Jan 2013	4.0	0.40	0.14	WHTC mode
1st Jan 2016	4.0	0.40	0.14	WHTC mode

· Vehicles that use gasoline or gas include vehicles that use a mixture of gasoline, alcohol, and gas or use them together, and vehicles that use other fuels such as gasoline as an auxiliary power source among electric vehicles
· The permissible emission standard for ammonia (NH_3) from heavy-duty commercial vehicles is 10 ppm or less. (From 1st Jan 2013)

CURRENTLY IN FORCE (BHARAT VI) DIESEL/CNG/LPG-FUELED VEHICLE ENGINE EXHAUST EMISSION STANDARDS

The emission standards for the Bharat stage VI (BS-VI)

For category M and N vehicles having Gross Vehicle Weight exceeding 3,500kg, manufactured on or after 1st April 2020 for all models, as per GSR. 889(E) dated 16th Sept 2016.

Limit values for M and N category vehicles: BS-VI

	Limit Values							
	C0 (mg/kWh)	THC (mg/kWh)	NMHC (mg/kWh)	CH_4 (mg/kWh)	NOx (mg/kWh)	NH_3 (ppm)	PM mass (mg/kWh)	PM number (numbers/kWh)
WHSC (CI)	1,500	130	-	-	400	10	10	8.0×10^{11}
WHTC (CI)	4,000	160	-	-	460	10	10	6.0×10^{11}
WHTC (PI)	4,000	-	160	500	460	10	10	6.0×10^{11}

Deterioration Factor for BS-VI

Test Cycle	CO	THC[a]	NMHC[b]	CH_4[b]	NOx	NH_3	PM	PM number
	(g/kWh)							
WHTC	1.3	1.3	1.4	1.4	1.15	1.0	1.05	1.0
WHSC	1.3	1.3	-	-	1.15	1.0	1.05	1.0

Footnotes:

[a] Applies in case of a Compression-Ignition engine

[b] Applies in case of a positive ignition engine

PI = Positive Ignition

CI = Compression-Ignition

PREVIOUS (BHARAT IV) DIESEL/CNG/LPG-FUELED VEHICLE ENGINE EXHAUST EMISSION STANDARDS

Indian Bharat emission standards (BS) are based on Euro norms

Effective Date	Category	Test Cycle	CO (g/kWh)	THC (g/kWh)	NOx (g/kWh)	NMHC (g/kWh)	CH_4[c] (g/kWh)	PM[a] (g/kWh)	ELR Smoke Opacity Value (per m)[a]	Free Accl. Smoke Opacity Value (per m)[a]
1.04.10 BS-IV	Only diesel vehicles with GVW > 3500	Engine Steady-state Cycle (ESC)	1.50	0.46	3.50	NA	NA	0.02	0.50	1.62
	Diesel, CNG or LPG vehicles with GVW > 3500	Engine Transient Cycle (ETC)	4.00	-	3.50	0.55[b]	1.10[c]	0.03	NA	NA

BS IV implementation dates

April 2010	NCR, 13 cities
July 2015	Above plus 29 cities mainly in the states of Haryana, Uttar Pradesh, Rajasthan and Maharashtra
October 2015	North India plus bordering districts of Rajasthan (9 states)
April 2016	Western India plus parts of south and East India
April 2017	Nationwide

Footnotes:

[a] Only for diesel engines

[b] A manufacturer may choose to measure the mass of THC instead of NMHC

[c] Only for CNG vehicles

PREVIOUS (BHARAT IV) DIESEL/CNG/LPG-FUELED VEHICLE ENGINE EXHAUST EMISSION STANDARDS

Deterioration Factor

The measured emission value multiplied by the deterioration factor must be lower than the limit value.

i) Vehicle manufacturers may opt for fixed deterioration factor

Engine Type	Test Cycle	CO	HC	NMHC	CH_4	NOx	PM
Diesel Engine	ESC	1.1	1.05	-	-	1.05	1.1
Diesel Engine	ETC	1.1	1.05	-	-	1.05	1.1
Gaseous Fueled Engine	ETC	1.1	1.05	1.05	1.2	1.05	-

ii) Alternatively, vehicle manufacturers may opt for evaluation of deterioration factor by minimum service accumulation period

Category of Vehicle	Minimum. Service Accumulation Period in km
Category N_1 vehicles	100,000
Category N_2 vehicles	125,000
Category N_3 vehicles with GVW ≤ 16,000kg	125,000
Category N_3 vehicles with GVW > 16,000kg	167,000
Category M_2 vehicles	100,000
Category M_3 vehicles with GVW ≤ 7,500kg	125,000
Category M_3 vehicles with GVW > 7,500kg	167,000

OTHER AREAS OF THE WORLD

Argentina	From 2016 for new models, 2018 for all vehicles Euro V
Australia	ADR 80/03 Euro V from 1st January 2010 for new vehicles (2011 for Diesel) US 07 or Japanese 05 Long Term as alternative Euro VI to be implemented 1st November 2024 (new models) and from 1st November 2025 (new registrations)
Brazil	P-7 (Euro V) from 1st January 2012 P-8 (Euro VI) from 1st January 2022
Canada	Canada HD Emissions standards are aligned with the latest US EPA standards
Chile	1st October 2014 New models (exc. Metropolitan area) Euro V 1st September 2015 Urban bus – Euro V 1st October 2015 All models – US 2004/US 2007 PM

Indonesia	Implementation of Euro IV standards came into effect on 1st April 2022
Mexico	Diesel Regulation Transitional (phase AA) standards equivalent to US EPA 2007 or Euro V from 1st January 2019 Phase B (US EPA 2010 or Euro VI) standards will be mandatory from 1st January 2025
Peru	From 1st April 2018 Euro IV
Russia	From 1st January 2016 Ecological Class 5 (Euro V)
Singapore	From 1st January 2018 Euro VI or Japan 2016 with Euro VI PN level PN level
Switzerland	Latest EU standards adopted
Thailand	All HD Diesel applications need to comply with Level 6 (Euro V) from 1st January 2024
Turkey	From 1st February 2011 Euro V From 1st January 2015 Euro VI
Vietnam	From 1st January 2022 Euro V (diesel)

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ADVANCING SUSTAINABILITY TODAY, POWERING A CARBON-FREE TOMORROW

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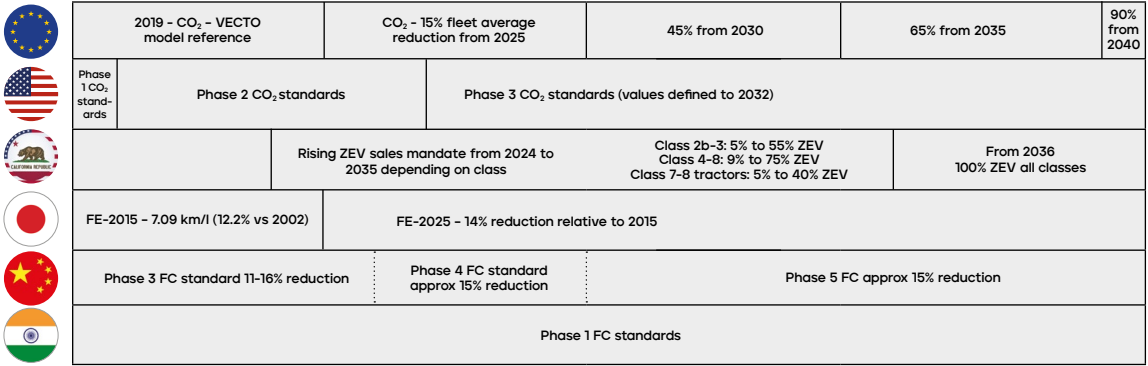
CO_2 / GREENHOUSE GAS / FUEL CONSUMPTION / ZEV

ROAD MAP FOR HEAVY-DUTY VEHICLE CO_2/FC/ZEV STANDARDS

All units per kWh except US/California where per bhp-hr is used



Dotted line means standard and introduction date to be confirmed.

2025 AND 2030 CO_2 FLEET AVERAGE EMISSION STANDARDS (AMENDED IN 2024, SEE NEXT PAGE)

Regulation (EU) 2019/1242 of 20th June 2019 sets CO_2 emission performance standards for new heavy-duty vehicles, amending Regulations (EC) no. 2022/1379, (EU) 2018/956 and Council Directive 96/53/EC - (595/2009 - 2017/2400 - 2022/1379).

EU has developed a computer simulation called VECTO (Vehicle Energy Consumption Tool) used to determine CO_2 and fuel consumption of HDVs. Since 1st January 2019, the tool is mandatory for new trucks of vehicle categories within the scope of the regulation.

The inputs for VECTO are characteristic parameters for determining the power consumption of each relevant vehicle component, such as rolling resistance, air drag, masses and inertias, gearbox friction, auxiliary power and engine performance. Some of them are application-specific (e.g. dynamometer-based engine fuel consumption and load maps) and others may be default values from the tool database.

A core physical model then performs the simulation of vehicle operation and predicts the corresponding vehicle fuel consumption and CO_2 emissions from the engine maps. The results are then used for vehicle certification, and fed into the monitoring and reporting as required by EU 2018/956. This monitoring and reporting applies to all categories of vehicles, and CO_2 emissions and average payload values have to be reported. They are also published to allow potential customers to compare vehicle efficiencies.

The CO_2 standard

This regulation shall apply to new heavy-duty vehicles of categories N_2 and N_3 meeting the following characteristics:

a) Rigid trucks with an axle configuration of 4x2 and a technically permissible maximum laden mass exceeding 16 tons

b) Rigid trucks with an axle configuration of 6x2

c) Articulated tractors with an axle configuration of 4x2 and technically permissible maximum laden mass exceeding 16 tons

d) Articulated tractors with an axle configuration of 6x2

In order to contribute to the reduction of EU greenhouse gas emissions, the regulation states that the average specific CO_2 emissions of each manufacturer's EU fleet of new heavy-duty vehicles shall be reduced compared to the reference values as follows:

a) For the reporting periods of the year 2025 onwards by 15%

b) For the reporting periods of the year 2030 onwards by 30% (unless decided otherwise by EU)

The reference CO_2 emissions shall be based on the monitoring data reported in the period from 1st July 2019 to 30th June 2020 (Regulation (EU) 2018/956), excluding vocational vehicles.

AMENDED 2030 AND NEW 2035 AND 2040 CO_2 FLEET AVERAGE EMISSION STANDARDS

Regulation (EU) 2024/1610 of 14th May 2024 revises CO_2 emission performance standards for new heavy-duty, with the main following changes in comparison to previous legislation:

- The scope increased to all M_2, M_3, N_1 (for vehicles which do not fall under LDV Regulation EU-2019/631), N_2, N_3, O_3 and O_4 vehicles
- The average CO_2 emissions of the EU fleet of new heavy-duty motor vehicles, except vehicles with derogation, shall be reduced by the following percentages compared to the average CO_2 emissions of the reference reported period (Reference CO_2)

% Reduction in Comparison to the Reference Period	Reference Period	Reporting Period of the Years			
		2025-29	2030-34	2035-39	2040-
Heavy trucks with GVW > 16t with standard axle configurations (4x2 or 6x4)	2019	15%	43%	64%	90%
Heavy trucks with GVW > 16t with special axle configurations Heavy trucks with GVW > 7.4t	2021	-	43%	64%	90%
Others (medium trucks, interurban buses, coaches)	2025	-	43%	64%	90%
Vocational vehicles	2025	-	-	64%	90%
Urban buses	2025	-	90%	100%	

Comments:

- The "Reference CO_2" shall be calculated on the basis of all new heavy-duty vehicles of all manufacturers for the reference period applicable to the sub-group
- Each vehicle category has its own "Reference CO_2" and then its own target (e.g. M, N, heavy truck etc.)
- For the purpose of calculating the average specific CO_2 emissions of manufacturers, individual heavy-duty vehicles may be transferred between manufacturers, following some conditions
- If less than 100 new heavy-duty vehicles of a manufacturer were registered in a given reporting period, the average specific CO_2 emissions shall be set at '0' in that reporting period

EPA HEAVY-DUTY GREENHOUSE GAS (GHG) AND NHTSA FUEL CONSUMPTION PROGRAMS - OVERVIEW

The US applies both greenhouse gas and fuel consumption fleet average standards for both engines and full vehicles:

- Engine standards are based on the SET load cycle (page 42) for engines certified as tractor, SET and FTP (page 43) for engines certified as both tractor and vocational and FTP for all other engines including heavy-duty SI.
- Vehicle standards are based on a simulation of vehicle emissions calculated from the engine emissions and the characteristics of the vehicle using the greenhouse gas emissions model (GEM)

The EPA and NHTSA cooperated to ensure the CO_2 and fuel consumption standards are equivalent.

Phase 1 (2014-2020)

The Phase 1 Heavy-Duty GHG and fuel consumption program was implemented from model year 2014, including separate standards for highway heavy-duty engines and heavy-duty vehicles. The program offered flexibility allowing manufacturers to attain these standards through a mix of technologies, and the use of various emissions credit averaging and banking programs.

Phase 2 (2021-2027)

In 2016, the EPA and NHTSA finalized the Phase 2 Heavy-Duty GHG and fuel efficiency program. Phase 2 includes technology-advancing performance-based standards that phased in commencing model year 2021, increasing in stringency in model year 2024, and culminating in model year 2027 standards.

Phase 2 included standards based not only on currently available technologies, but also on technologies under development or not yet widely deployed, with up to 10 years' lead time.

Phase 3 standards from 2027 (from page 74)

In April 2023, the EPA issued a proposed rule that applies more stringent heavy-duty vehicle CO_2 standards for model year 2027 to 2032. On 29th March 2024, the final rule was adopted.

The assessment of this rule identified the penetration rates of low and zero-emission vehicles required to meet the targets.

2018-2027 FUEL CONSUMPTION AND GHG FLEET AVERAGE VEHICLE LIMIT VALUES - PICKUPS AND VANS

Phase 2 HD Pickups and Vans Coefficient Tables for Target Standards

Heavy-duty pickups and vans (8,501-14,000 lbs) are subject to a chassis testing standard for CO_2 and fuel consumption. They are tested on the federal test procedure (FTP) and highway fuel economy test (HFET) cycles, with the composite result calculated by weighted average of FTP (55%) and HFET (45%).

CO_2 and fuel consumption targets were developed to be equivalent in stringency for diesel and gasoline vehicles respectively.

They are adjusted to the capacity of the vehicles based on a 'work factor' and coefficients that tighten each year (tables on right).

Work Factor (WF) = (0.75 x [Payload Capacity + xwd]) + (0.25 x Towing Capacity) [a,b,c]

CO_2 target (CO_2 / 100 miles) = a · WF + b

Fuel Consumption Target (gallons / 100miles)= [c x WF] + d

Coefficients for CO_2 standards

MY	Diesel Vehicles		Gasoline Vehicles	
	Coefficient a	Coefficient b	Coefficient a	Coefficient b
2018-2020	0.0416	320	0.0440	339
2021	0.0406	312	0.0429	331
2022	0.0395	304	0.0418	322
2023	0.0386	297	0.0408	314
2024	0.0376	289	0.0398	306
2025	0.0367	282	0.0388	299
2026	0.0357	275	0.0378	291
2027+	0.0348	268	0.0348	268

Coefficients for fuel consumption standards

MY	Diesel Vehicles		Gasoline Vehicles	
	Coefficient c	Coefficient d	Coefficient c	Coefficient d
2018-2020	0.0004086	3.143	0.0004951	3.815
2021	0.0003988	3.065	0.0004827	3.725
2022	0.0003880	2.986	0.0004703	3.623
2023	0.0003792	2.917	0.0004591	3.533
2024	0.0003694	2.839	0.0004478	3.443
2025	0.0003605	2.770	0.0004366	3.364
2026	0.0003507	2.701	0.0004253	3.274
2027+	0.0003418	2.633	0.0004152	3.196

Footnotes:

[a] Payload Capacity = GVWR (lbs) - Curb Weight (lbs)

[b] xwd = 500 lbs if vehicle is 4WD or AWD, otherwise zero

[c] Towing Capacity = GCWR (lbs) - GVWR (lbs)

2014-2027 FUEL CONSUMPTION AND GHG FLEET AVERAGE VEHICLE LIMIT VALUES - VOCATIONAL VEHICLES

US FEDERAL (EPA and NHTSA)

Phase 1 and 2 Class 2b-8 Vocation Vehicle Fuel Consumption and CO_2 Standards (based on GEM simulation of whole vehicle emissions/consumption)

	MY	Duty Cycle	Fuel Consumption (gallon/1,000 ton-mile)					CO_2 (g/ton-mile)				
			Light HD Class 2b-5	Medium HD Class 6-7	Heavy HD Class 8	Light HD Class 2b-5	Medium HD Class 6-7	Light HD Class 2b-5	Medium HD Class 6-7	Heavy HD Class 8	Light HD Class 2b-5	Medium HD Class 6-7
			Compression-Ignition			Spark-Ignition		Compression-Ignition			Spark-Ignition	
Phase 1	2014		38.1	23.0	22.2	Same as Compression-Ignition		388	234	226	Same as Compression-Ignition	
	2017		36.7	22.1	21.8			373	225	222		
Phase 2	2021	Urban	41.6503	29.0766	30.2554	51.8735	36.9078	424	296	308	461	328
		Multi-purpose	36.6405	26.0314	25.6385	45.7972	32.9695	373	265	261	407	293
		Regional	30.5501	22.9862	20.1375	37.6955	29.3687	311	234	205	335	261
	2024	Urban	37.8193	26.6208	27.7996	48.6103	34.8824	385	271	283	432	310
		Multi-purpose	33.7917	24.1650	23.7721	43.3217	31.3942	344	246	242	385	279
		Regional	29.0766	21.7092	19.0570	36.4577	28.2435	296	221	194	324	251
	2027	Urban	36.0511	25.3438	26.4244	46.4724	33.4196	367	258	269	413	297
		Multi-purpose	32.4165	23.0845	22.5933	41.8589	30.1564	330	235	230	372	268
		Regional	28.5855	21.4145	18.5658	35.8951	27.7934	291	218	189	319	247

Footnote: For HD gasoline engines the CO_2 limit is 627 g/bhph and the fuel consumption limit is 7.06 gal/100 bhph, both applicable from the 2016 model year to check

2014-2027 FUEL CONSUMPTION AND GHG FLEET AVERAGE VEHICLE LIMIT VALUES - TRACTORS

US FEDERAL (EPA and NHTSA)

Phase 1 and 2 HD Combination Tractor Fuel Consumption and CO_2 Standards (based on GEM simulation of whole vehicle emissions/consumption)

	MY	Roof	Fuel Consumption (gallon/1,000 ton-mile)				CO_2 (g/ton-mile)			
			Day Cab		Sleeper Cab	Heavy-Haul[a]	Day Cab		Sleeper Cab	Heavy-Haul[a]
			Class 7	Class 8	Class 8	Class 8	Class 7	Class 8	Class 8	Class 8
Phase 1	2014	Low roof	10.5	8	6.7	n/a	107	81	68	n/a
		Medium roof	11.7	8.7	7.4		119	88	76	
		High roof	12.2	9	7.3		124	92	75	
	2017	Low roof	10.2	7.8	6.5	n/a	104	80	66	n/a
		Medium roof	11.3	8.4	7.2		115	86	73	
		High roof	11.8	8.7	7.1		120	89	72	
Phase 2	2021	Low roof	10.36346	7.90766	7.10216	5.14735	105.5	80.5	72.3	52.4
		Medium roof	11.11984	8.38900	7.66208		113.2	85.4	78.0	
		High roof	11.14931	8.40864	7.43615		113.5	85.6	75.7	
	2024	Low roof	9.80354	7.48527	6.67976	4.93124	99.8	76.2	68.0	50.2
		Medium roof	10.52063	7.94695	7.22004		107.1	80.9	73.5	
		High roof	10.47151	7.89784	6.94499		106.6	80.4	70.7	
	2027	Low roof	9.44990	7.21022	6.29666	4.74460	96.2	73.4	64.1	48.3
		Medium roof	10.15717	7.66208	6.83694		103.4	78.0	69.6	
		High roof	9.82318	7.43615	6.31631		100.0	75.7	64.3	

[a] New sub-category adopted in Phase 2

2014-2027 FUEL CONSUMPTION AND GHG FLEET AVERAGE ENGINE LIMIT VALUES - ENGINES IN TRACTORS AND VOCATIONAL VEHICLES

US FEDERAL (EPA and NHTSA)

Limits for engines used in medium-heavy and heavy heavy-duty tractor units (using the SET cycle)

	Model Year	MHDDE	HHDDE	Medium HD Engines	Heavy HD Engines
		GHG Emissions CO_2 (g/bhp-hr)		Fuel Consumption (gallons/100 bhp-hr)	
Phase 1[a]	2014-2016	502	475	4.93[c]	4.67[c]
	2017-2020	487	460	4.78	4.52
	2021-2023	473	447	4.6464	4.3910
Phase 2[b]	2024-2026	461	436	4.5285	4.2829
	2027 and later[d]	457	432	4.4892	4.2436

Footnotes:

[a] Diesel only
[b] Diesel, gasoline and CNG
[c] Voluntary
[d] Post-2027 superseded by Phase 3

US FEDERAL (EPA and NHTSA)

Phase 2 Class 2b-8 Vocational Diesel Engine Fuel Consumption and CO_2 Standards (using the FTP cycle)

	MY	Duty Cycle	CO_2 (g/bhp-hr)	Fuel Consumption (gallon/100bhp-hr)
Phase 1	2014	LHDDE	600	5.89[c]
		MHDDE	600	5.89[c]
		HHDDE	567	5.57[c]
	2017	LHDDE	576	5.66
		MHDDE	576	5.66
		HHDDE	555	5.45
Phase 2	2021	LHDDE	563	5.5305
		MHDDE	545	5.3536
		HHDDE	513	5.0393
	2024	LHDDE	555	5.4519
		MHDDE	538	5.2849
		HHDDE	506	4.9705
	2027 and later[d]	LHDDE	552	5.4224
		MHDDE	535	5.2554
		HHDDE	503	4.9411

2027+ PHASE 3 FUEL CONSUMPTION AND GHG FLEET AVERAGE VEHICLE LIMIT VALUES – CLASS 2B AND 3 PICKUPS AND VANS

US FEDERAL (EPA)

As part of its March 2024 final multi-pollutant rule for light and medium duty vehicles, the EPA revised the CO_2 emission standards for class 2b and 3 pickups and vans. The targets continue to be based on the work factor described on page 70, with one set of coefficients for all powertrain types, below. For MY 2028 to 2031, "cutpoint" weight limits for the work factor are defined, above which an absolute CO_2 target is set. For MY 2028 to 2032, when the work factor is above a defined cutpoint, the target is set at an absolute value, see table.

Proposed coefficients for CO_2 targets for class 2b and 3 pickups and vans

MY	WF Cutpoint (lbs)	Below cutpoint		Equal to or above cutpoint
		Coefficient A	Coefficient B	
2027	n/a	0.0348	268	n/a
2028	8,000	0.0339	270	541
2029	6,800	0.031	246	457
2030	5,500	0.028	220	374
2031	5,500	0.0251	195	333
2032 and later	5,500	0.0221	170	292

The proposed rule includes a projection of the resulting CO_2 fleet targets for pickups and vans respectively, and a combined figure, based on an estimated fleet profile.

Projected CO_2 fleet average targets

MY	Vans CO_2 (g/mile)	Pickups CO_2 (g/mile)	Combined CO_2 (g/mile)
2027	393	462	438
2028	379	452	427
2029	345	413	389
2030	309	374	352
2031	276	331	312
2032 and later	243	292	275

2027+ PHASE 3 HEAVY-DUTY CO_2 EMISSION FLEET AVERAGE STANDARDS – VOCATIONAL VEHICLES

US FEDERAL (EPA)

Final MY 2027 through 2032+ Vocational Vehicle CO_2 Emission Standards (based on GEM simulation of whole vehicle emissions/consumption)

Model Year	Subcategory	Compression-Ignition (g CO_2/ton-mile)			Spark-Ignition (g CO_2/ton-mile)	
		Light Heavy	Medium Heavy	Heavy Heavy	Light Heavy	Medium Heavy
Phase 2: 2024 through 2026	Urban	385	271	283	432	310
	Multi-purpose	344	246	242	385	279
	Regional	296	221	194	324	251
Phase 3: 2027	Urban	305	224	269	351	263
	Multi-purpose	274	204	230	316	237
	Regional	242	190	189	270	219
Phase 3: 2028	Urban	286	217	269	332	256
	Multi-purpose	257	197	230	299	230
	Regional	227	183	189	255	212
Phase 3: 2029	Urban	268	209	234	314	248
	Multi-purpose	241	190	200	283	223
	Regional	212	177	164	240	206
Phase 3: 2030	Urban	250	201	229	296	240
	Multi-purpose	224	183	196	266	216
	Regional	198	170	161	226	199
Phase 3: 2031	Urban	198	178	207	244	217
	Multi-purpose	178	162	177	220	195
	Regional	157	150	146	185	179
Phase 3: 2032 and later	Urban	147	155	188	193	194
	Multi-purpose	132	141	161	174	174
	Regional	116	131	132	144	160

2027+ PHASE 3 HEAVY-DUTY CO_2 FLEET AVERAGE EMISSION FLEET STANDARDS – TRACTORS

US FEDERAL (EPA) – Final MY 2027 through MY 2032+ Tractor CO_2 Emission Standards (based on GEM simulation of whole vehicle emissions/consumption)

(g CO_2/ton-mile)

Model Year	Roof Height	Class 7 All Cab Styles	Class 8 Day Cab	Class 8 Sleeper Cab
Phase 2: 2024 through 2026	Low roof	99.8	76.2	68.0
	Mid roof	107.1	80.9	73.5
	High roof	106.6	80.4	70.7
Phase 3: 2027	Low roof	96.2	73.4	64.1
	Mid roof	103.4	78.0	69.6
	High roof	100.0	75.7	64.3
Phase 3: 2028	Low roof	88.5	67.5	64.1
	Mid roof	95.1	71.8	69.6
	High roof	92.0	69.6	64.3
Phase 3: 2029	Low roof	84.7	64.6	64.1
	Mid roof	91.0	68.6	69.6
	High roof	88.0	66.6	64.3
Phase 3: 2030	Low roof	80.8	61.7	60.3
	Mid roof	86.9	65.5	65.4
	High roof	84.0	63.6	60.4
Phase 3: 2031	Low roof	69.3	52.8	56.4
	Mid roof	74.4	56.2	61.2
	High roof	72.0	54.5	56.6
Phase 3: 2032 and later	Low roof	57.7	44.0	48.1
	Mid roof	62.0	46.8	52.2
	High roof	60.0	45.4	48.2

2027+ PHASE 3 HEAVY-DUTY STANDARDS PROJECTED IMPACT ON VEHICLE SALES

The regulatory impact assessments for the final rules (LDV and MDV multi-pollutant rule and HDV GHG rule) provide projections of the share of zero-emission vehicles required to meet the CO_2 standards in each year, see table below.

Modeled potential ZEV Adoption Rates in Technology Packages for the Final 2027-2032 Standards

Rule	Regulatory Subcategory Grouping	MY 2027	MY 2028	MY 2029	MY 2030	MY 2031	MY 2032
LDV and MDV multi-pollutant rule	Light heavy-duty pickups	3%	4%	8%	10%	10%	10%
	Light heavy-duty vans	3%	4%	24%	44%	64%	75%
HDV GHG rule	Light-heavy duty vocational	17%	22%	27%	32%	46%	60%
	Medium heavy-duty vocational	13%	16%	19%	22%	31%	40%
	Heavy heavy-duty vocational	0%	0%	13%	15%	23%	30%
	Day cab tractors	0%	8%	12%	16%	28%	40%
	Sleeper cab tractors	0%	0%	0%	6%	12%	25%

ZERO EMISSION VEHICLE STANDARDS

Advanced Clean Trucks (ACT) zero-emission vehicle (ZEV) sales requirements

Model Year	Class 2b-3	Class 4-8	Class 7-8 Tractors
2024	5%	9%	5%
2025	7%	11%	7%
2026	10%	13%	10%
2027	15%	20%	15%
2028	20%	30%	20%
2029	25%	40%	25%
2030	30%	50%	30%
2031	35%	55%	35%
2032	40%	60%	40%
2033	45%	65%	40%
2034	50%	70%	40%
2035	55%	75%	40%
2036*	100%	100%	100%

Notes:
Applies to OEMs' vehicle sales.
ZEV = zero tailpipe (battery electric and fuel cell electric).
Near-ZEV (NZEV) = plug-in hybrid with ZEV credit = 0.01 x all-electric range (maximum 0.75).
2036 100% target adopted via ACF (see right-hand side).

Advanced Clean Fleets (ACF) zero-emission vehicle (ZEV) fleet purchase requirements

Applies to public and priority fleets (priority = at least 2 trucks in California and 50 nationwide), with two compliance options:

1. Default model year option
- From 1st January 2024: all newly added trucks must be ZEV or NZEV
- From 1st January 2024: ICE vehicles removed after useful life exceeded

2. Alternative milestone option - percentage of California segment of fleet that must be zero-emission:

Zero-Emission Fleet Percentage	10%	25%	50%	75%	100%
Group 1: box trucks, vans, 2-axle buses, yard trucks, light-duty package delivery vehicles	2025	2028	2031	2033	2035
Group 2: work trucks, day cab tractors, 3-axle buses	2027	2030	2033	2036	2039
Group 3: sleeper cab tractors and specialty vehicles	2030	2033	2036	2039	2042

CURRENTLY IN FORCE CORPORATE AVERAGE FUEL ECONOMY STANDARDS

Heavy vehicle fuel economy standards set by the Ministry of Economy, Trade and Industry (METI) have been in force in Japan since 2015. These require the vehicle manufacturers to monitor and regulate their corporate fleet averaged CO_2 emissions with penalties levied against manufacturers failing to submit or to meet these targets.

1. Freight: Vehicle Trucks, etc.

Class	Total Vehicle Weight CVW (ton)	Maximum Loading Capacity PL (ton)	Target FE Value (km/l)	Test Mode Weighting	
				City Driving Mode (JE05)	Intercity Driving Mode
1	3.5 ≤ GVW < 7.5	PL ≤ 1.5	10.83	0.9	0.1
2		1.5 < PL ≤ 2.0	10.35	0.9	0.1
3		2 < PL ≤ 3	9.51	0.9	0.1
4		PL < 3	8.12	0.9	0.1
5	7.5 < GVW ≤ 8		7.24	0.9	0.1
6	8 < GVW ≤ 10		6.52	0.9	0.1
7	10 < GVW ≤ 12		6.00	0.9	0.1
8	12 < GVW ≤ 14		5.69	0.9	0.1
9	14 < GVW ≤ 16		4.97	0.9	0.1
10	16 < GVW ≤ 20		4.15	0.9	0.1
11	20 < GVW ≤ 25		4.04	0.7	0.3

Tractor Unit

Class	Total Vehicle Weight CVW (ton)	Target FE Value (km/l)	Test Mode Weighting	
			City Driving Mode (JE05)	Intercity Driving Mode
1	GVW ≤ 20	3.09	0.8	0.2
2	20 < GVW	2.01	0.9	0.1

CURRENTLY IN FORCE CORPORATE AVERAGE FUEL ECONOMY STANDARDS

2. Passenger vehicle: transit bus

Class	Total Vehicle Weight CVW (ton)	Target FE Value (km/l)	Test Mode Weighting	
			City Driving Mode (JE05)	Intercity Driving Mode
1	6 < GVW ≤ 8	6.97	1	0
2	8 < GVW ≤ 10	6.30	1	0
3	10 < GVW ≤ 12	5.77	1	0
4	12 < GVW ≤ 14	5.14	1	0
5	14 < GVW	4.23	1	0

General (non-transit) bus

Class	Total Vehicle Weight CVW (ton)	Target FE Value (km/l)	Test Mode Weighting	
			City Driving Mode (JE05)	Intercity Driving Mode
1	3.5 < GVW ≤ 6	9.04	0.9	0.1
2	6 < GVW ≤ 8	6.52	0.9	0.1
3	8 < GVW ≤ 10	6.37	0.9	0.1
4	10 < GVW ≤ 12	5.70	0.9	0.1
5	12 < GVW ≤ 14	5.21	0.9	0.1
6	14 < GVW ≤ 16	4.06	0.65	0.35
7	16 < GVW	3.57	0.65	0.35

2025+ CORPORATE AVERAGE FUEL ECONOMY STANDARDS

In 2015, the Japanese government determined that a further standard is necessary. This was finally promulgated in March 2019. These standards are to be met by 2025.

1. Freight: Vehicle Trucks, etc.

Class	Total Vehicle Weight CVW (ton)	Maximum Loading Capacity PL (ton)	Target FE Value (km/l)	Test Mode Weighting	
				City Driving Mode (JE05)	Intercity Driving Mode
1	3.5 < GVW ≤ 7.5	PL ≤ 1.5	13.45	0.9	0.1
2		1.5 < PL ≤ 2.0	11.93	0.9	0.1
3		2 < PL ≤ 3	10.59	0.9	0.1
4		PL > 3	9.91	0.9	0.1
5	7.5 < GVW ≤ 8		8.39	0.9	0.1
6	8 < GVW ≤ 10		7.46	0.9	0.1
7	10 < GVW ≤ 12		7.44	0.9	0.1
8	12 < GVW ≤ 14		6.42	0.9	0.1
9	14 < GVW ≤ 16		5.89	0.9	0.1
10	16 < GVW ≤ 20		4.88	0.9	0.1
11	20 < GVW ≤ 25		4.42	0.7	0.3

Tractor Unit

Class	Total Vehicle Weight CVW (ton)	Target FE Value (km/l)	Test Mode Weighting	
			City Driving Mode (JE05)	Intercity Driving Mode
1	GVW ≤ 20	3.11	0.8	0.2
2	20 < GVW	2.32	0.9	0.1

2025+ CORPORATE AVERAGE FUEL ECONOMY STANDARDS

2. Passenger vehicle: transit bus

Class	Total Vehicle Weight CVW (ton)	Target FE Value (km/l)	Test Mode Weighting	
			City Driving Mode (JE05)	Intercity Driving Mode
1	6 < GVW ≤ 8	7.15	1	0
2	8 < GVW ≤ 10	6.3	1	0
3	10 < GVW ≤ 12	5.8	1	0
4	12 < GVW ≤ 14	5.27	1	0
5	14 < GVW	4.52	1	0

General (non-transit) bus

Class	Total Vehicle Weight CVW (ton)	Target FE Value (km/l)	Test Mode Weighting	
			City Driving Mode (JE05)	Intercity Driving Mode
1	3.5 < GVW ≤ 6	9.54	0.9	0.1
2	6 < GVW ≤ 8	7.73	0.9	0.1
3	8 < GVW ≤ 10	6.37	0.9	0.1
4	10 < GVW ≤ 12	6.06	0.9	0.1
5	12 < GVW ≤ 14	5.29	0.9	0.1
6	14 < GVW ≤ 16	5.28	0.65	0.35
7	16 < GVW	5.14	0.65	0.35

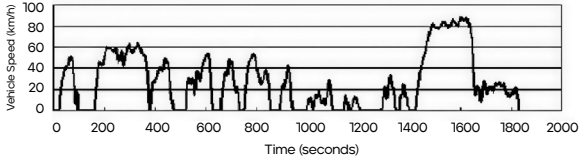
FUEL ECONOMY TEST METHODS AND CYCLES

Test method

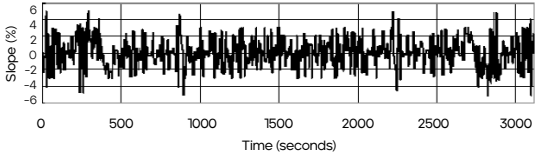
The fuel economy (in km/liter) of heavy-duty trucks and buses is calculated by a computer simulation procedure using data inputs from engine dynamometer tests.

The engine test is performed over the JE05 city driving test cycle and the intercity driving transient test cycle with the combined results weighted as shown in the tables on pages 79-82. Vehicle specifications including mass, payload, axles, tire size, gear ratios etc. are included in the computer simulation.

City driving mode (JE05 mode)



Intercity driving mode (80km/h constant speed mode)



CURRENTLY IN FORCE PHASE 3 FUEL CONSUMPTION LIMIT VALUES

The current applicable standard for heavy-duty fuel consumption is GB30510-2018 (Fuel consumption limits for individual HD commercial vehicles):

- Replaces GB30510-2014 from 2nd July 2019
- All the limits are based on C-WTVC (refer to page 88) which is defined in test method GB/T27840-2011
- The implementation date is 1st July 2019 for newly certified vehicles, and 1st July 2021 for approved in-production vehicles
- Compared with Phase II, the fuel consumption limits decreased around 15%, taking a 10-tonne truck as an example

FC Limits for individual semi-trailer combinations

Gross Combination Weight (GCW) [kg]	FC Limits (l/100 km)
	For Semi-Trailer Towing Vehicle
GCW ≤ 18,000	28.0
18,000 < GCW ≤ 27,000	30.5
27,000 < GCW ≤ 35,000	32.0
35,000 < GCW ≤ 40,000	34.0
40,000 < GCW ≤ 43,000	35.5
43,000 < GCW ≤ 46,000	38.0
43,000 < GCW ≤ 49,000	40.0
49,000 < GCW	40.5

FC Limits for individual HD Diesel Vehicles, GB 30510-2018

Gross Vehicle Weight (GVW) [kg]	FC Limits (l/100 km)	
	For Truck	For Dump Trucks
3,500 < GVW ≤ 4,500	11.5[a]	13.0
4,500 < GVW ≤ 5,500	12.2[a]	13.5
5,500 < GVW ≤ 7,000	13.8[a]	15.0
7,000 < GVW ≤ 8,500	16.3[a]	17.5
8,500 < GVW ≤ 10,500	18.3[a]	19.5
10,500 < GVW ≤ 12,500	21.3[a]	22.0
12,500 < GVW ≤ 16,000	24.0	25.0
16,000 < GVW ≤ 20,000	27.0	29.5
20,000 < GVW ≤ 25,000	32.5	37.5
25,000 < GVW ≤ 31,000	37.5	41.0
31,000 < GVW	38.5	41.5

Footnotes:

[a] For gasoline vehicles, the limit is 1.2 x the diesel limit rounded up to one decimal place

CURRENTLY IN FORCE PHASE 3 FUEL CONSUMPTION LIMIT VALUES

FC Limits for individual HD Diesel Vehicles, GB 30510-2018

Gross Vehicle Weight (GVW) [kg]	FC Limits (l/100 km)	
	For Coaches	For City Buses
3,500 < GVW ≤ 4,500	10.6[a]	11.5
4,500 < GVW ≤ 5,500	11.5[a]	13.0
5,500 < GVW ≤ 7,000	13.3[a]	14.7
7,000 < GVW ≤ 8,500	14.5	16.7
8,500 < GVW ≤ 10,500	16.0	19.4
10,500 < GVW ≤ 12,500	17.7	22.3
12,500 < GVW ≤ 14,500	19.1	25.5
14,500 < GVW ≤ 16,500	20.1	28.0
16,500 < GVW ≤ 18,000	21.3	31.0
18,000 < GVW ≤ 22,000	22.3	34.5
22,000 < GVW ≤ 25,000	24.0	38.5
25,000 < GVW	25.0	41.5

Footnotes:
[a] For gasoline vehicles, the limit is 1.2 x the diesel limit rounded up to one decimal place

FUTURE PHASE 4 FUEL CONSUMPTION LIMIT VALUES

CHINA

The next applicable standard for heavy-duty fuel consumption is GB30510-202x (Fuel consumption limits for individual HD commercial vehicles):

- It is still to be finalized and will replace GB30510-2018. Current indications are for implementation in January 2026.
- All the limits are based on GB/T 27840-2021 for diesel and gasoline vehicles and GB/T 19754-2021 for hybrid vehicles. The test cycle will be the China heavy-duty test cycle (CHTC, refer to page 89).
- Compared to Phase III, the limits decrease (around 15% taking a 10-ton truck as an example) and the test cycle change has an impact (CHTC).

Gross Combination Weight (GCW) [kg]	FC Limits (l/100 km)
	For Semi-Trailer Towing Vehicle
GCW ≤ 18,000	24.3
18,000 < GCW ≤ 27,000	26.5
27,000 < GCW ≤ 35,000	27.8
35,000 < GCW ≤ 40,000	29.5
40,000 < GCW ≤ 43,000	31.2
43,000 < GCW ≤ 46,000	33.7
46,000 < GCW ≤ 49,000	35.8
49,000 < GCW	35.9

FC Limits for individual HD Diesel Vehicles, GB 30510-202x

Gross Vehicle Weight (GVW) [kg]	FC Limits (l/100 km)	
	For Trucks	For Dump Trucks
3,500 < GVW ≤ 4,500	10.6[a]	12.0
4,500 < GVW ≤ 5,500	11.0[a]	12.5
5,500 < GVW ≤ 7,000	12.3[a]	13.9
7,000 < GVW ≤ 8,500	14.4[a]	16.2
8,500 < GVW ≤ 10,500	16.2[a]	18.0
10,500 < GVW ≤ 12,500	18.8[a]	20.3
12,500 < GVW ≤ 16,000	21.2	23.1
16,000 < GVW ≤ 20,000	23.9	27.3
20,000 < GVW ≤ 25,000	29.5	35.0
25,000 < GVW ≤ 31,000	33.7	38.2
31,000 < GVW	34.6	38.7

Footnotes:

[a] For gasoline vehicle, the limit is 1.3 x the diesel limit rounded up to one decimal place

FUTURE PHASE 4 FUEL CONSUMPTION LIMIT VALUES

FC Limits for individual HD Diesel Vehicles, GB 30510-202x

Gross Vehicle Weight (GVW)[b] [kg]	FC Limits (l/100 km)	
	For Coaches	For City Buses
3,500 < GVW ≤ 4,500	9.7[a]	10.9[c]
4,500 < GVW ≤ 5,500	11.4[a]	12.5[c]
5,500 < GVW ≤ 7,000	13.1[a]	14.3[c]
7,000 < GVW ≤ 8,500	14.3	16.5[c]
8,500 < GVW ≤ 10,500	15.8	19.4[c]
10,500 < GVW ≤ 12,500	17.8	22.6[c]
12,500 < GVW ≤ 14,500	19.4	26.1[c]
14,500 < GVW ≤ 16,500	20.6	29.0
16,500 < GVW ≤ 18,000	21.9	32.5
18,000 < GVW ≤ 22,000	23.1	36.5
22,000 < GVW ≤ 25,000	25.0	41.2
25,000 < GVW	26.2	44.9

Footnotes for future fuel consumption limit values:

[a] For gasoline vehicle, the limit is 1.3 x the diesel limit. rounded up to one decimal place

[b] For external rechargeable or non-rechargeable hybrid vehicles tested according to the 65% maximum design load stated in GB/T 17954-2021, the limit value corresponding to the GVW minus 35% maximum design load mass shall be taken as the limit value of the vehicle

[c] For dedicated school buses, the limit is 1.15 x limit rounded up to one decimal place

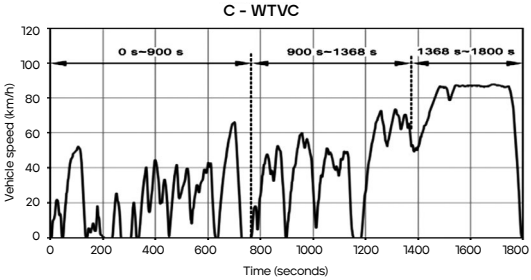
VEHICLE TEST CYCLES

CHINA Adapt World Transient Vehicle Cycle

C-WTVC was formed by adjusting acceleration and deceleration based on the world heavy-duty commercial vehicle transient cycle.

C-WTVC was used in heavy-duty fuel consumption test methods GB/T 27840-2011 for diesel and gasoline vehicles, which adopted Phase II (GB30510-2014) and Phase III (GB30510-2018) fuel consumption regulations.

The Phase IV (GB30510-20xx) fuel consumption limit will use a new (CHTC) test cycle.



Operation mode	Running Time	Idle Time	Running Mileage	High Speed	Average Speed	Maximum Acceleration	Maximum Deceleration	Mileage Ratio
	s	s	km	km/h	km/h	m/s^2	m/s^2	%
Urban part	900	150	5.730	66.2	22.895	0.917	1.033	27.94
Suburban part	468	30	5.687	73.5	43.746	0.833	1.000	27.73
Highway part	432	6	9.093	87.8	75.772	0.389	0.967	44.33
C-WTVC	1,800	186	20.510	87.8	40.997	0.917	1.033	100.00

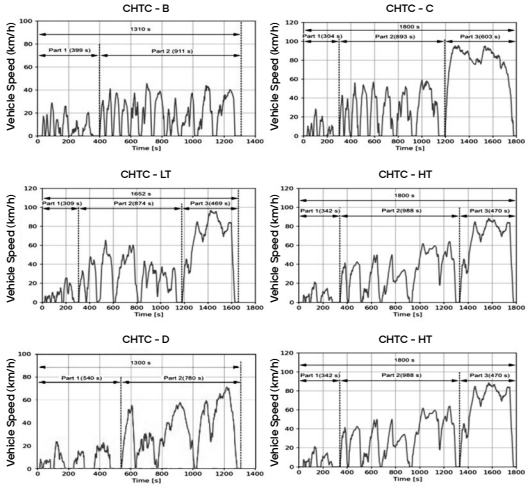
TEST CYCLES

The applicable standard on China heavy-duty commercial vehicle test cycle (CHTC) is defined and published in GB/T: 38146.2-2019, which includes six test cycles for different types of heavy-duty vehicles (GVM > 3,500kg):

- CHTC-B: China heavy-duty commercial vehicle test cycle for city buses
- CHTC-C: China heavy-duty commercial vehicle test cycle for coaches
- CHTC-LT: China heavy-duty commercial vehicle test cycle for trucks (≤ 5,500kg)
- CHTC-HT: China heavy-duty commercial vehicle test cycle for trucks (> 5,500kg)
- CHTC-D: China heavy-duty commercial vehicle test cycle for dump-trucks
- CHTC-TT: China heavy-duty commercial vehicle test cycle for articulated-trucks

CHTC was used in heavy-duty fuel consumption test methods GB/T 27840-2021 for diesel and gasoline vehicle and GB/T 19754-2021 for hybrid vehicles.

The test method with CHTC will be used for China next step fuel consumption GB30510-20xx (draft version finished in Nov 2022).



2014-2019 PHASE 2 FUEL CONSUMPTION LIMIT VALUES

CHINA

The past applicable standard for heavy-duty fuel consumption is GB30510-2014 (Fuel Consumption limits for individual HD commercial vehicles):

- All the limits based on C-WTVC (refer to page 88 which defines fuel consumption test methods for HD commercial vehicles GB/T27840-2011
- Implementation date is 1st July 2015 for approved in-production vehicles
- This regulation was replaced by GB30510-2018 from 2nd July 2019

FC limits for individual semi-trailer combinations

Gross Combination Weight (GCW) [kg]	FC Limits (l/100 km)
	For Semi-Trailer Towing Vehicles
GCW ≤ 18,000	33.0
18,000 < GCW ≤ 27,000	36.0
27,000 < GCW ≤ 35,000	38.0
35,000 < GCW ≤ 40,000	40.0
40,000 < GCW ≤ 43,000	42.0
43,000 < GCW ≤ 46,000	45.0
46,000 < GCW ≤ 49,000	47.0
49,000 < GCW	48.0

FC Limits for individual HD Diesel Vehicles, GB 30510-2014

Gross Vehicle Weight (GVW) [kg]	FC Limits (l/100 km)	
	For Trucks	For Dump Trucks
3,500 < GVW ≤ 4,500	13.0[a]	15.0
4,500 < GVW ≤ 5,500	14.0[a]	16.0
5,500 < GVW ≤ 7,000	16.0[a]	17.5
7,000 < GVW ≤ 8,500	19.0[a]	20.5
8,500 < GVW ≤ 10,500	21.5[a]	23.0
10,500 < GVW ≤ 12,500	25.0[a]	25.5
12,500 < GVW ≤ 16,000	28.0	28.0
16,000 < GVW ≤ 20,000	31.5	34.0
20,000 < GVW ≤ 25,000	37.5	43.5
25,000 < GVW ≤ 31,000	43.0	47.0
31,000 < GVW	43.5	49.0

Footnotes:

[a]For gasoline vehicle, the limit is 1.2 x the diesel limit rounded up to one decimal place

2014-2019 PHASE 2 FUEL CONSUMPTION LIMIT VALUES

FC Limits for individual HD Diesel Vehicles, GB 30510-2014

Gross Vehicle Weight (GVW) [kg]	FC Limits (l/100 km)	
	For Coaches	For City Buses
3,500 < GVW ≤ 4,500	12.5[a]	14.0
4,500 < GVW ≤ 5,500	13.5[a]	15.5
5,500 < GVW ≤ 7,000	15.0	17.5
7,000 < GVW ≤ 8,500	16.5	19.5
8,500 < GVW ≤ 10,500	18.5	22.5
10,500 < GVW ≤ 12,500	20.0	26.0
12,500 < GVW ≤ 14,500	21.5	30.5
14,500 < GVW ≤ 16,500	22.5	34.0
16,500 < GVW ≤ 18,000	24.0	37.5
18,000 < GVW ≤ 22,000	25.0	41.0
22,000 < GVW ≤ 25,000	27.5	45.5
25,000 < GVW	29.5	49.0

Footnotes:
[a] For gasoline vehicles, the limit is 1.2 x the diesel limit rounded up to one decimal place

CURRENTLY IN FORCE PHASE 1 FUEL CONSUMPTION STANDARDS

Current regulation: Phase 1 standards

Scope:

- All vehicles from M_3 and N_3 categories with GVW ≥ 12 tons since 2017
- All vehicles certified to BS VI emissions standards (M & N categories with GVW ≥ 3.5 tons) since 2019

Cycle: Constant Speed Fuel Consumption (CSFC) driving cycle at 40 km/h and 60 km/h. The fuel consumption is measured over a set speed without any transient behavior.

The Fuel Consumption minimal requirement is given by an equation depending on the type of vehicle, axle configuration and GVW range.

To demonstrate compliance, each vehicle model and configuration is required to meet the fuel consumption levels shown in the table on the right.

Phase 1 fuel consumption limit values

GVW (tons)	Axle Configuration	Fuel Consumption (l/100km) at 40km/h	Fuel Consumption (l/100km) at 60km/h
N_3 Rigid Vehicles			
12 ≤ GVW < 16.2	4 x 2	FC ≤ 0.362 x GVW + 10.327	FC ≤ 0.788 x GVW + 9.003
16.2 ≤ GVW < 25	6 x 2	FC ≤ 0.603 x GVW + 6.415	FC ≤ 0.755 x GVW + 9.546
	6 x 4	FC ≤ 0.723 x GVW + 4.482	FC ≤ 1.151 x GVW + 3.122
25 ≤ GVW < 31	8 x 2	FC ≤ 0.527 x GVW + 8.333	FC ≤ 0.650 x GVW + 12.160
	8 x 4	FC ≤ 0.928 x GVW - 0.658	FC ≤ 0.968 x GVW + 7.692
31 ≤ GVW	10 x 2	FC ≤ 0.960 x GVW - 5.100	FC ≤ 0.650 x GVW + 12.160
N_3 Tractors - Trailers Vehicles			
35.2 ≤ GVW < 40.2	4 x 2	FC ≤ 0.986 x GVW - 7.727	FC ≤ 0.208 x GVW + 32.198
40.2 ≤ GVW	6 x 2	FC ≤ 0.628 x GVW + 6.648	FC ≤ 0.628 x GVW + 15.298
	6 x 4	FC ≤ 1.255 x GVW - 18.523	FC ≤ 1.342 x GVW - 13.390
M_3 Vehicles			
12 ≤ GVW	4 x 2 & 6 x 2	FC ≤ 0.509 x GVW + 11.062	FC ≤ 0.199 x GVW + 19.342

(FOR REFERENCE) NOT ADOPTED PHASE 2 FUEL CONSUMPTION STANDARDS

Phase 2 regulation

In 2017, Phase 2 limits were adopted for implementation in April 2023.
In 2020, the Phase 2 limits were removed from the regulation.

Phase 2 fuel consumption limit values for N_2, M_2 & M_3 vehicles, GVW < 12t

GVW (tons)	Fuel Consumption (l/100km) at 40 km/h	Fuel Consumption (l/100km) at 50 km/h	Fuel Consumption (l/100km) at 60 km/h
N_2 Vehicles			
3.5 ≤ GVW < 7.5	-	FC ≤ 1.038 x GVW + 3.372	-
7.5 ≤ GVW < 12	FC ≤ 1.080 x GVW + 1.708	-	FC ≤ 1.038 x GVW + 6.008
M_2 and M_3 Vehicles			
3.5 ≤ GVW < 7.5	-	FC ≤ 1.293 x GVW + 2.806	-
7.5 ≤ GVW < 12	FC ≤ 1.399 x GVW + 0.381	-	FC ≤ 1.768 x GVW + 0.509

(FOR REFERENCE) NOT ADOPTED PHASE 2 FUEL CONSUMPTION STANDARDS

Phase 2 fuel consumption limit values for GVW ≥ 12t

Vehicle Category	Gross Vehicle Weight (tons)	Axie Configuration	Equation	Fuel Consumption (l/100 km)		Equation	Fuel Consumption (l/100 km)	
				Value at Lower Weight Limit	Value at Upper Weight Limit		Value at Lower Weight Limit	Value at Upper Weight Limit
			40 km/h			60 km/h		
N_3 Rigid Vehicles	12.0 - 16.2	4 x 2	Y = 0.329X + 9.607	13.6	14.9	Y = 0.600X + 9.890	17.1	19.6
	16.2 - 25.0	6 x 2	Y = 0.523X + 6.462	14.9	19.5	Y = 0.515X + 11.271	19.6	24.6
	16.2 - 25.0	6 x 4	Y = 0.673X + 4.032	14.9	20.9	Y = 0.932X + 4.515	19.6	27.8
	25.0 - 31.0	8 x 2	Y = 0.430X + 8.780	19.5	22.1	Y = 0.382X + 14.598	24.2	26.4
	25.0 - 31.0	8 x 4	Y = 0.732X + 2.558	15.7	20.1	Y = 1.318X - 5.148	27.8	35.7
	31.0 - 37.0	10 x 2	Y = 0.963X + 7.753	22.1	27.9	Y = 1.043X - 5.913	26.4	32.7
N_3 Tractor Trailers	35.2 - 40.2	4 x 2	Y = 0.826X + 3.165	25.9	30.0	Y = 0.260X + 27.888	37.0	38.3
	40.2 - 49.0	6 x 2	Y = 0.630X + 4.732	20.6	26.1	Y = 0.2364X + 28.838	38.3	40.4
	40.2 - 49.0	6 x 4	Y = 1.008X - 10.480	30.0	38.9	Y = 0.563X + 15.728	38.4	43.3
M_3 Vehicles	12.0 and above	4 x 2 and 6 x 2	Y = 0.659X + 6.582	14.5	-	Y = 0.340X + 14.300	18.4	-

CANADA

Regulation: SOR/2013-24 // SOR/2022-204.

Canada is harmonized with US EPA GHG regulation (regulatory design, vehicle categories, limits values, timing). Phase 2 standards are currently in effect.

Implementation date: starting MY 2021.

Scope: all on-road vehicles with GVW ≥ 8500 lbs.

Specific rules are defined for some heavy-haul tractors.

UK

Regulation: SI 2020/1402 with amendments SI 2022/1361.

The UK is following the EU CO_2 emission standards (Regulation EU 2019/1242), transposed into UK and GB regulations.

Implementation date: from 1st January 2021.

Scope: same as EU regulations but including the vehicles approved according to GB and UK regulations.

Monitoring and reporting follow the same rules as the EU regulations but are adapted to suit the agreed UK requirements:

- Reporting periods and format are carry-over with the first UK report from 1st July 2020 to 30th June 2021
- Applicable to new heavy-duty vehicles registered in the UK
- Targets are similar to the current EU regulations but refer to the UK fleet
- The CO_2 reference values refer to those used by the EU

Zero-emission

In 2020, the UK government announced the end of sale of non-zero tailpipe emission heavy-duty vehicles under 26 t GVW by 2035 and all heavy-duty vehicles by 2040. The relevant legislation has not yet been enacted.

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ON-BOARD DIAGNOSTIC AND MONITORING

ON-BOARD DIAGNOSTICS INTRODUCTION

On-board diagnostics (OBD) permits rapid detection of failure of emission-critical components and systems on vehicles. OBD identifies deteriorations and malfunctions of components calculated to exceed defined OBD threshold limits (OTLs).

The driver is notified of the malfunction upon detection through illumination of the Malfunction Indicator Lamp (MIL).

Euro IV OBD are demonstrated over the ESC (European Stationary Cycle) test cycle where the length of each mode is reduced to 60 seconds.

OBD Thresholds Limits	NOx (g/kWh)	PM (g/kWh)
Euro IV	7.0	0.1
Euro V		

OBD Stage I (Euro IV) (Directive 2005/55/EC and 2005/78/EC) application dates:
New types (NT): 1st October 2005
All new vehicles (NV): 1st October 2006

Monitoring Areas:
- Reduction in the efficiency of the catalyst
- Complete removal of a catalyst (fitted in separate housing)
- Reduction in the efficiency of the DeNOx System
- Reduction in the efficiency of the diesel particulate system
- Reduction in the efficiency of the combined DeNOx-particulate filter system

As an alternative, OBD systems may monitor for major failure of:
- Catalyst (separated unit or part of a DeNOx system or of a diesel particulate filter)
- DeNOx system
- Particulate filter
- Combined DeNOx – particulate filter system

OBD Stage II (Euro V): applicable for diesel and gas engines application dates:
NT: 1st October 2008; NV: 1st October 2009

Monitoring Area: Stage I monitoring area, additionally to any interface between the engine electronic control unit (EECU) and any other powertrain or vehicle electrical or electronic system for electrical disconnection.

Additional Requirements for both Stage I and Stage II:
- Monitoring of the fuel-injection system electronic, fuel quantity and timing actuator for circuit continuity and total functional failure
- Any other emission-related component (airflow, EGR, etc.) if a malfunction causes increases above the threshold
- Check of circuit continuity of any other emission-related components connected to the computer, unless monitored otherwise
- In case of aftertreatment system using a consumable reagent, monitoring of lack of any required reagent, reagent quality, reagent consumption and dosing activity

General Requirements applicable to both Euro IV and Euro V:
- Standardization of emission-related fault codes, data transfer, diagnostic tools and connector according to ISO standards (ISO 15031-4 or J1939-73)
- Repair information to be provided, excluding information covered by intellectual rights or that constitute any specific know-how of manufacturers/suppliers

REQUIREMENTS FOR CORRECT OPERATION OF NOx CONTROL MEASURES (Directive 2005/78/EC)

Application dates: NT 1st October 2006 NV 1st October 2007

1. In case of engine systems requiring a reagent, NH_3 emissions, over the applicable emissions test cycle, should not exceed 25 ppm (mean value).

2. Engine NOx control

· Malfunction Indicator Lamp (MIL) illuminated if emission control system is not functioning correctly
· Incorrect operation of the NOx control detected => MIL
· NOx level > 1.5 g/kWh above the applicable NOx limit => MIL
· NOx level exceeds OBD threshold (7.0 g/kWh) => torque limiter activation
· No erasable fault code saved for 400 days or 9,600 hours of engine operation
· Alternative method possible if use of EGR only for NOx emission control

3. Reagent control

· Warning when level of reagent:
  - < 10% of the tank or
  - < level corresponding to the driving distance possible with full fuel tank
· Reagent consumption to be monitored
· Reagent indicator on dashboard
· Torque limiter and MIL activations required in case of:
  - Consumption deviation of > 50% compared to demand
  - Reagent tank empty
  - Wrong reagent quality/concentration
  - Interruption in reagent dosing activity

4. Torque limited to:

· Maximum 60% of maximum torque for
  - N_3 > 16 tons
  - M_3, M_3/III and
  - M_2/B > 7.5 tons
· Maximum 75% of maximum torque for
  - N_1, N_2, N_3 ≤ 16 tons
  - 3.5 < M_2 < 7.5 tons
  - M_2, M_2/I, M_2/II, M_2/A, M_2/B ≤ 7.5 tons
· Deactivation of the torque limiter not feasible by switch or maintenance tool

5. Operating conditions of the emission control monitoring system

· Ambient temperature: -7°C to 35°C
· Altitude below 1,600 m
· Engine coolant temperatures > 70°C

6. Emission control monitoring system monitored for:

· Electrical failures
· Removal or deactivation of any sensor
· If failure not remedied within 50 hrs engine operation => torque limiter

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EURO VI OBD

Regulation EC 595/2009, EC 582/2011 and EC 133/2014
Application date:
· From First Phase in – 31st December 2012
· General requirement for all vehicles from 31st December 2012

Euro VI OBD are demonstrated over the WHTC test cycle.

Globally, Euro VI follows all requirements from UN Regulation 49 (R49). It is aligned to the Worldwide Harmonized OBD (WWH-OBD – see page 102).

Requirements largely referring to R49 with some provisions:

· Monitoring of reagent injection performance in closed-loop
· Monitoring of particulate aftertreatment device
· Monitoring of periodic regeneration

Alternative approach for certification can be applied for vehicle categories M_1, M_2, N_1, N_2 and some M_3, following UN Regulation 154 for LDV, if GVW does not exceed 7,500kg.

Additional monitoring requirements compared to R49:

· Low EGR Flow (achievement of the EGR demand)
· EGR Cooler Underperformance (no cooling capacity)
· Low Boost Pressure (achievement of boost demand)
· Malfunctioning of Injector (monitoring of control limits)

OBD Thresholds Limits (mg/kWh)						
Implementation Dates: ALL Types	PI Engines	CI Engines	ALL Engines			
	CO	PM	NOx	IUPR[a]	Reagent Quality & Consumption Monitoring	Additional OBD Requirements
Phase in	7,500	--	1,500	Phase-in[b]	Phase-in[b]	N/A
Final	7,500	25	1,200	General[c]	General[c]	Yes

Footnotes:
[a] IUPR – In-use performance ratio - see page 103
[b] Phase-in requirements shall apply until 31/12/2016:
- IUPR requirement not needed for certification
- NOx emissions limits during transition: 900 mg/kWh instead of 460 on WHTC

[c] The general (final) requirements shall apply

EURO 7 ON-BOARD MONITORING AND ON-BOARD DIAGNOSTICS

The Euro 7 legislation was adopted in May 2024

Technical requirements for implementing Euro 7, including the detailed OBD requirements, are still under discussion. Statements in this summary mainly refer to LDV, and a similar concept is foreseen for HDV.

Entry into force for HDV:

- New types (NT): May 29th 2028
- All new vehicles (NV) May 29th 2029

OBD: All requirements defined in Euro VI will be applicable for Euro 7 (Reg49-06 Annex 9x is currently referred as the OBD reference).

On-board Monitoring (OBM):

Concept: on-board system capable of monitoring emissions, detecting exhaust emission exceedances and communicating this information together with the State of Health information off-board.

Pollutants:

Monitoring and registering all **NOx, NH_3 and PM** exhaust emissions and detecting exceedances of 2.5 times the exhaust emission limit.

OBM objectives:

Vehicle level:

- Identification of high emitting vehicles by activating the warning system (EEEDWS - Exhaust Emission Exceedance Driver Warning System), when OBM emissions exceed by 2.5 times the standard emissions (on RDE basis)
- When the EEEDWS is activated, inducement system starts to enforce repair actions
- As long as the EEEDWS is not active, the vehicle can be included in in-service Conformity-testing

Market surveillance:

OBM emission results should be memorized (last 10 trips) within the Engine Control Unit and made available through the OBD port. Randomly, emission trips results will be selected to be sent Over the Air (OTA) to OEM servers. OBM emission results will have to be standardized and secured against manipulation and tampering by using hash functions.

OBM Compliance:

Compliance of the OBM will be assessed based on in-service conformity tests run using RDE cycles.

OBM emission results (on RDE cycles) should not under-report emissions results by more than 30% compared to PEMS results.

WWH (WORLDWIDE HARMONIZED) ON-BOARD DIAGNOSTIC

UN Regulation 49 Rev 06 includes:

- Annex 9A: On-Board Diagnostic OBD
- Annex 9B: Technical requirements for OBD System
- Annex 9C: Technical requirements of In-Use Performance (IUPR) of OBD System

Definition of MIL Illumination conditions:

- Behavior at Key on / Engine Off: MIL Discriminatory (bulb check)
- When Engine Running: MIL behavior according to classification below

Classification of Malfunctions

Class A: malfunction when OBD threshold limits (OTL) are assumed to be exceeded. It is accepted that the emissions may not be above the OTLs when this class of malfunction occurs.

Class B1: malfunction can lead to emissions above the OTLs but for which the exact influence on emissions cannot be estimated.

Class B2: malfunction that can influence the emissions but not to a level that exceeds the OTLs.

Class C: malfunction that can influence the emissions but to a level that would not exceed the regulated emission limits.

Monitoring Requirements (UN49 Annex 9B)

WWH OBD are demonstrated over the WHTC test cycle

- Electric, electronic components
- Diesel particulate filter
- Selective Catalytic Reduction (SCR) System
- Lean NOx trap or NOx adsorber
- Oxidation Catalyst
- EGR System
- Fuel System
- Air/Boost Handling
- Variable Valve Timing
- Misfire
- Engine Cooling System
- Crankcase Ventilation System
- Exhaust Gas and Oxygen Sensor
- Idle Speed Control System
- Three Way Catalyst Monitoring (gasoline applications)

Communication Requirements

- WWH OBD implementation must be in accordance with ISO 27145

IN-USE PERFORMANCE RATIO (GENERIC)

Based on Regulation 49 – Annex 9C

- IUPR(m) = Numerator(m) / Denominator(m)
- (m) correspond to a monitor
- Numerator of a specific monitor (m) is a counter indicating the number of times a vehicle has been operated such that all monitoring conditions necessary for that specific monitor to detect a malfunction have been encountered.
- The general denominator is a counter indicating the number of times a vehicle has been operated, taking into account general conditions:
  - Cumulative time since start of driving cycle is greater than or equal to 600 seconds while remaining.
  - Cumulative engine operation at or above 1,150 rpm for greater than or equal to 300 seconds as alternatives left to the manufacturer an engine operation at or above 15 percent calculated load or a vehicle operation at or above 40 km/h may be used in lieu of the 1,150 rpm criterion.
  - Continuous vehicle operation at idle for greater than or equal to 30 seconds while under the conditions specified in the above subparagraph.
- The numerator and denominator can be incremented only by +1 into a one driving cycle.
- The value of minimum in-use-performance ratio IUPR(min) is 0.1 for all monitors.
- Additionally, some specific conditions can be added for each monitor:
  - System or actuator: Should be commanded "on", on two or more occasions or for cumulative time greater than 10 sec.
  - DPF monitoring: 800 cumulative kilometer (or alternatively 750 minutes) since the last incrementation of the denominator
  - Oxidation catalyst: DPF regeneration mode activated for at least 10 sec.
  - Specific conditions for Evap, secondary air system, component or system operating only at Start up, CSERS, system or component activation for more than 10 sec, PM monitor specific requirements, NMHC specific requirement, hybrid vehicle with more than 10 sec of "fueled engine operation".*

*US requirement only

US EPA MY 10-26 ON-BOARD DIAGNOSTICS

EPA HD OBD section-86.010-18 (MY 10 to 26)

OBD identifies deteriorations and malfunctions of components calculated to exceed defined OBD threshold limits (OTL). These limits are defined according to the applicable model year (MY) by reference to the emissions standards.

EPA OBD are demonstrated over the transient FTP or the supplemental emissions test (SET).

The driver is notified of the malfunction upon detection through illumination of the MIL.

Communication Requirements

- Standardization of emission-related fault codes, data transfer, diagnostic tools and connector according to the table on the right
- Manufacturers must meet 40 CFR 1036.110 from MY27, making reference to CARB 1971.1 HD including J1979-2 option

Options for communication protocol (selected by OEM)

MY13-26	OEM Decides Option	OEM Decides Option
Communication protocol	ISO 15765-4:2005(E)	SAE J1939
Connector	"Type A" specifications of SAE J1962	SAE J1939-13
Scantool (standard OBD communication tool)	SAE J1978	
Cert Document	SAE J1930 or SAE J2403	

US EPA MY 10-26 ON-BOARD DIAGNOSTICS

MY 13-26a: OBD Emission Threshold Limits (OTLs) for diesel-fueled/compression-ignition engines

OBD Thresholds Limits (g/bhp-hr)					
Component	Monitoring	NMHC[b]	CO[b]	NOx[c]	PM[d]
NOx aftertreatment system	Selective catalytic reduction (SCR) and lean NOx catalyst monitoring NOx adsorber system monitoring	--	--	+0.3	--
Diesel particulate filter (DPF) system	Diesel particulate filter (DPF) system monitoring	2x std	--	--	0.05/ + 0.04
Air-fuel ratio sensors upstream of aftertreatment devices	Exhaust gas sensor and sensor heater monitoring	2x std	2x std	+0.3	0.03/ + 0.02
Air-fuel ratio sensors downstream of aftertreatment devices	Exhaust gas sensor and sensor heater monitoring		--	+0.3	0.05/ + 0.04
NOx sensors	Exhaust gas sensor and sensor heater monitoring		--	+0.3	0.05/ + 0.04
"Other monitors" with emissions thresholds	Fuel system monitoring Engine misfire monitoring EGR system monitoring Turbo boost control system monitoring Variable Valve Timing (VVT) system monitoring	2x std	2x std	+0.3	0.03/ + 0.02

Footnotes:

[a] MY 10-12 is not covered here, please refer to 40 CFR-86.010-18

[b] 2x std means a multiple of 2 times the applicable emissions standard

[c] + 0.3 means the standard or FEL5 plus 0.3g/bhp-hr

[d] 0.05/ + 0.04 means an absolute level of 0.05 or an additive level of the standard or FEL plus 0.04, whichever level is higher

[e] FEL = Family Emissions Limit (certified emission level for a given engine family, which can be below the standard to generate credits)

US EPA MY 10-26 ON-BOARD DIAGNOSTICS

MY13-26: OBD Emissions Thresholds for Gasoline-Fueled/Spark-Ignition Engines (g/bhp-hr)

Component	Monitoring	NMHC[a,c]	CO	NOx[c]	PM
Catalyst system	Catalyst system monitoring	1.75x std[c]		1.75x std	Not applicable
Evaporative emissions control system	Evaporative system monitoring	Equivalent to leak through a 0.150" (3.8 mm) diameter orifice[b]			
"Other monitors" with emissions thresholds	Fuel system monitoring Engine misfire monitoring Exhaust gas recirculation system monitoring Cold start emission reduction strategy monitoring Secondary air system monitoring Exhaust gas sensor monitoring Variable valve timing (VVT) system monitoring	1.5x std	1.5x std	1.5x std	

Footnotes:

[a] 1.75x std means a multiple of 1.75 times the applicable emissions standard

[b] The evaporative emissions control system threshold is not, technically, an emissions threshold but rather a leak size that must be detected

[c] Std = standard (emissions limit value)

US EPA MY 10-26 ON-BOARD DIAGNOSTICS

Description of criteria and conditions for emissions monitoring areas

Monitoring Area		Compression-Ignition	Spark-Ignition
Fuel system monitoring	Malfunction criteria	A. Fuel system pressure control B. Fuel system injection quantity C. Fuel system injection timing D. Combined monitor for 2, 3 in case of common rail system E. Fuel system feedback control	A. Emission threshold monitor B. Adaptive feedback control has used up all of the adjustment C. Feedback control reached limit of emission threshold D. Unable to enter closed loop
	Monitoring conditions	· Continuously for A and E · Occur every time the monitoring conditions are met for B, C and D	· Continuous monitoring
Engine misfire monitoring	Malfunction criteria	· Specific Diagnostic Trouble Code (DTC) per cylinder · Detect misfire occurring in one or more cylinders if > 5% misfire	A. Misfire causing catalyst damage. B. Misfire causing emissions to exceed thresholds
	Monitoring conditions	· During engine idle conditions at least once per drive cycle · Continuously for engine misfire under all positive torque engine speed conditions with some exemptions	· Continuous misfire monitoring except for settling in time during Engine start
EGR system monitoring	Malfunction criteria	A. EGR low flow B. EGR high flow C. EGR slow response D. EGR system feedback control E. EGR cooler performance	A. Decrease in EGR flow rate that could reach emission threshold B. Increase in EGR flow rate that could reach emission threshold
	Monitoring conditions	· Continuously for A, B and D · Occurs every time the monitoring conditions are met for C · At least once per driving cycle (DCY) when monitoring conditions are met for E	· At least once per DCY when monitoring conditions are met
Turbo boost control system monitoring	Malfunction criteria	A. Turbo under boost B. Turbo over boost C. VGT slow response D. Turbo boost feedback control E. Charge air undercooling	Not applicable
	Monitoring conditions	· Continuously for A, B and D. · Occurs every time the monitoring conditions are met for C and E	--

US EPA MY 10-26 ON-BOARD DIAGNOSTICS

Monitoring Requirements			
Monitoring Area		**Compression-Ignition**	**Spark-Ignition**
NMHC converting catalyst monitoring	Malfunction criteria	A. Conversion efficiency B. Aftertreatment assistance functions	Not applicable
	Monitoring conditions	· At least once per DCY when monitoring conditions are met	--
Selective catalytic reduction (SCR) and lean NOx catalyst monitoring	Malfunction criteria	A. SCR and lean NOx catalyst conversion efficiency B. SCR and lean NOx catalyst active/intrusive reductant delivery performance C. SCR and lean NOx catalyst active/intrusive reductant quantity D. SCR and lean NOx catalyst active/intrusive reductant quality E. SCR and lean NOx catalyst active/intrusive reductant feedback control	Not applicable
	Monitoring conditions	· At least once per drive cycle when monitoring conditions are met for A and D · Continuously for B, C and E	--
NOx absorber system monitoring	Malfunction criteria	A. NOx adsorber system capability B. NOx adsorber system active/intrusive reductant delivery performance C. NOx adsorber system feedback control	Not applicable
	Monitoring conditions	· At least once per drive cycle when monitoring conditions are met for A · Continuously for B and C	--
Diesel particulate filter (DPF) system monitoring	Malfunction criteria	DPF filtering performance DPF regeneration frequency DPF incomplete regeneration DPF missing substrate DPF system active/intrusive injection DPF regeneration feedback control	Not applicable
	Monitoring conditions	· Occur every time the monitoring conditions are met during the drive cycle rather than once per drive cycle	--

US EPA MY 10-26 ON-BOARD DIAGNOSTICS

Monitoring Area		Compression-Ignition	Spark-Ignition
Exhaust gas sensor and sensor heater monitoring	Malfunction criteria	Air-fuel ratio sensors located 1) upstream, 2) downstream, 3) NOx Sensors of aftertreatment devices A. Sensor performance. B. Circuit integrity. C. Feedback function D. Monitoring function 4) Other Exhaust Gas sensors : evaluation and demonstration 5) Exhaust gas Heaters: A. Performance when the current or voltage drop outside manufacturer limits B. Open or short circuits	1. Primary exhaust gas sensor malfunction criteria A. Detect failure or deterioration of the exhaust gas sensor output voltage, resistance, impedance, current, response rate, amplitude, offset, or other characteristic(s) that would result in emission exceedance than emission thresholds B. Detect malfunctions due to lack of circuit continuity or out-of-range values. C. Sensor failure or deterioration causes the fuel system to stop using that sensor as a feedback input (Open-loop operation) D. Detect a malfunction of the exhaust gas sensor when the sensor output voltage, resistance, impedance, current, amplitude, activity, or other characteristics are no longer sufficient for use 2. Secondary exhaust gas sensor malfunction criteria A. Detect a malfunction prior to any failure or deterioration of the exhaust gas sensor voltage, resistance, impedance, current, response rate, amplitude, offset, or other characteristic(s) that would cause an engine's emissions to exceed the emissions thresholds B. Detect malfunctions of the exhaust gas sensor caused by a lack of circuit continuity C. Detect a malfunction of the exhaust gas sensor when the sensor output voltage, resistance, impedance, current, amplitude, activity, offset, or other characteristics are no longer sufficient for use as an OBD system monitoring device D. Detect malfunctions of the exhaust gas sensor caused by out-of-range values E. Detect a malfunction of the exhaust gas sensor when a sensor failure or deterioration causes the fuel system (e.g., fuel control) to stop using that sensor as a feedback input 3. Exhaust gas sensor heater malfunction criteria A. Detect a malfunction of the heater performance when the current or voltage drop in the heater circuit is no longer within the manufacturer's specified limits for normal operation B. Detect malfunctions of the heater circuit including open or short circuits
	Monitoring conditions	1), 2), 3) Must occur at least once per DCY when monitoring conditions are met For all others: continuous monitoring	1. Primary EGS: may disable continuous primary exhaust gas sensor monitoring when a primary exhaust gas sensor malfunction cannot be distinguished from other effects, otherwise should be continuously monitored every DCY 2. Secondary EGS: may disable continuous secondary exhaust gas sensor monitoring when a secondary exhaust gas sensor malfunction cannot be distinguished from other effects, , otherwise should be continuously monitored every DCY 3. Exhaust gas sensor heater: · At least once per DCY every time monitoring conditions are met for A · Continuously for B

US EPA MY 10-26 ON-BOARD DIAGNOSTICS

Monitoring Area		Compression-Ignition	Spark-Ignition
Variable Valve Timing (VVT) system monitoring	Malfunction criteria	A. VVT system target error B. VVT slow response C. VVT Improper functional response of the system	A. VVT system target error B. VVT slow response C. Detect when proper functional response of the system to computer commands does not occur
	Monitoring conditions	· At least once per DCY every time monitoring conditions are met	· At least once per DCY every time monitoring conditions are met
Cold start emission reduction (CSER) strategy monitoring	Malfunction criteria	Not applicable	A. Emission threshold exceedance failure or deterioration of the individual components of CSER B. Functional response if no emission exceedance of components used when CSER active
	Monitoring conditions	--	· At least once per DCY every time monitoring conditions are met
Secondary air system monitoring	Malfunction criteria	Not applicable	Malfunction effecting A. decrease and B. increase manufacturer specified limits airflow that would cause emission exceeding thresholds
	Secondary air system monitoring	--	· At least once per DCY every time monitoring conditions are met

US EPA MY 10-26 ON-BOARD DIAGNOSTICS

Monitoring Area		Compression-Ignition	Spark-Ignition
Catalyst system monitoring	Malfunction criteria	Not applicable	Detect conversion capability decrease which could cause emission to exceed thresholds
	Monitoring conditions	--	· At least once per DCY every time monitoring conditions are met
Evaporative system monitoring	Malfunction criteria	Not applicable	A. Purge monitor. Detect when no purge flow from the evaporative system to the engine B. Leak monitor: Detect when the complete evaporative system contains a leak or leaks that cumulatively are greater than or equal to a leak caused by a 0.150 inch (3.8 mm) diameter hole
	Monitoring conditions	--	· At least once per DCY every time monitoring conditions are met · May disable or abort an evaporative system monitor when the fuel tank level is over 85% of nominal tank capacity or during a refueling event · May disable temporarily the evaporative purge system to run an evaporative system leak monitor

CONTENTS

US EPA MY 27+ ON-BOARD DIAGNOSTICS

EPA HD OBD section-1036.110 Starting MY 27+
(allows early adoption)

All vehicles must use OBD requirements from 2019 CARB 1971.1 HD OBD (see page 114) (optionally later revisions)

- This includes J1979-2 along with J1939 and J1979 for scantool
- In-Use compliance does not apply
- Manufacturer self-testing does not apply
- Deficiencies are provided for a single model year and never retroactively

US EPA MY 27+ ON-BOARD DIAGNOSTICS

Additional Freezeframe and Data stream requirements apply		
Freezeframe	(h)(4.2.3)(E): reductant quality sensor output and corrected NOx sensor output (h)(4.2.3)(F): NOx mass emission rate -engine out and NOx mass emission rate -tailpipe (h)(4.2.3)(G): commanded diesel emission fluid (DEF) dosing, DEF dosing mode, DEF dosing rate, DEF usage for current driving cycle, target ammonia storage level on SCR, modelled actual ammonia storage level on SCR, SCR intake temperature, SCR outlet temperature, stability of NOx sensor reading, EGR mass flow rate, engine fuel rate, vehicle fuel rate, hydrocarbon doser flow rate, hydrocarbon doser injector duty cycle, aftertreatment fuel pressure, charge air cooler outlet temperature, propulsion system active, chassis odometer reading, engine odometer reading (if available), hybrid/EV charging state, hybrid/EV battery system voltage, hybrid/EV battery system current, commanded/target fresh airflow, crankcase pressure sensor output, crankcase oil separator rotational speed, evaporative system purge pressure sensor output, and vehicle speed limiter speed limit	
Data stream	Compression-Ignition: Engine and vehicle parameters Diesel oxidation catalyst parameters Particulate filter parameters EGR parameters SCR parameters Derating parameters	Spark-Ignition: Air-fuel enrichment parameters
In-cab display of diagnostic information	Inducement-related fault code Derate and speed restrictions DEF Consumption DPF Regeneration	

CALIFORNIA (CARB) ON-BOARD DIAGNOSTICS (DIESEL)

CARB HD OBD CCR Title 13, sec. 1971.1: MY 2013+ (Approved by 22nd Nov 2022) Diesel Vehicles
Description of conditions for emissions monitoring areas

Monitoring Area	Malfunction Criteria
Fuel System · Pressure Control · Injection Quantity · Injection Timing	a) NMHC, NOx, CO: 2.0 x standard b) PM: Standard + 0.02 grams/bhp-hr Note: Failure modes incl. both single & all injectors equally deteriorated
· Feedback Control	a) Fails to begin control within manufacturer-defined time b) Failure or deterioration causes open loop or default operation c) Control maximum authority reached & cannot achieve control target
Misfire Monitoring during idle (systems without combustion sensor) Continuous monitoring for all positive engine torque/speed/loads (systems with combustion sensor)	Misfire detection level: · 2018+ MY: 100%. Applies low-level misfire detection to ALL vehicles (must detect 5% misfire) Monitoring conditions: · Monitoring required under ALL positive torque engine speed conditions, except: 1) Positive torque line to 50% maximum engine speed @ positive torque line 2) 100% maximum engine speed & (+10%) torque above positive torque line
Exhaust Gas Recirculation (EGR) · Low Flow Rate · High Flow Rate (incl. leaking EGR valve bypass flow) · Slow response (both increasing and decreasing directions) · EGR Cooler Performance (monitoring of multiple coolers requires Executive Officer approval)	a) NMHC, NOx, CO: 2.0 x standard b) PM: Standard + 0.02 grams/bhp-hr Note: Failure modes incl. both single & all injectors equally deteriorated

CALIFORNIA (CARB) ON-BOARD DIAGNOSTICS (DIESEL)

Monitoring Area	Malfunction Criteria
· Feedback Control	a) Fails to begin control within manufacturer-defined time b) Failure or deterioration causes open loop or default operation c) Control maximum authority reached & cannot achieve control target Note: a) and b) may be met by monitoring of EGR input parameters instead of system, if all equivalent failure modes are detectable No detectable amount of constituent oxidation (monitoring not required)
· EGR Catalyst Performance	
Boost Pressure Control · Underboost - Overboost · Slow Response Boost System) · Charge Air Undercooling (monitoring of multiple coolers requires Executive Officer approval)	If no emission impact under driving condition where impact is most likely a) NMHC, NOx, CO: 2.0 x standard b) PM: Standard + 0.02 grams/bhp-hr
· Feedback Control	a) Fails to begin control within manufacturer-defined time b) Failure or deterioration causes open loop or default operation c) Control maximum authority reached and cannot achieve control target Note: a) and b) may be met by monitoring of Boost pressure input parameters instead of system, if all equivalent failure modes are detectable

CALIFORNIA (CARB) ON-BOARD DIAGNOSTICS (DIESEL)

Monitoring Area	Malfunction Criteria
NMHC Converting Catalyst (exl. downstream or PM filter for regeneration) · Conversion Efficiency · Other Aftertreatment · Assistance Function	a) NMHC: 2.0 x standard b) NOx: standard + 0.2 g/bhp-hr **Exotherm generation (PM Filter regeneration assistance):** · Catalyst unable to generate sufficient exotherm for regeneration Feedgas constituency (SCR assistance): · Catalyst unable to generate sufficient feedgas for proper SCR operation, with no monitoring required if < 15% emission increase and < std. under test cycle **NMHC conversion downstream of PM filter for use during regeneration:** · No detectable amount of NMHC conversion Converter downstream of SCR system · No detectable amount of NMHC, CO, NOx or PM conversion capability

CALIFORNIA (CARB) ON-BOARD DIAGNOSTICS (DIESEL)

Monitoring Area	Malfunction Criteria
NOx Converting Catalyst · Conversion Efficiency	· 2016 + MY: standard + 0.2 g/bhp-hr NOx, 2.0 x standard NMHC Note: carry-over allowed from previous 2014 or 2015 phase-in volume certification for 2016 MY only
· Selective Catalytic Reduction (SCR)	For reductant other than engine fuel: · Insufficient reductant for proper operation · Improper reductant in reservoir/tank · 2016 + MY: standard + 0.2 g/bhp-hr NOx, 2.0 x standard NMHC Note: carry-over allowed from previous 2014 or 2015 phase-in volume certification for 2016 MY only
· Feedback Control	a) Fails to begin control within manufacturer-defined time b) Failure or deterioration causes open loop or default operation c) Control maximum authority reached and cannot achieve control target Notes (a) and (b) may be met by monitoring of NOx catalyst input parameters instead of system, if all equivalent failure modes are detectable
NOx Adsorber · Capability	· NOx: standard + 0.2 g/bhp-hr, 2.0 x standard NMHC
· Active/Intrusion Injection	· Unable to achieve desorption of the NOx adsorber
· Feedback Control	a) Fails to begin control within manufacturer-defined time b) Failure or deterioration causes open loop or default operation c) Control maximum authority reached and cannot achieve control target Notes (a) and (b) may be met by monitoring of NOx adsorber input parameters instead of system, if all equivalent failure modes are detectable

CALIFORNIA (CARB) ON-BOARD DIAGNOSTICS (DIESEL)

Monitoring Area	Malfunction Criteria
Particulate Matter Filtering · Filtering Performance	· 2017+ MY: 100% higher of 0.03 OR std. + 0.02 g/bhp-hr PM, with NO failure mode relief
· Frequent Regeneration	a) NMHC: 2.0 x standard b) NOx: standard + 0.2 g/bhp-hr
· Incomplete Regeneration	Improper regeneration where regeneration is designed to occur under manufacturer-defined conditions
· NMHC Conversion	NMHC: 2.0 x standard, with no monitoring required if < 15% emission increase AND < standard under test cycle
· Missing Substrate	a) PM filter substrate completely destroyed, removed, or missing b) PM filter assembly replaced with a muffler or straight pipe
· Active/Intrusion Injection	(fuel injected to achieve regeneration of the PM): unable to achieve regeneration
· Feedback Control	a) Fails to begin control within manufacturer-defined time b) Failure or deterioration causes open loop or default operation c) Control maximum authority reached and cannot achieve control target Notes (a) and (b) may be met by monitoring of PM changes input parameters instead of system, if all equivalent failure modes are detectable
· Feedgas Constituency (SCR assistance)	· 2016+ MY: PM Filter unable to generate sufficient feedgas for proper SCR operation, with no monitoring required if < 15% emission increase AND < standard under test cycle

CALIFORNIA (CARB) ON-BOARD DIAGNOSTICS (DIESEL)

Monitoring Area	Malfunction Criteria
All Sensors	a) Lack of circuit continuity b) Out of "normal" range
A/F Sensors - Upstream of Exhaust Treatment	Sensor Performance: a) NMHC, CO, NOx: 2.0 x standard b) PM: standard + 0.02 g/bhp-hr · Feedback: failure or deterioration causes an emission control system to stop using that sensor as an input (default or open loop) · Monitoring capability: any characteristic no longer sufficient for use as input to other monitoring strategy
A/F Sensors - Downstream of Exhaust Treatment	Sensor Performance: a) NMHC: 2.0 x standard b) NOx: standard + 0.2 g/bhp-hr c) PM: 0.03 g/bhp-hr (FTP or SET), OR std. + 0.02 g/bhp-hr whichever is higher · Feedback: failure or deterioration causes an emission control system to stop using that sensor as an input (default or open loop) · Monitoring capability: any characteristic no longer sufficient for use as input to other monitoring strategy
NOx & PM Sensor Performance	2016+ MY: 100%: std. + 0.2 g/bhp-hr NOx, 2.0 x std. NMHC, higher of 0.03 g/bhp-hr OR std. + 0.02 g/bhp-hr PM. Note: The manufacturer is allowed to carry-over from previous 2014 or 2015 phase-in volume certification for the 2016 MY only · Feedback: failure or deterioration causes an emission control system to stop using that sensor as an input (default or open loop) · Monitoring capability: any characteristic no longer sufficient for use as input to other monitoring strategy

CALIFORNIA (CARB) ON-BOARD DIAGNOSTICS (DIESEL)

Monitoring Area	Malfunction Criteria
Other Exhaust Sensors	Manufacturer to submit plan and obtain approval of Executive Officer
Exhaust Gas Sensor Heaters	a) Current or voltage drop no longer within sensor manufacturer's limits for normal operation b) Faults that result in conflict between commanded and actual state of the heater
Variable Valve Timing and/or Control · Target Error (outside crank angle and/or lift tolerance) · Slow Response	a) NMHC, CO, NOx: 2.0 x standard b) PM: standard + 0.02 g/bhp-hr
Cold Start Emission Reduction Strategy	a) Any single commanded element does not respond properly: · By a robustly measurable amount · In the commanded direction · By an amount that is greater than otherwise would have been commanded without the cold start strategy activated b) Deterioration: · NMHC, NOx, or CO: 2.0 x standard · PM: standard + 0.02 g/bhp-hr c) Cold Start System Capability: · Desired effect not achieved (as feasible) · Individual elements/components (when desired effect method is NOT feasible) Note: Fault codes must isolate cold start related failures

CALIFORNIA (CARB) ON-BOARD DIAGNOSTICS (GASOLINE)

Monitoring Area	Malfunction Criteria
Fuel System	Fuel delivery system: 1.5 x std. (all constituents) / Feedback control: 1.5 x std. (all constituents) / A/F cylinder imbalance: 2014-2016 / MY: 3.0 x std. (all constituents) / 2017+ MY: 1.5 x std. (all constituents)
Feedback Control	a) Control maximum authority reached (if based on secondary oxygen sensor, also allowed to verify if control target is achieved prior to failure) b) Fails to begin control within manufacture-defined time (time period requires Executive Officer approval). Engine-off strategies must monitor every engine start
Misfire Continuous monitoring for all positive engine torque speed/loads from the 2nd crankshaft revolution after engine start (150 rpm below normal, warmed-up idle speed)	a) Diagnostic trouble code if emissions above 1.5 x std. (all constituents) · single detection of misfire rate in 1st 1000 engine revolutions · 4 detections of misfire rate in 1,000 engine revolution blocks b) Misfire rate that causes temperature to reach catalyst damaging level Specific cylinder diagnostic trouble code (DTC) required for > 90% misfire occurring on a single cylinder
Exhaust Gas Recirculation (EGR) · Low Flow Rate · High Flow Rate (incl. leaking EGR valve bypass flow)	· 1.5 x std. (all constituents)
Cold Start Emission Reduction Strategy	a) Any single commanded element does not respond properly: · By a robustly measurable amount · In the commanded direction · By an amount that is greater than otherwise would have been commanded without the cold start strategy activated

CALIFORNIA (CARB) ON-BOARD DIAGNOSTICS (GASOLINE)

Monitoring Area	Malfunction Criteria
Cold Start Emission Reduction Strategy (continued)	b) Deterioration and Cold Start System Capability (desired effect not achieved OR individual elements/components not achieved): · 1.5 x std. (all constituents) Note: fault codes must isolate cold start related failures
Secondary Air System	1.5 x standard (all constituents) · Both reduction in secondary flow and excessive secondary flow must be monitored · Monitoring required while control strategy is normally activated · When < 1.5 x standard due to failure, must monitor control system for being at the limit of authority to reduce air delivery
Catalyst	Conversion capability: a) NMHC, NOx: 1.75 x standard b) NMHC conversion efficiency below 50% For threshold testing purposes, the catalyst system is to be aged simultaneously (full catalyst volume) · If fuel is shut off for misfiring cylinder, the monitored volume catalyst(s) must be aged simultaneously to the threshold limit, while unmonitored volume must be aged to the end of the vehicle's full useful life
Evaporative System	a) No purge flow (must monitor all purge flow paths) b) Cumulative evaporative system leak ≥ 0.150 inch diameter orifice (may be revised upward for technical incapability or < 1.5 x std. with Executive Officer approval) Note: MIL illumination not required for approved alternate indicator for fuel cap missing or improperly secured. Alternate fuel engines require Executive Officer approval of a strategy equating to gasoline
Exhaust Gas Sensor · Primary & Secondary Exhaust Gas Sensors	a) Sensor Performance: · 1.5 x standard (all constituents) · (Primary sensors only): symmetric and asymmetric delay to respond and response rates, lean-to-rich and rich-to-lean (certification data/analysis required) b) Lack of circuit continuity c) Out of "normal" range

CALIFORNIA (CARB) ON-BOARD DIAGNOSTICS (GASOLINE)

Monitoring Area	Malfunction Criteria
	d) Feedback: failure or deterioration causes fuel system to stop using that sensor as an input (default or open loop) - (Primary sensors only): delayed entry to closed loop e) Monitoring Capability: Any characteristic no longer sufficient for use as input to other monitoring strategy
Exhaust Gas Sensor Heaters	a) Current or voltage drop no longer within sensor manufacturer's limit for normal operation b) Faults that result in conflict between commanded and actual state of the heater
Variable Valve Timing and/or Control · Target Error (outside crank angle and/ or lift tolerance) · Slow Response	· 1.5 x std. (all constituents)

CARB HD OBD – ALL Fuels

Monitoring Area	Malfunction Criteria
Engine Cooling System - Thermostat	a) Engine coolant temperature does not reach the following within a time approved by the Executive Officer · Within 20 deg F of normal operating temp (may use higher threshold if < 50% emissions increase; may disable when ambient temp < 20 deg F) · Highest temp required by the OBD system to enable other monitors b) 2016 + MY: Engine coolant temperature reaches the temp defined above, but then drops below the highest temperature required by OBD system to enable other monitors Note: must disable thermostat monitoring for (thermostat threshold – Start-Up coolant temperature < 35 deg F). Executive Officer approval required to enable in this temperature range

CALIFORNIA (CARB) ON-BOARD DIAGNOSTICS (ALL FUELS)

CARB HD OBD – ALL Fuels

Monitoring Area	Malfunction Criteria
Engine Cooling System - Thermostat Sensor	a) Circuit continuity b) Time to reach closed-loop/feedback enable temp c) Stuck in range below the highest minimum enabled temperature required by other monitors d) Stuck in range above the lowest maximum enabled temperature required by other monitors (exemption allowed when temperature gauge is based on same sensor and indicates overheating)
Crankcase Ventilation (CV) - Includes all CV related external tubing/hoses	Disconnection of CV system (possible exemptions follow): a) Between Crankcase and CV Valve b) Between CV Valve and Intake Ducting Exemptions may apply (with Executive Officer approval) for: · Systems where vehicle operator is certain to respond or where disconnection of an unmonitored portion first requires disconnection of a monitored portion · Connection between Crankcase and CV Valve, when tubing is used such that there is resistance to deterioration or disconnection, difficult to remove relative to connection between CV Valve and Intake, and not part of non-CV repair/maintenance · Connection between CV Valve and Intake, when the disconnection either causes the vehicle to stall OR CV design is integral to the induction system (no tubing, hoses, etc.) Engines certified on an engine dynamometer and having open CV system (vent to atmosphere): monitoring plan to be provided for Executive Officer review/approval
Comprehensive Components	· Monitoring required for any input or output component that can impact emissions (by any amount) under any reasonable driving condition · Those components/systems that affect only engine mechanical or electrical load (not related to fuel, air, or emissions control) are only to be monitored if they are used by any other system or component monitor · Hybrid monitoring requires Executive Officer approval: at a minimum, must monitor components used by any other system or component monitor, energy input devices, battery and charging system performance, electric motor performance, and regenerative braking performance

CALIFORNIA (CARB) ON-BOARD DIAGNOSTICS (ALL FUELS)

Monitoring Area	Malfunction Criteria
Vehicle Speed (when received by OBD system from another controller, such as transmission control unit)	a) Monitoring as Input Component, as feasible (refer to "Input Components" below) b) Unable to properly receive vehicle speed information (communication failure) c) If other controller monitors the vehicle speed & provides "invalid" determination, must handle as default mode of operation (with MIL illumination) for the OBD systems
Input Components	a) Lack of circuit continuity b) Out of "normal" range c) Irrational sensor value (2-sided monitoring) d) Alternate Strategy Activation (that can affect emissions): · Malfunctions that cause the system to erroneously activate or deactivate · Failures that invoke erroneous control, as feasible (rationality) e) Components used for emission control strategies not specifically addressed by CARB regulations. · Failures that cause the strategy not to operate in its intended manner (delayed enable, erroneous exit, authority limit) f) Camshaft/Crankshaft Position Sensors: · Engines requiring precise cam/crank alignment: improper alignment · Engines equipped with VVT and belt/chain: one or more tooth improper alignment (larger if no emission impact for single tooth)

CALIFORNIA (CARB) ON-BOARD DIAGNOSTICS (ALL FUELS)

Monitoring Area	Malfunction Criteria
Output Components	a) Improper functional response, as feasible b) Circuit continuity faults c) Idle Control System (Gasoline engines with monitoring strategies based on deviation from target idle speed): · Speed control cannot maintain within 200 rpm above or 100 rpm below the target idle speed · Speed control cannot maintain within the smallest engine speed tolerance range for any other monitor's enable d) Idle Control System (Diesel Engines): · Speed control cannot maintain within +/- 50% of target speed · Speed control cannot maintain within the smallest engine speed tolerance range for any other monitor's enable Idle control cannot achieve the target idle speed with fuel injection quantity within (smallest quantity tolerance range for enabling other monitors) OR (+/- 50% of properly functioning quantity) e) Glow Plugs/Intake Air Heaters: · Improper functional response · Circuit continuity faults · Proper current and voltage drop · Single glow plug no longer operates in manufacturer's limits f) "Wait to Start" Lamp: failures that prevent illumination g) Components used for emission control strategies not specifically addressed by CARB regulations: · Failures that cause the strategy to not operate in its intended manner (delayed enable, erroneous exit, authority limit) h) "Tolerance Compensation": Improper compensation being applied by controller for connected hardware, with no monitoring required if < 15% emission increase AND < std. under test cycle (Executive Officer review/approval required)

CALIFORNIA (CARB) ON-BOARD DIAGNOSTICS

Monitoring Area	Malfunction Criteria
'Other' Emission Control Systems	Executive Officer approval required for proposed strategy. Engines utilizing emission control through intake airflow or cylinder charge characteristics: may monitor the intake valve shaft (incl. all segments) instead of airflow, cylinder charge, or individual valve(s)/flap(s)
Default (Limp-Home) Mode	MIL and fault code storage required, when emissions impact or OBD system performance is changed (includes controller failures)
General OBD Requirements – Full vs. Extrapolated OBD	MY 16+ (excluding alternate fueled engines) · OBD requirements from 1971.1 applies to all engine ratings in all engine families. · Tracking requirements: Option-1: · MY 22+ to meet all tracking requirements and · Demonstration testing of 15 Executive officer selected monitors for MY 22/23 Option-2: · MY 22-23 to meet tracking requirements with some exemptions (active and stored 100-hour array) and · MY 24+ to meet all tracking requirements
In-Use Performance Ratio (IUPR)	MY 24+ · 0.100 for the diesel catalyst warm-up strategy · 0.500 for the gasoline CSER cold start catalyst heating monitor · 0.100 for crankcase ventilation (CV) system monitors (interim 2024-31) · 0.300 for all other monitors Interim lower ratios allowed for: · Alternate fueled engines: 0.100 for all (2024-25) monitors. · PHEVs (2022-27): 0.100 for first 3 years of certification for monitors requiring Engine operation after which MY 24+ requirements apply

CALIFORNIA (CARB) ON-BOARD DIAGNOSTICS

Monitoring Area	Malfunction Criteria
Exceptions to Monitoring Requirements	a) Executive Officer may revise emission thresholds or exempt certain PM failure modes (refer to PM monitoring). b) Disabling at (ambient temperature < 20 deg F or component freezing) OR (altitude > 8,000 feet): Requires Executive Officer approval. c) Disabling at fuel level ≥ 15% full (OBD system must be capable of detecting faults at the disabling level and Executive Officer approval is required). d) Disabling at battery voltage < 11.0 V (Executive Officer approval required for use of higher level of low voltage for disable, as well as disabling for high voltage with accompanying voltage monitor). e) Disablement for PTO activation (requires PTO activation time and IM Readiness reset at 750 minutes activation without related monitor completion). f) Exemption from component monitoring if no emissions impact for any reasonable driving condition AND component is not used for other OBD purposes. g) Small volume diesel manufacturers are allowed relaxed phase-in schedules for misfire, NOx catalyst, PM filter, and NOx sensor monitoring

CHINA ON-BOARD DIAGNOSTICS

China VI according to GB17691-2018 applicable to all vehicles from July 2021

OBD Requirements similar to EU VI

CN VI OBD tests are demonstrated over the WHTC test cycle

Specific requirements different from EU VI:

Permanent Diagnostic Trouble Codes (DTC)

- Definition: Class A and Class B fault active more than 200 hours
- Healing needs only one Driving Cycle with a Pass

Inducement

Aftertreatment class A faults cause the driver alarm system to be active, two stages inducement required:

- Engine continuous running 36 hours, stage 1 inducement active with 25% torque derate
- Engine continuous running 100 hours, stage 2 inducement active with 20 km/h vehicle speed derate

DEF thaw (system must ensure system functioning at indicated temperature within defined time):

- -17°C in 70 mins (instead of -7°C in Euro VI)

OBD Thresholds Limits	Limits in mg/kWh		
	NOx	PM Mass	CO
Compression-Ignition Engine	1,200	25	25
Spark-Ignition Engine	1,200	-	7,500

Additional freeze frame and data stream requirement

- Intake air temp, DPF delta pressure, SCR inlet temp, and NOx sensor output
- Requirements for telematics gateway to gather and report real time OBD data

INDIA ON-BOARD DIAGNOSTICS

BS_VI according to GSR 889 and AIS 137 Part 4

From 1st April 2020, BS_VI_OBD I

OBD Thresholds Limits	Limits in mg/kWh		
	NOx	PM Mass	CO
Compression-Ignition Engine	1,500	Performance Monitoring	-
Spark-Ignition Engine	1,500	-	-

BS_VI_OBD-II threshold for BS VI vehicles manufactured on or after April 2023

OBD Thresholds Limits	Limits in mg/kWh		
	NOx	PM Mass	CO
Compression-Ignition Engine	1,200	25	-
Spark-Ignition Engine	1,200	-	7,500

OBD Requirements similar to EU VI

BRAZIL ON-BOARD DIAGNOSTICS

Proconve P8 according to Normative instruction 18, of Dec 1st 2021

OBD Requirements similar to EU VI

Ref to Annexes 9A, 9B, 9C, 11 and 14 of UN Regulation 49.06 and EC 582/2011

Specific requirements (deviation from Euro VI):

- Permanent Fault code
- Specific NOx threshold for urea concentration

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OFF-ROAD POLLUTANT EMISSIONS STANDARDS

OFF-ROAD ROADMAP FOR NON-ROAD ENGINES IN THE EUROPEAN UNION AND UNITED STATES

Key: Unregulated | Stage II | Stage IIIA | Stage IIIB | Stage IV | Stage V

Proposed US Tier 5 phase-in staggered from 2029 (for EU no successor to Stage V yet in planning)

Engine Rating (kW)	Engine Rating (hp)	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
P < 8	P < 11																									
8 ≤ P < 19	11 ≤ P < 25																									
19 ≤ P < 37	25 ≤ P < 50																									
37 ≤ P < 56	50 ≤ P < 75																									
56 ≤ P < 75	75 ≤ P < 100																									
75 ≤ P < 130	100 ≤ P < 175																									
130 ≤ P < 225	175 ≤ P < 300																									
225≤ P < 450	300 ≤ P < 600																									
450 ≤ P < 560	600 ≤ P < 750																									
P ≥ 560	P ≥ 750																									

Key: Tier 2 | Tier 3 | Tier 4i | Tier 4f | Future Tier 5

Engine Rating (kW)	Engine Rating (hp)	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
P < 8	P < 11																									
8 ≤ P < 19	11 ≤ P < 25																									
19 ≤ P < 37	25 ≤ P < 50																									
37 ≤ P < 56	50 ≤ P < 75																									
56 ≤ P < 75	75 ≤ P < 100																									
75 ≤ P < 130	100 ≤ P < 175																									
130 ≤ P < 225	175 ≤ P < 300																									
225≤ P < 450	300 ≤ P < 600																									
450 ≤ P < 560	600 ≤ P < 750																									
P ≥ 560	P ≥ 750																									

CURRENTLY IN FORCE STAGE V NON-ROAD MOBILE MACHINERY (NRMM) VEHICLE CATEGORIES

(Regulation 2016/1628)

The regulation is divided into 10 categories (replacing the categories A to R used in stages I to IV):

NRE Engines for non-road mobile machinery intended and suited to move, or to be moved, by road or otherwise

NRG Generator sets

NRS SI engines < 56 kW

NRSh SI engines < 19 kW specifically designed for handheld equipment

IWP Inland waterway vessels, propulsion

IWA Inland waterway vessels, auxiliary

RLL Railway locomotives

RLR Railcars

SMB Snowmobiles

ATS All-terrain vehicles with side-by-side seating

N.B. There are some variations in limits and timings for specific machine classes such as IWP and RLL. Please check the published EU documents for details.

Engine Category	Designation	Ignition	Power Output (kW)
Gensets ≤ 560kW	NRE	CI	0 < P < 56
IWP ≤ 560kW		All	56 ≤ P < 130
IWA ≤ 560kW			P ≥ 130
Other Gensets	NRG	All	P > 560
Handheld	NRSh	SI	P < 19
Other SI Engines	NRS	SI	P < 56
Inland Waterways	IWP	All	19 ≤ P < 300
			P ≥ 300
Auxiliary Engines for IWP	IWA	All	19 ≤ P < 300
			P ≥ 300
Snowmobiles	SMB	SI	All
All-Terrain & Side-by-Side	ATS	SI	All
Locomotives	RLL	All	All
Railcars	RLR	All	All

CURRENTLY IN FORCE STAGE V NRMM CI ENGINE EXHAUST EMISSION LIMIT VALUES AND TEST PROCEDURES

This EU Regulation entered into force on 6th October 2016 and was applicable from 1st January 2017. Implementation dates (type approval):

- 37 ≤ P < 56: 1st January 2018
- All others: 1st January 2019

It was amended by (EU) 2020/1040 to delay some transitional provisions due to the impact of the COVID-19 crisis.

Delegated Regulation (EU) 2017/654 relates to technical and general requirements [test methods & type approval process] and as amended by (EU) 2018/989. Delegated Regulation (EU) 2017/655 relates to monitoring of gaseous pollutant emissions[a] and as amended by (EU) 2018/987.

Footnotes:

[a] In-Service Monitoring (ISM)
- Requirement to test engines installed in machines over their normal operating duty cycle using Portable Emissions Monitoring Systems (PEMS)
- Requires in-service monitoring of emissions (ISM), reported and made publicly available – currently there are no specified in-service conformity (ISC) emissions limits. The Commission "shall then review the situation and propose final prescriptive requirements for ISM." There is currently no timetable for these requirements

[b] Engines must meet the emissions requirements on the reference test fuel and on all fuels specified by the manufacturer for use in their engine (e.g. B30 biodiesel). This also carries over to ISM

[c] For variable speed engines, use maximum net power. For constant speed engines use rated net power

[d] 0.6 for hand-startable, air-cooled direct-injection engines

Emission Limits[b] for NRE & NRG engine categories

Engine Power[c] (kW)	Ignition Type	Operation Speed	Category	CO	HC	NOx	PM	PN	'A' Factor
				(g/kWh)				(#/kWh)	
0 < P < 8	CI	Variable & Constant	NRE	8.00	HC + NOx ≤ 7.50		0.40[d]	-	1.10
8 ≤ P < 19				6.60	HC + NOx ≤ 7.50		0.40	-	1.10
19 ≤ P < 37				5.00	HC + NOx ≤ 4.70		0.015	1 x 10^{12}	1.10
37 ≤ P < 56				5.00	HC + NOx ≤ 4.70		0.015	1 x 10^{12}	1.10
56 ≤ P < 130	All			5.00	0.19	0.40	0.015	1 x 10^{12}	1.10
130 ≤ P < 560				3.50	0.19	0.40	0.015	1 x 10^{12}	1.10
P > 560				3.50	0.19	3.50	0.045	-	6.00
P > 560			NRG	3.50	0.19	0.67	0.035	-	6.00

Test cycles: NRSC & NRTC (see pages 176-179)

CURRENTLY IN FORCE STAGE V NRMM ENGINE SI EXHAUST EMISSION LIMIT VALUES AND TEST PROCEDURES

(Regulation 2016/1628)

For selected sub-categories of Spark-Ignition (SI) engines

NRMM Stage V Emission Limits[a] for NRSh & NRS SI engine categories (< 56kW)

Category	Subcategory	Power (kW)	CO (g/kWh)	HC + NOx (g/kWh)
NRSh	NRSh-v-1a	0 < P < 19	805	50
	NRSh-v-1b		603	72
NRS	NRS-vr-1a	0 < P < 19	610	10
	NRS-vi-1a			
	NRS-vr-1b			8
	NRS-vi-1b			
	NRS-v-2a	19 < P < 30	610	8
	NRS-v-2b	19 < P < 56	4.40[a]	2.70[a]
	NRS-v-3			

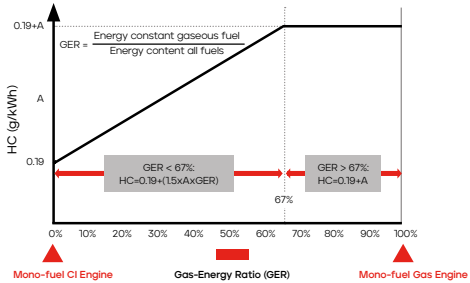
Footnotes:

[a] Optionally, as an alternative, any combination of values satisfying the equation $(HC + NOx) \times CO^{0.784} \leq 8.57$ as well as the following conditions: $CO \leq 20.6$ g/kWh and $(HC + NOx) \leq 2.7$ g/kWh

For Gaseous and Dual-Fuel Engines:

For all engines other than SI < 56 kW, an "A-factor" is used to calculate the HC limit (see equation in graph below), applicable to fully or partially gaseous fueled engines.

For NRE < 560kW, A = 1.1. For NRE & NRG > 560kW A = 6



For sub-categories with a combined HC and NOx limit, the combined limit value for HC and NOx shall be reduced by 0.19 g/kWh and apply for NOx only.

CURRENTLY IN FORCE STAGE V EMISSION DURABILITY PERIODS

Emission Durability requirements are stated in Annex V of EU 2016/1628. The methodology for adapting the deterioration factors is given in Annex III of EU 2017/654. These Regulations set out a process for demonstrating the durability of the engine and emissions control devices throughout their life.

There are three key terms:

1 - Emissions Durability Period (EDP). This is an agreed operating life for each engine category throughout which it must continue to meet emissions limits.

2 - Service Accumulation Schedule. This is a period of engine operating time over which the engine and emissions control devices 'bed in' and begin to age in a predictable manner. The form and duration of this (ageing cycle) shall be determined in a manner consistent with good engineering judgment.

3 - Deterioration Factor (DF). This indicates the relationship between emissions at the start and end of the EDP. Emissions are measured at several points during the Service Accumulation Schedule and a 'best fit' linear regression applied.

This 'best fit' line is extrapolated between the beginning and end of the EDP, and from the ratio of emission values taken at the start of the Service Accumulation Schedule and the end of the EDP. From this the DF is derived.

If the DF is less than 1, then a value of 1.0 must be applied.

The DF is then applied to the emissions values measured during the official certification test. Using this method the intention is to ensure the engine and emissions control devices remain within regulated emissions levels over the life of the vehicle.

Example of EDP for engine category NRE

Engine Power (kW)	Ignition Type	Operation Speed	Sub- category	EDP (hours)
0 < P < 8	CI	Variable & Constant	NRE-v-1/NRE-c-1	3000
8 ≤ P < 19	CI	Variable & Constant	NRE-v-2/NRE-c-2	
19 ≤ P < 37	CI	Constant	NRE-c-3	
	CI	Variable	NRE-v-3	5000
37 ≤ P < 56	CI	Variable & Constant	NRE-v-4/NRE-c-4	8000
56 ≤ P < 130	All	Variable & Constant	NRE-v-5/NRE-c-5	
130 ≤ P < 560	All	Variable & Constant	NRE-v-6/NRE-c-6	
P > 560	All	Variable & Constant	NRE-v-7/NRE-c-7	

STAGE I TO IV NRMM EMISSION LIMIT VALUES AND TEST PROCEDURES

Euro Stage I and Stage II (Dir 97/68/EC) as amended by 2002/88/EC
For positive Spark-Ignition engines, the power limit is 19kW and these are categorized in terms of swept volume (capacity)

EU Stage I emission standards for small SI engines below 19 kW

Class[a]	Displacement (V) (cm³)	Date	CO (g/kWh)	HC (g/kWh)	NOx (g/kWh)	HC + NOx (g/kWh)
Handheld Engines						
SH:1	V < 20	12th Aug 04	805	295	5.36	-
SH:2	20 ≤ D < 50	12th Aug 04	805	241	5.36	-
SH:3	V ≥ 50	12th Aug 04	603	161	5.36	-
Non-Handheld Engines						
SN:1	V < 66	12th Aug 04	519	-	-	50
SN:2	66 ≤ V < 100	12th Aug 04	519	-	-	40
SN:3	100 ≤ V < 225	12th Aug 04	519	-	-	16.1
SN:4	V ≥ 225	12th Aug 04	519	-	-	13.4

EU Stage II emission standards for small SI engines below 19 kW

Class	Displacement (V) (cm³)	Date	CO (g/kWh)	HC+NOx[b] (g/kWh)
Handheld Engines				
SH:1	V < 20	Aug 07	805	50
SH:2	20 ≤ D < 50	Aug 07	805	50
SH:3	V ≥ 50	Aug 08	603	72
Non-Handheld Engines				
SN:1	V < 66	Aug 04	610	50.0
SN:2	66 ≤ V < 100	Aug 04	610	40.0
SN:3	100 ≤ V < 225	Aug 07	610	16.1
SN:4	V ≥ 225	Aug 06	610	12.1

Footnotes:

[a] SH = small handheld; SN = small non-handheld

[b] Additionally, NOx for all engine classes must not exceed 10 g/kWh

STAGE I TO IV NRMM EMISSION LIMIT VALUES AND TEST PROCEDURES

COMPRESSION-IGNITION (CI) ENGINES – Euro Stage I & II (2002/88/EC)

For Compression-Ignition (CI) engines, standards are based on the engine class categorized by the engine net power

Category	Net Power(kW)	CO	HC	NOx	PM	Type Approval from	New Registrations
		(g/kWh)					
Stage I (engine out emissions)							
A	130-560	5.0	1.3	9.2	0.54	1st Jul 98	1st Jan 99
B	75-130	5.0	1.3	9.2	0.70	1st Jul 98[a]	1st Jan 99[b]
C	37-75	6.5	1.3	9.2	0.85	1st Jul 98[a]	1st Apr 99[b]
Stage II[d]							
E	130-560	3.5	1.0	6.0	0.2	1st Jan 01	1st Jul 02
F	75-130	5.0	1.0	6.0	0.3	1st Jan 02	1st Jul 03
G	37-75	5.0	1.3	7.0	0.4	1st Jan 03	1st Jan 04
D	18-37	5.5	1.5	8.0	0.8	1st Jan 00[c]	1st Jan 01[c]

Test cycle Stage I and II: NRSC (page 176)

ISO 8178-C1 is the test cycle for CI engines operated under **intermittent speed**

ISO 8178-D2 is the test cycle for CI engines operated under **constant speed**

Footnotes:

[a] 1st January 2001 for agricultural and forestry tractors

[b] 1st July 2001 for agricultural and forestry tractors

[c] 1 year later for agricultural applications and forestry tractors

[d] For constant speed engines, implementation date: 1st January 2007

STAGE I TO IV NRMM EMISSION LIMIT VALUES AND TEST PROCEDURES

Euro Stage III and Stage IV (Dir 97/68/EC) as amended by Dir 2006/105/EC and Dir 2010/26/EU

Test cycles:

NRSC: variable speed engines: Stage III A (gaseous pollutants) see page 176

NRSC: variable speed engines: Stage III B and Stage IV (gaseous and particulate emissions):

Test cycles are ISO 8178-4: 2007 C1 for intermittent speed engines and ISO 8178-4 D2 for constant speed engines

NRTC: variable speed engines: Stage III B and Stage IV (gaseous and particulate emissions) see page 179

Category	Net Power(kW)	CO	HC	NOx	PM	Type Approval from	New Registrations
		(g/kWh)					
Stage IIIA[a]							
H	130-560	3.5	NOx + HC: 4.0		0.2	30th Jun 05	31st Dec 05
I	75-130	5.0	NOx + HC: 4.0		0.3	31st Dec 05	31st Dec 06
J	37-75	5.0	NOx + HC: 4.7		0.4	31st Dec 06	31st Dec 07
K	19-37	5.5	NOx + HC: 7.5		0.6	31st Dec 05	31st Dec 06
Stage IIIB							
L	130-560	3.5	0.19	2.0	0.025	31st Dec 09	31st Dec 10
M	75-130	5.0	0.19	3.3	0.025	31st Dec 10	31st Dec 11
N	56-75	5.0	0.19	3.3	0.025	31st Dec 10	31st Dec 11
P	37-56	5.0	NOx + HC: 4.7		0.025	31st Dec 11	31st Dec 12
Stage IV							
Q	130-560	3.5	0.19	0.4	0.025	31st Dec 12	31st Dec 13
R	56-130	5.0	0.19	0.4	0.025	30th Sept 13	30th Sept 14

FEDERAL AND CALIFORNIA NON-ROAD ENGINE EXHAUST AND EVAPORATIVE EMISSION AND STANDARDS

The Clean Air Act Section 209(e)(1)(A) (42 U.S. Code § 7543) pre-empts other states (including California) from adopting emission standards for engines which are used in construction equipment or vehicles, or used in farm equipment or vehicles and which are smaller than 175 horsepower (hp).

California applies EPA standards for off-road CI engines, including those above 175 hp.

California has adopted its own standards for engines used in other types of equipment, specifically for large and small SI engines, as well as evaporative emission standards for vehicles and equipment using those engines. California has proposed new Tier 5 standards to be phased in from 2029, with harmonization with federal standards expected.

The Tier 5 proposal also includes CO_2 standards for off-road vehicles.

TIER 1 TO 4 NON-ROAD CI ENGINE EXHAUST EMISSION LIMIT VALUES AND TEST PROCEDURES – HISTORICAL AND CURRENT

Off-Road CI Engines

40 CFR part 89 covered mobile non-road diesel engines Tier 1, 2 and 3, used in construction, agricultural and industrial applications, which then migrated to 40 CFR Part 1039 (Appendix 1). US non-road regulations use the metric system of units, all standards expressed in g/kWh.

General notes to CI engine standards:

- For Tier 1, 2 and 3 standards, exhaust emissions of NOx, CO, HC and NMHC are measured using the procedures in 40 CFR Part 89 Subpart E. For Tier 1,2,3 standards PM exhaust emissions are measured using the California Regulations for New 1996 and Later HD Off-Road Diesel Cycle Engines.
- For Tier 4 standards, engines are tested for transient and steady-state exhaust emissions using the procedures in 40 CFR Part 1039 Subpart F. Transient standards did not apply to engines < 37 KW, before the 2013 MY, constant-speed engines, engines certified to Option 1, and engines > 560 kW.
- Tier 2 and later model naturally aspirated non-road engines shall not discharge crankcase emissions into the atmosphere unless these emissions are permanently routed into the exhaust. This prohibition does not apply to engines using turbochargers, pumps, blowers or superchargers.
- In lieu of the Tier 1, 2 and 3 standards for NOx, NMHC + NOx and PM manufacturers may elect to participate in averaging, banking and trading (ABT) program described in 40 CFR Part 89 Subpart C.
- Recall testing period is limited to 75% of useful life.

TIER 1 TO 4 CI ENGINE EXHAUST EMISSION LIMIT VALUES – HISTORICAL AND CURRENT STANDARDS

Off-Road CI Engines

Rated Power (kW)	Tier	Model Year	NMHC	NMHC + NOx	NOx	PM	CO	Smoke Opacity (%)[a]	Useful Period (hrs/yrs)[b]	Emissions Warranty (hrs/yrs)[b]
			(g/kWh)							
< 8 kW	1	2000-2004	–	10.5	–	1.0	8.0	20 / 15 / 50	3,000/5	1,500/2
	2	2005-2007	–	7.5	–	0.80	8.0			
	4	2008+	–	7.5	–	0.40[c]	8.0			
8 ≤ kW < 19	1	2000-2004	–	9.5	–	0.80	6.6		3,000/5	1,500/2
	2	2005-2007	–	7.5	–	0.80	6.6			
	4	2008+	–	7.5	–	0.40	6.6			
19 ≤ kW < 37	1	1999-2003	–	9.5	–	0.80	5.5		5,000/7[d]	3,000/5[e]
	2	2004-2007	–	7.5	–	0.60	5.5			
	4	2008-2012	–	7.5	–	0.30	5.5			
		2013+	–	4.7	–	0.03	5.5			
37 ≤ kW < 56 (Option 1) (Option 2)	1	1998-2003	–	–	9.2	–	–		8,000/10	3,000/5
	2	2004-2007	–	7.5	–	0.40	5.0			
	3[f]	2008-2011	–	4.7	–	0.40	5.0			
	4[g]	2008-2012	–	4.7	–	0.30	5.0			
	4[g]	2012	–	4.7	–	0.03	5.0			
	4	2013+	–	4.7	–	0.03	5.0			

TIER 1 TO 4 CI ENGINE EXHAUST EMISSION LIMIT VALUES - HISTORICAL AND CURRENT STANDARDS

Off-Road CI Engines... continued

Rated Power (kW)	Tier	Model Year	NMHC	NMHC + NOx	NOx	PM	CO	Smoke Opacity (%)[a]	Useful Period (hrs/yrs)[b]	Emissions Warranty (hrs/yrs)[b]
			(g/kWh)							
56 ≤ kW < 75	1	1998-2003	–	–	9.2	–	–	20 / 15 / 50	8,000/10	3,000/5
	2	2004-2007	–	7.5	–	0.40	5.0			
	3	2008-2011	–	4.7	–	0.40	5.0			
	4	2012-2013[h]	–	4.7	–	0.02	5.0			
		2014+	0.19	–	0.40	0.02	5.0			
75 ≤ kW < 130	1	1997 - 2002	–	–	9.2	–	–			
	2	2003 - 2006	–	6.6	–	0.30	5.0			
	3	2007 - 2011	–	4.0	–	0.30	5.0			
	4	2012 - 2013[h]	–	4.0	–	0.02	5.0			
		2014+	0.19	–	0.40	0.02	5.0			
130 ≤ kW < 225	1	1996- 2002	1.3[i]	–	9.2	0.54	11.4			
	2	2003- 2005	–	6.6	–	0.20	3.5			
	3	2006 - 2010	–	4.0	–	0.20	3.5			
	4	2011 - 2013[h]	–	4.0	–	0.02	3.5			
		2014+	0.19	–	0.40	0.02	3.5			
225 ≤ kW < 450	1	1996 - 2000	1.3[i]	–	9.2	0.54	11.4			
	2	2001 - 2005	–	6.4	–	0.20	3.5			
	3	2006 - 2010	–	4.0	–	0.20	3.5			
	4	2011- 2013[h]	–	4.0	–	0.02	3.5			
		2014+	0.19	–	0.40	0.02	3.5			

TIER 1 TO 4 CI ENGINE EXHAUST EMISSION LIMIT VALUES - HISTORICAL AND CURRENT STANDARDS

Off-Road CI Engines... continued

Rated Power (kW)	Tier	Model Year	NMHC	NMHC + NOx	NOx	PM	CO	Smoke Opacity (%)[a]	Useful Period (hrs/yrs)[b]	Emissions Warranty (hrs/yrs)[b]
			(g/kWh)							
450 ≤ kW ≤ 560	1	1996 - 2001	1.3[j]	-	9.2	0.54	11.4	20 / 15 / 50	8,000/10	3,000/5
	2	2002 - 2005	-	6.4	-	0.20	3.5			
	3	2006 - 2010	-	4.0	-	0.20	3.5			
	4	2011 - 2013[h]	-	4.0	-	0.02	3.5			
		2014+[i]	0.19	-	0.40	0.02	3.5			
560 < kW < 900	1	2000 - 2005	1.3[j]	-	9.2	0.54	11.4			
	2	2006 - 2010	-	6.4	-	0.20	3.5			
	4	2011 - 2014	0.40	-	3.5	0.10	3.5			
		2015+[i]	0.19	-	3.5[k]	0.04[l]	3.5			

TIER 1 TO 4 ENGINE EXHAUST EMISSION LIMIT VALUES - HISTORICAL AND CURRENT STANDARDS

Footnotes to tables:

[a] Smoke emissions may not exceed 20% opacity during the acceleration mode, 15% during the lugging mode and 50% during the peaks in either mode. Smoke emission standards do not apply to single-cylinder engines, constant-speed engines, or engines certified to a PM emission standard of 0.07 g/kW-hr or lower. Smoke emissions are measured using procedures in 40 CFR Part 86 Subpart L.

[b] Useful life and warranty period are expressed in hours and years, whichever comes first.

[c] Hand-startable air-cooled direct injection engines may optionally meet PM standard of 0.60 g/ kW-hr. These engines may optionally meet Tier 2 standards through 2009 MY, in 2010 these are required to meet PM standard of 0.60 g/kW-hr.

[d] Useful life for constant speed engines with rated speed 3,000 rpm or higher is 5 years or 3,000 hrs, whichever comes first.

[e] Warranty period for constant speed engines with rated speed 3,000 rpm or higher is 2 years or 1,500 hrs, whichever comes first.

[f] These Tier 3 standards apply only to manufacturers selecting Tier 4 Option 2. Manufacturers selecting Tier 4 Option 1 will be meeting those standards in lieu of Tier 3 standards.

[g] Interim standards. A manufacturer may certify all their engines to either Option 1 or 2 sets of standards starting in the indicated MY. Manufacturers selecting Option 2 must meet Tier 3 standards in the 2008-2011 MY.

[h] These standards are interim standards. Not more than 50% of a manufacturer's engine production is allowed to meet these standards in each MY of the phase out period. Engines not meeting these standards must meet the final Tier 4 standards.

[i] These standards are phased in during the indicated years. At least 50% of a manufacturer's engine production must meet these standards during each year of the phase in. Engines not meeting these standards must meet the applicable phase-out standards.

[j] For Tier 1 engines the standard is for total hydrocarbons.

[k] NOx standard for generator sets above 900kW is 0.67 g/kW-hr.

[l] PM standard for generator sets is 0.03 g/kW-hr.

Also included: averaging, banking and trading (ABT) of emission credits and NTE "Family Emissions limits" (FEL) for emission averaging.

Amended requirements in September 2007 to allow Tier 3 phase-in relief in exchange for equivalent loss of Tier 4 flexibility.

Federal Smoke Test (40 CFR Part 86, sub part I) Harmonized smoke test: ISO 8178-9.

A. (Acceleration) = 20% opacity

B. (Lugging Mode) = 15% opacity

C. (Peak) = 50% opacity

Engine Useful Life

The emissions standards must be met over the entire useful life of the engine. DFs are applicable to all engines.

CURRENTLY IN FORCE TIER 4 CI ENGINE EXHAUST EMISSION LIMIT VALUES

Final Tier 4 limit values g/kWh (also included in table pages 143-145)

Engine Power / Category	Model Year	CO	NMHC	NMHC + NOx	NOx	PM
kW < 8 (hp < 11)	2008	8.0	-	7.5	-	0.4[a]
8 ≤ kW < 19 (11 ≤ hp < 25)	2008	6.6	-	7.5	-	0.4
Generator sets > 900 kW	2011	3.5	0.40	-	0.67	0.10
All engines except gensets > 900 kW		3.5	0.40	-	3.5	0.10
19 ≤ kW < 37 (25 ≤ hp < 50)	2013	5.5	-	-	-	0.03
37 ≤ kW < 56 (50 ≤ hp < 75)	2013	5.0	-	-	-	0.03
56 ≤ kW < 130 (75 ≤ hp < 175)	2012-2014[b]	5.0	0.19	-	0.40	0.02
130 ≤ kW < 560 (175 ≤ hp ≤ 750)	2012-2014[c]	3.5	0.19	-	0.40	0.02
Generator sets	2015	3.5	0.19	-	0.67	0.03
All engines except gensets		3.5	0.19	-	3.5	0.04

CURRENTLY IN FORCE TIER 4 ENGINE EXHAUST EMISSION TEST PROCEDURES

Footnotes to table:

[a] Hand-startable, air cooled, DI engines may be certified to Tier 2 standards through 2009 and to an optional PM standard of 0.6 g/kWh starting in 2010

[b] PM/CO: full compliance from 2012: NOx/HC: Option 1 (if banked Tier 2 credits used)

- 50% engines must comply in 2012-2013. Option 2 (if no Tier 2 credits claimed)
- 25% engines must comply in 2012-2014, with full compliance from 31st December 14

[c] PM/C-O: full compliance from 2011: NOx/HC: 50% engines must comply in 2011-2013

Tier 4 test cycles (see pages 176-179)

Tier 4 standards to be met on both NRSC (page 176) and NRTC (page 179) cycles.

Testing using the NRTC cycle (and meeting the tabulated targets above) is required from:

- 2011 for engines 130-560 kW
- 2012 for engines 56-130 kW
- 2013 for engines < 56 kW

Not-to-exceed (NTE) Standards

Measured without any specific test schedule.

Effective in:

- 2011 for engines > 130 kW
- 2012 for engines 56-130 kW
- 2013 for engines < 56 kW

NTE limits are set at 1.25 times the regular standard for each pollutant. Exceptions: if NOx < 2.5 g/kWh or PM < 0.07 g/kWh, NTE multiplier is 1.5 NTE standards apply on certification of engines and useful life of the engine. NTE purpose is to prevent the use of defeat devices.

Certification Fuels (see page 188-190)

SMALL SI ENGINE (≤19KW) CLASSES AND TEST PROCEDURES

The small SI engine classes are determined by engine displacement and differ according to emissions standards phase

Phase	Non-handheld				Handheld		
	Class I			Class II	Class III	Class IV	Class V
1	< 225 cc			≥ 225 cc	< 20 cc	20 cc ≤ Class IV < 50 cc	≥ 50 cc
2	Class I-A < 66cc	66 ≤ Class I-B < 100 cc	100 ≤ Class I < 225cc				
3	< 225 cc						

Test cycle: SAE J1088 cycles A, B and C

Cycle A: Non-handheld engines to be tested at an intermediate speed "similar to" ISO 8178-G1.

Cycle B: Non-handheld engines to be tested at rated speed "similar to" ISO 8178-G2.

Cycle C: Handheld engines to be tested at conditions "similar to" ISO 8178-G3 except weighting Mode 1: 85% and Mode 2: 15%.

Averaging, banking and trading (ABT) Program: Phase II handheld engines and Class I-A and I-B non-handheld engines to fulfil a certification, averaging, banking & trading program.

Any engines certified to the non-handheld emission standards in 40 Code of Federal Regulations (CFR) 1054.105 may be used in either handheld or non-handheld equipment. Engines greater than 80 cubic centimeters (cc) certified to the handheld emission standards in 40 CFR 1054.103 may not be used in non-handheld equipment. Engines less than or equal to 80 cc are considered handheld engines, but may be installed in either handheld or non-handheld equipment.

PREVIOUS AND CURRENTLY IN FORCE PHASE 1, 2 AND 3[d] ENGINE EXHAUST EMISSION LIMIT VALUES FOR SMALL OFF-ROAD SI ENGINES

Phase 1 Standards

(g/kWh)

Class[a]	Year	HC	HC+ NOx	NOx	CO	Useful Life (hrs)	Emissions Warranty
I	1997+	–	16.1	–	519	Engines must meet the Phase 1 standards as new engines, but are not required to meet these standards throughout their useful life.	2
II	1997+	–	13.4	–	519		
III	1997+	295	–	5.36	805		
IV	1997+	241	–	5.36	805		
V	1998+	161	–	5.36	603		

Phase 2 Standards

(g/kWh)

Class[a]	Year	HC+ NOx	NMHC+ NOx[c]	CO	Useful Life (hrs)	Emissions Warranty
I	2003+[c]	16.1	14.8	610	125 / 250 / 500[d]	2[e]
I - A	2001+	50	–		50 / 125 / 300[d]	
I - B	2001+	40	37		125 / 250 / 500[d]	
II	2001	18.0	16.7	610	250 / 500 / 1000[d]	
	2002	16.6	15.3			
	2003	15.0	14.0			
	2004	13.6	12.7			
	2005+	12.1	11.3			

Class[a]	Year	HC+ NOx	NMHC+ NOx[b]	CO	Useful Life (hrs)	Emissions Warranty
III	2002	238	–	805	50 / 125 / 300[d]	2[e]
	2003	175	–			
	2004	113	–			
	2005+	50	–			
IV	2002	196	–	805	50 / 125 / 300[d]	
	2003	148	–			
	2004	99	–			
	2005+	50	–			
V	2004	143	–	603	50 / 125 / 300[d]	
	2005	119	–			
	2006	96	–			
	2007+	72	–			

PREVIOUS AND CURRENTLY IN FORCE PHASE 1, 2 AND 3 ENGINE EXHAUST EMISSION LIMIT VALUES FOR SMALL OFF-ROAD SI ENGINES

Phase 3 Standards (g/kWh)

Class[a]	Model Year	HC+ NOx	NMHC+ NOx	CO	Useful Life (hrs)			Emissions Warranty
					Residential[g]	Extended Life[g]	Commercial[g]	
I	2012	10.0[f] (ABT)	-	610	125	250	500	2 years[e]
II	2011	8.0[f] (ABT)	-	610	250	500	1,000	
III-V	The Phase 3 exhaust standards are the same as the long-term Phase 2 exhaust standards noted above.							

PREVIOUS AND CURRENTLY IN FORCE PHASE 1, 2 AND 3 ENGINE EXHAUST EMISSION LIMIT VALUES FOR SMALL OFF-ROAD SI ENGINES

Footnotes to tables:

[a] The engines that are covered by or exempt from these standards are defined in 40 CFR 90.1 and 1054.1. Engines less than or equal to 30 kilowatts (kW) and that have a total displacement of 1,000 cc or less may certify to the Class II engine standards for the appropriate model year. The test procedures are the small spark-ignition (SI) engine federal steady-state test procedures. They consist of a 6-mode test for non-handheld engines and a 2-mode test for handheld engines.

[b] Non-methane hydrocarbon (NMHC) plus nitrogen oxides (NOx) standards are applicable only to natural gas fueled engines at the option of the manufacturer, in lieu of HC+NOx standards.

[c] The effective date is August 1, 2007; in addition, any Class I engine family initially produced on or after August 1, 2003 must meet the Phase 2 Class I standards before they may be introduced into commerce.

[d] Manufacturers certify for the useful life category which most closely approximates the expected useful life of the equipment into which the engines will be installed. Engines with gross power output greater than 19 kW that have an engine displacement less than or equal to 1 liter that optionally certify under 40 CFR Part 90 must certify to a useful life period of 1,000 hours.

[e] For Phase 2 and Phase 3 handheld engines, EPA may establish a shorter warranty period for handheld engines subject to severe service in seasonal equipment if EPA determines that these engines are likely to operate for a number of hours greater than the applicable useful life within 24 months.

[f] The Phase 3 numerical emission standards for HC must be met based on the following types of hydrocarbon emissions for engines powered by the following fuels: (1) total hydrocarbon equivalent for alcohol; (2) non-methane hydrocarbon for natural gas; and (3) total hydrocarbons for other fuels.

[g] The useful life period is the number of engine operating hours listed in the table that most closely matches the expected median in-use life of the engines as described in 40 CFR 1054.107. The minimum useful life period for engines with maximum engine power above 19kW is 1,000 hours. For non-handheld engines, a longer useful life may be selected in 100 hour increments not to exceed 3,000 hours for Class I engines or 5,000 hours for Class II engines.

Code of Federal Regulations (CFR) Citations:

- 40 CFR 90.103 = Phases 1 & 2 exhaust emission standards
- 40 CFR 90.105 = Phase 2 useful life
- 40 CFR 90.1103 = Phases 1 & 2 warranty period
- 40 CFR 90 Subpart C = ABT programs
- 40 CFR 1054.103 + 1054.105 = Phase 3 exhaust emission standards
- 40 CFR 1054.107 = Phase 3 useful life
- 40 CFR 1054.120 = Phase 3 warranty requirements

PREVIOUS AND CURRENTLY IN FORCE EVAPORATIVE EMISSION LIMIT VALUES FOR SMALL OFF-ROAD SI ENGINES

Engine Category			Model Year	Fuel Line Permeation[a] (g/m²/day)		Fuel Tank Permeation (g/m²/day at 28°C)	Running Losses	Diurnal (g/gal/day)	Useful Life[c] (yrs)	Emissions Warranty (yrs)
				Non-Road	Cold Weather[b]					
Small SI Equipment	Non-handheld	Class I	2012+	15[e,f]	-	1.5[f,g,h] (ABT)	Design Standard[i]	Optional[i]	5	2
		Class 2	2011+	15[e,f]	-	1.5[f,g,h] (ABT)	Design Standard[i]	Optional[i]	5	2
	Handheld (Classes III, IV, V)		2010	-	-	1.5[g,h] (ABT)	-		5	2
			2012	15[k]	290					
			2013		275					
			2014		260					
			2015		245					
			2016+		225					

PREVIOUS AND CURRENTLY IN FORCE EVAPORATIVE EMISSION LIMIT VALUES FOR SMALL OFF-ROAD SI ENGINES

Footnotes:

[a] Fuel lines used with handheld small SI. engines installed in cold-weather equipment (as defined in 40 Code of Federal Regulations (CFR) 1054.80) must meet the standards for EPA cold-weather fuel lines.

[b] In the 2012-2015 MY, certifying equipment manufacturers may generate or use emission credits for averaging to show compliance but not for banking or trading.

[c] A two-year useful life period applies for fuel tanks of fuel caps certified to meet permeation emission standards in 2013 and earlier MY for small SI and marine SI.

[d] The small SI engine classes are determined by engine:

Any engines certified to non-handheld emission standards in 40 CFR 1054.105 may be used in either handheld or non-handheld equipment. Engines greater than 80 cc certified to the handheld emission standards in 40 CFR 1054.103 may not be used in non-handheld equipment. Engines less than or equal to 80 cc are considered handheld engines, but may be installed in either handheld or non-handheld equipment.

[e] Non-handheld fuel line permeation requirements begin 01 Jan 09.

[f] Small SI fuel tanks and fuels lines that are installed in equipment certified to meet the optional diurnal emission standards under 40 CFR 1060.105(e) do not have to meet these permeation standards.

[g] Or 2.5 grams per square meter per day if testing performed at 40°C.

[h] For handheld equipment, these requirements apply starting in the 2010 MY, except that they apply starting in the 2011 MY for structurally integrated nylon fuel tanks, in the 2012 MY for handheld equipment using non-handheld engines, and in the 2013 MY for all small-volume emission families. Some handheld fuel tanks have to comply in 01 Jan 09 with a two-year useful life (40 CFR 90.129(a)). For non-handheld equipment using engines at or below 80 cc, these requirements apply starting in the 2012 MY.

[i] Running loss requirements apply to non-handheld Small SI engines and equipment that are not used in wintertime equipment.

[j] Non-handheld equipment may optionally be certified to the diurnal emission standards in 40 CFR 1060.105(e), in which case the fuel line and fuel tank permeation standards do not apply.

[k] These requirements apply starting in the 2013 MY for small-volume families that are not used in cold-weather equipment.

PREVIOUS AND CURRENTLY IN FORCE TIER 1 AND 2 EXHAUST EMISSION LIMIT VALUES FOR LARGE SI ENGINES > 19KW

Limit values (harmonized with CARB through MY 2009)

40 CFR Part 1048

Includes non-road equipment such as forklift, sweeper, pump and generator.

(g/kWh)

Standards	MY	Testing Type	Emission Standards[a]		Alternate Standard for Severe-Duty Engines	
			HC + NOx	CO	HC + NOx	CO
Tier 1	2004 - 2006	Duty cycle[b]	4.0	50.0	4.0	130
		Field testing	5.4	50.0	5.4	130
Tier 2	2007	Duty cycle[b]	2.7	4.4	2.7	130
		Field testing	3.8	6.5	3.8	200

Footnotes:

[a] Alternative according to the following formula: (HC + NOx) x ($CO^{0.784}$) ≤ 8.57
Field testing limits use: (HC + NOx) x ($CO^{0.791}$) ≤ 16.78

[b] Tier 1: Steady-State cycle. Tier 2: Steady-State + transient cycles

Useful life period: 7 years or 5,000 operating hours, severe duty 7 years / 1,500 hours (evaporate emissions: useful life 5 years).

TEST PROCEDURE

MY 2004-2006: ISO 8178-4 C2, D2

MY 2007 additional requirements:
a. Warm up Segment **b.** Transient Segment **c.** Steady-State Segment

OTHER REQUIREMENTS

Warranty: minimum half of engine's useful life or 3 years.
Diagnostic system: from MY 2007.

Monitoring area: air-fuel ratio maintained at λ1 if control system depends on λ = 1 emission control system malfunction.

Manufacturers required to perform In-Use testing:

- test minimum of 4 engines in 25% of engine families.
- small engine families (< 500 engines) require minimum of 2 engines tested.
- if manufacturer's total production < 2,000 minimum testing is 2 engines.

EVAPORATIVE EMISSIONS

Diurnal emissions: from MY 2007+.
Evaporative HC emissions may not exceed 0.2 grams per gallon of fuel tank capacity.

Fuel Lines permeation: must meet SAE J2260 if not metal.

Running Loss: Liquid fuel in the fuel tank may not reach boiling during continuous engine operation in the final installation at an ambient temperature of 30°C.

OVERVIEW OF STANDARDS FOR SMALL OFF-ROAD SI ENGINES ≤ 19KW (SORE)

"Small Off-Road Engine" (SORE) = any engine that produces a gross power < 25 hp (≤ 19 kW) for 2005 and later MY or is designed (e.g. through fuel feed, valve timing etc.) to produce < 25 hp (≤ 19 kW) for 2005 and later MY that is not used to propel a licensed on-road motor vehicle, all-terrain vehicle, off-road motorcycle, marine vessel, snowmobile, model airplane/car/boat.
If an engine family has models both < 19kW and >= 19kW, only those models < 19kW would be considered SORE. Uses for SORE include, but are not limited to, applications such as mowers, weed trimmers, chain saws, golf carts, specialty vehicles, generators, pumps. All engines/equipment that fall within the scope of pre-emption of Section 209(e)(1)(A) of FCAA, as amended, and as defined by regulation of EPA, are specifically not included within this category. Any CI engine as defined in Section 2421, produced during the 2000 and later MY shall not be defined as SORE.

CARB Standards are based on: engine displacement (no handheld/ non-handheld categories) for tailpipe emission. Category limit 65 cc.

Vertical and horizontal crankshaft engine classifications.

Test Procedures: SAE J1088 / Cycle A: engine > 65 cc configured for intermediate speed / Cycle B: engine > 65 cc configured for rated speed/ Cycle C: engine > 65 cc. Similar to ISO 8178 G1/G2/G3.

No SORE may be equipped with a defeat device.

SMALL SI ENGINES (< 19KW): MY 2024 AND SUBSEQUENT EXHAUST EMISSION STANDARDS AND DURABILITY PERIODS

- From model year 2024, emissions limits except CO and evaporative emissions limits for small SI engines will be zero, except generator engines and pressure washer engines with displacement ≥ 225 cc, for which the zero limits apply from 2028
- For generator engines and pressure washer engines with displacement ≥ 225 cc, more stringent interim emissions standards apply from model years 2024 to 2027

Exhaust emissions limits[a] and durability requirements for small SI engines

Model Year	Displacement (cm^3)	Durability Period (hours)	HC + NOx [b,c] (g/kWh)	CO (g/kWh)	PM (g/kWh)
2024 and after	< 50	300	0.00	536	0.00 [d]
	50 ≤ ≤ 80	300	0.00	536	0.00 [d]
	80 < < 225	500	0.00	549	-
	225 ≤ ≤ 825	1000	0.00	549	-
	> 825	1000	0.00	20.6	-

Footnotes:

[a] These requirements apply to all engines except generator engines and engines with D ≥ 225 cc and used for pressure washers

[b] Engine families using gas fuels may be certified to NMHC + NOx

[c] Engines used exclusively in winter time, such as snow throwers and ice augers, need not comply with standards regulating emissions of HC+NOx or NMHC+NOx, as applicable.

[d] 2-stroke engines only

SMALL SI ENGINES (< 19KW): MY 2024 AND SUBSEQUENT EXHAUST EMISSION STANDARDS AND DURABILITY PERIODS

Emissions requirements for small SI generator engines

Model Year	Displacement D (cc)	Durability Period (hours)	HC + NOx [a] (g/kWh)	CO [b] (g/kWh)	PM (g/kWh)
2024 to 2027	D < 50	500	6.0	400	2.0 [c]
	50 ≤ D ≤ 80	500	6.0	400	2.0 [c]
	80 < D < 225	500	6.0	400	-
	225 ≤ D ≤ 825	1000	3.0	200	-
	> 825	1000	0.80	20.6	-
2028 and after	D < 50	300	0.00	400	0.00 [c]
	50 ≤ D ≤ 80	300	0.00	400	0.00 [c]
	80 < D < 225	500	0.00	400	-
	225 ≤ D ≤ 825	1000	0.00	200	-
	> 825	1000	0.00	20.6	-

Footnotes: [a] Engine families using gas fuels may be certified to NMHC + NOx

Emissions requirements for pressure washers small SI engines with D ≥ 225 cc - from MY 2024 (CCR 13, section 2403 [7])

Model Year	Displacement D (cc)	Durability Period (hours)	HC + NOx [a] (g/kWh)	CO (g/kWh)	PM (g/kWh)
2024 to 2027	225 ≤ D ≤ 825	1000	3.0	200	-
	> 825	1000	0.80	20.6	-
2028 and after	225 ≤ D ≤ 825	1000	0.00	200	-
	> 825	1000	0.00	20.6	-

EVAPORATIVE EMISSION LIMIT VALUES AND TEST PROCEDURES FOR SMALL SI ENGINES (FROM 2007)

Evaporative emissions standards for small off-road SI engines through the 2023 model year

Displacement (cc)	Description	Model Year	1 Day Diurnal Emission (g HC/day)	Fuel Hose (ROg/m²/day)	Fuel Tank (ROg/m²/day)	Carbon Canister
≤ 80	Handheld	2007 - 2019	None	None	2.0	N/A
		2020+		15	2.0	
> 80 < 225	Walk behind Mowers	2006	None	15	None	None
		2007-2008	1.30	N/A	N/A	N/A
		2009-2013+	1.00	N/A	N/A	N/A
> 80 to < 225	Others	2006	None	15	None	None
		2007-2011	1.20 + 0.056 x tank vol (l)		2.5	TP-902
		2012-2013+	0.95 + 0.056 x tank vol (l)		1.50	
≥ 225	All	2006-2007	-	15	None	None
		2008-2012	1.20 + 0.056 x tank vol (l)		2.5	TP-902
		2013+	1.20 + 0.056 x tank vol (l)		1.5	

Small production volume exempted from diurnal and fuel tank permeation standards; low fuel hoses and carbon canister required from MY 2010.

Engine Type	Displacement Category (cc)	Model Year	Hot Soak Diurnal Emission Standards (g/day)[a]	Test Standard
All other than Generators & Pressure Washers	Displacement ≤ 80	2024	0.00	TP-902
	80 < displacement < 225	2024	0.00	
	Displacement ≥ 225	2024	0.00	

Footnotes:

[a] The standards for hot-soak plus diurnal emissions are measured in grams of organic material hydrocarbon equivalent per test. This includes both hot-soak and the 24-hour diurnal test. 0.00 means 54mg maximum with margin for measurement equipment accuracy

EVAPORATIVE EMISSION LIMIT VALUES FOR GENERATORS AND PRESSURE WASHERS (FROM 2007)

Hot Soak Plus Diurnal Emission Standards for Generator Engines and Pressure Washers

Engine Type	Displacement Category (cc)	Model Year	Hot Soak Diurnal Emission Standards (g/day)[a]	Test Standard
Generators	displacement ≤ 80	2024	0.50	TP-902
		2028	0.00	
	80 < displacement < 225	2024	0.60	
		2028	0.00	
	displacement ≥ 225	2024	0.70	
		2028	0.00	
Pressure Washers	displacement ≥ 225	2024	0.70	
		2028	0.00	

Footnotes:

[a] The standards for hot-soak plus Diurnal emissions are measured in grams of organic material hydrocarbon equivalent per test. This includes both hot-soak and the 24-hour diurnal test

PREVIOUS AND CURRENTLY IN FORCE LIMIT VALUES AND DURABILITY PERIODS FOR LARGE (> 19KW) SI ENGINES

LARGE OFF-ROAD SI ENGINES
Applied to SI engines ≥ 19 kW (25hp), except construction and farm equipment engines < 175 hp, off-road motorcycle, all-terrain vehicles, snowmobiles.
Test Procedure: ISO 8178-4 C2 all the engines except:
· Generator or constant speed applications: ISO 8178-4 D2
· Engines with characteristics similar to SORE (< 25 hp): G1
· Evaporative emissions harmonized with EPA (page 156)

Limit values for HC + NOx / CO in g/kWh (durability periods in brackets)

<table>
<tr><th>Displacement Category</th><th>Test Cycle</th><th>2001</th><th>2002</th><th>2003</th><th>2004</th><th>2005</th><th>2006</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015+</th></tr>
<tr><td>≤ 825 cc</td><td rowspan="2">Steady-state Testing</td><td rowspan="2">-</td><td colspan="9" rowspan="2">12.0 / 549
(1,000 hrs or 2 yrs)</td><td colspan="5">8.0 / 549 (1,000 hrs or 2 yrs)</td></tr>
<tr><td>> 825 cc ≤ 1.0 liter</td><td colspan="4">6.5 / 375 (1,000 hrs or 2 yrs)</td><td>0.8 / 20.6[d] (1,000 hrs or 2 yrs)</td></tr>
<tr><td rowspan="3">> 1.0 liter</td><td>Steady-state Testing</td><td colspan="3">4.0 / 49.6[a]</td><td colspan="3">4.0 / 49.6
(3,500 hrs or 5 yrs)</td><td rowspan="2">2.7 / 4,4[b]
(5,000 hrs or 7 yrs)</td><td rowspan="2" colspan="2">0.8 / 20.6
(5,000 hrs or 7 yrs)</td><td colspan="4" rowspan="2">0.8 / 20.6
(5,000 hrs or 7 yrs)</td></tr>
<tr><td>Transient Testing</td><td colspan="6">-</td></tr>
<tr><td>Field Testing</td><td colspan="8">-</td><td colspan="5">3.8 / 6.5[c] (5,000 hrs or 7 yrs)</td></tr>
</table>

Footnotes:
[a] A manufacturer must show that at least 25% of its California engine sales comply with the standards in 2001, 50% in 2002, 75% in 2003
[b] For the 2007-2009 MY manufacturers may alternatively certify their engines according to the following formula: (HC + NOx) + CO0,784 ≤ 8.57
[c] Starting in 2007 manufacturers may apply the following formula to determine alternate emissions standards: (HC + NOx) + CO0,791 ≤ 16.78
[d] For 2011 and subsequent MY large SI engines used in off-highway motor vehicles that, with the exception of payload capacity, meet the "Off-Road Sport Vehicle" or "Off-Road Utility Vehicle" definitions need not meet the 2015 and subsequent exhaust emissions standards

EPA 96 – TIER 1 INITIAL SCHEDULE

Applied to engines between 175 bhp (130 kW) and 750 bhp (560 kW). Other engine categories were added later. Test cycle: ISO 8178 is an international standard for exhaust emission measurement.

Engine Power		Model Year	NOx	HC	CO	PM
(hp)	(kW)		(g/kWh)			
hp ≥ 750	P ≥ 560	2000	9.2	1.3	11.4	0.54
175 ≤ hp < 750	130 ≤ P ≤ 560	1996	9.2	1.3	11.4	0.54
100 ≤ hp < 175	75 ≤ P < 130	1997	9.2	-	-	-
50 ≤ hp < 100	37 ≤ P < 75	1998	9.2	-	-	-

NEW EMISSION STANDARDS LIMIT VALUES FOR DIESEL-POWERED SPECIAL VEHICLES (OFF-HIGHWAY)

Special vehicles: Vehicles not running on the public road (e.g. forklift trucks, agricultural vehicles, bulldozers, etc.)
New Emissions Standards (from 2014)

Rated Power	NOx		NMHC		CO		PM		Smoke Opacity Value (per m)	Implementation Dates	
	(g/kWh)									New Vehicles	Existing Vehicles
	Mean	Max	Mean	Max	Mean	Max	Mean	Max			
19-37 kW	4.00	5.30	0.70	0.90	5.00	6.50	0.03	0.04	0.5	1st Oct 16	1st Sept 17
37-56 kW	4.00	5.30	0.70	0.90	5.00	6.50	0.025	0.033	0.5		
56-75 kW	0.40	0.53	0.19	0.25	5.00	6.50	0.02	0.03	0.5	1st Oct 15	
75-130 kW	0.40	0.53	0.19	0.25	5.00	6.50	0.02	0.03	0.5		
130-560 kW	0.40	0.53	0.19	0.25	3.50	4.60	0.02	0.03	0.5	1st Oct 14	1st Sept 16

Test mode for NOx, NMHC, CO and PM measurement is diesel powered special vehicle 8-mode, ISO 8178 C1 (page 176) and/or the NRTC (page 179).
Test mode for smoke measurement is diesel powered special vehicle 8-mode and no road acceleration smoke mode.
Smoke measurement is with an opacity meter.

NEW EMISSION STANDARDS LIMIT VALUES FOR GASOLINE AND LPG (SI) POWERED SPECIAL VEHICLES (OFF-HIGHWAY)

Rated Power	NOx		NMHC		CO		Implementation Dates	
	(g/kWh)						New Vehicles	Existing Vehicles
	Mean	Max	Mean	Max	Mean	Max		
19-560 kW	0.6	0.8	0.6	0.8	20.0	26.6	1st Oct 13	1st Sept 15

Test mode is "Gasoline LPG powered special vehicle 7-mode" (page 165)

SPECIAL VEHICLES FOR SMALL VOLUME PRODUCTION (applies US standards)

19-37 kW	Tier 2, Stage IIIA	1st Oct 07	
	Tier 4	1st Oct 13	1st Sept 15
37-56 kW	Tier 3, Stage IIIA	1st Oct 08	
	Tier 4, Stage IIIB	1st Oct 13	1st Nov 14
56-75 kW	Tier 3, Stage IIIA	1st Oct 08	
	Interim Tier 4, Stage IIIB	1st Oct 12	1st Apr 14

Tier2 and Tier3 represent the standard defined in the CFR Title 40 Chapter1 Part 89 (as per the US EPA regulations).
Tier4 and Interim Tier4 represent the standard defined in the Code of Federal Regulations Title 40 Chapter1 Part 1039.

Exceptions are as follows:

- Phase-out standard for 56 kW to 560 kW defined in the Part 1039 §1039.102
- The family emission limit for the engine family standard with negative emission credits value for ABT program when the averaging, banking, and trading program defined in the Part 1039
- Stage III A, Stage III B represent 97/68/EC

TEST CYCLES FOR CI AND SI VEHICLES

TEST CYCLES – DIESEL (CI) POWERED SPECIAL VEHICLE 8-MODE

Mode	Operations Conditions		Min. Operation Time (mins)	Weighting Factor
	Engine Speed (rpm)	Engine Load (%)		
1	Rated speed	100	10	0.15
2	Rated speed	75	10	0.15
3	Rated speed	50	10	0.15
4	Rated speed	10	10	0.10
5	Intermediate speed	100	10	0.10
6	Intermediate speed	75	10	0.10
7	Intermediate speed	50	10	0.10
8	Idle	0	10	0.15

GASOLINE / LPG (SI) POWERED SPECIAL VEHICLE 7-MODE

Mode	Operations Conditions		Min. Operation Time (mins)	Weighting Factor
	Engine Speed (rpm)	Engine Load (%)		
1	Rated speed	25	5	0.06
2	Intermediate speed	100	5	0.02
3	Intermediate speed	75	5	0.05
4	Intermediate speed	50	5	0.32
5	Intermediate speed	25	5	0.30
6	Intermediate speed	10	5	0.10
7	Idle	0	5	0.15

Rated speed is defined as maximum engine speed

Intermediate speed is defined as follows:

- If a speed at maximum torque is between 60-75% of the rated speed, the speed is defined as the intermediate speed
- If a speed at maximum torque is less than 60% of the rated speed, then 60% of the rated speed is defined as intermediate speed
- If a speed at maximum torque is greater than 75% of the rated speed, then 75% of the rated speed is defined as intermediate speed

CURRENTLY IN FORCE CHINA IV EMISSION STANDARDS TEST CONDITIONS AND LIMIT VALUES

China Stage IV standards for NRMM (off-road) diesel applications were initially equivalent to EU Stage IIIB, (within the power range of 37 to 560kW).
Additional requirements for Stage IV have been published in amendments to GB 20891-2014 and HJ1014-2020, issued in December 2020. This amendment was applicable from the 28th December 2020 and superseded any local standards.
For engines with net power < 560kW these revised standards are mandatory for all engines from 1st December 2022, with the implementation date for engines > 560kW to be published at a later date.
All China Stage IV engines are tested with steady-state (NRSC) and transient (NRTC) test cycles. Details of the CO_2, fuel consumption and average NH_3 emissions must now be recorded.
In addition, for China Stage IV, portable emissions monitoring systems (PEMS) results are required for all diesel engines above 37kW. The monitored pollutants are CO and NOx. In general, the test has to be carried out during the actual operation of the machine; CO and NOx emissions at or above the 90th percentile of the valid work-based windows must be lower than 2.5 times the emissions limits reported in the table opposite.

China Stage IV emission limits

Pollutants	CO	HC	NOx	PM	NH_3	PN
DF[a]	1.3	1.3	1.15	1.05	1.0	1.0

Footnotes:
[a] OEM can choose constant DF or update value based on actual durability test (NRSC or NRTC) within 1 year after homologation.

China Stage IV emission limits

Net Power	CO	HC	NOx	HC + NOx	PM	NH_3 (ppm)	PN (#/kWh)
kW	(g/kWh)						
P_{max} > 560	3.5	0.40	3.5, 0.67[a]	-	0.10	25[b]	-
130 ≤ P_{max} ≤ 560	3.5	0.19	2.0	-	0.025		5×10^{12}
75 ≤ P_{max} < 130	5.0	0.19	3.3	-	0.025		
56 ≤ P_{max}< 75	5.0	0.19	3.3	-	0.025		
37 ≤ P_{max} < 56	5.0	-	-	4.7	0.025		
P_{max} < 37	5.5	-	-	7.5	0.60		-

Footnotes:
[a] For generator sets diesel engine with Pmax > 900kW
[b] For diesel engines using reactants

Emissions Warranty

Power (kW)	Speed (rpm)	Emissions Warranty[a]	
		Time (hrs)	Years
P_{max} ≥ 37	Any speed	3,000	5
19 ≤ P_{max} < 37	Non-constant speed		
	Constant speed < 3,000		
	Constant speed ≥ 3,000	1,500	2
P_{max} < 19	Any speed		

Footnotes: [a] Calculated from sales date

CHINA V LIMIT VALUES AND TEST CONDITIONS (FUTURE STANDARD)

Off-Road CI Engines (China Stage V)

Based on Euro stage V standards, there is as yet no proposed implementation date for China V NRMM emissions.

GB 20891-20xx regulates the limits and measurement methods for exhaust pollutants from diesel engines (China Stages V).

Areas under consideration are:

- Addition of greenhouse gases requirement: CO_2, CH_4 and N_2O
- Addition of crankcase emission requirement
- Addition of the RMC cycle to replace the current NRSC test cycle
- Enlarge the non-standard cycle to lower speed A and lower torque limit
- Increase PEMS altitude to 2,000 m. The machine power extend to whole power range, limitation decrease to 1.5 times of corresponding power range emission
- Involve non-road remote online monitoring and networking requirement

China V proposed emission limits

Net Power (kW)	CO	HC	NOx	HC + NOx	PM	NH_3 (ppm)	PN (#/kWh)
	(g/kWh)						
$P_{max} > 560$	3.5	0.19	3.5 0.67[a]	-	0.045 0.035[a]	25	-
$130 \le P_{max} < 560$	3.5	0.19	0.40	-	0.015		1×10^{12}
$75 \le P_{max} < 130$	5.0	0.19	0.40	-	0.015		
$37 \le P_{max} < 75$	5.0	-	-	4.7	0.015		
$19 \le P_{max} < 37$	5.0	-	-	4.7	0.015		
$P_{max} < 19$	5.5	-	-	7.5	0.40		-

Footnotes:

[a] For generator sets diesel engine with Pmax > 900 kW

CHINA III EMISSION STANDARDS TEST CONDITIONS AND LIMIT VALUES (2015 TO 2020)

China Stage III standards for NRMM (off-road) diesel applications are equivalent to EU Stage IIIA, except for the addition of limits for engines with less than 19kW and more than 560 kW.

GB 20891-2014 and HJ1014-2020 (China Stage III) was introduced in October 2014 for new type approval, from October 2015 for all production and from October 2016 for imported vehicles.

All Stage III engines are tested with steady-state (NRSC) test cycles, equivalent to ISO 8178. For Stage IIIA variable speed engines, the NRTC (page 179) test can be chosen by the OEM if required.

For variable speed diesel engine:

· ISO 8178 C1 8-mode test cycle (see page 176)

For constant speed diesel engine:

· ISO 8178 D2 5-mode cycle (see page 176)

For variable speed diesel engines with net power < 19kW:

· OEM can also choose ISO 8178 G2 6-mode cycle (see page 177)

China Stage III emission limits

Net Power (kW)	CO	HC	NOx	HC + NOx	PM	NH_3 (ppm)	PN (#/kWh)
	(g/kWh)						
$P_{max} > 560$	3.5	-	-	6.4	0.20	-	-
$130 \leq P_{max} \leq 560$	3.5	-	-	4.0	0.20		
$75 \leq P_{max} < 130$	5.0	-	-	4.0	0.30		
$37 \leq P_{max} < 75$	5.0	-	-	4.7	0.40		
$P_{max} < 37$	5.5	-	-	7.5	0.60		

Durability Requirements

Net Power (kW)	Speed (rpm)	Useful Life (hrs)	Allowed Minimum Test Time (hrs)
$P_{max} \geq 37$	Any speed	8,000	2,000
$19 \leq P_{max} < 37$	Non-constant speed	5,000	1,250
	Constant speed < 3,000		
	Constant speed ≥ 3,000	3,000	750
$P_{max} < 19$	Any speed		

EXHAUST EMISSION LIMIT VALUES FOR CONSTRUCTION MACHINERY ENGINES

Implementation Date	Reference Standard	Engine Power (kW)	CO	NOx	HC	PM	PN (#/kWh)	NH_3 (ppm)	Test Cycle
			(g/kWh)						
1st Jan 09[a] 1st Jul 13[b]	US Tier 3	19-37	5.5	7.5		0.3	-	-	ISO8178, C1-8 Mode
		37-75	5.0	4.7		0.4			
		75-130	5.0	4.0		0.3			
		130-560	3.5	4.0		0.2			
1st Jan 15[a,b]	US Tier 4f	< 8	8.0	7.5		0.4	-	-	NRSC, NRTC
		8-19	6.6	7.5		0.4			
		19-37	5.5	4.7		0.03			
		37-56	5.0	4.7		0.03			
		56-130	5.0	0.4	0.19	0.025			
		130-560	3.5	0.4	0.19	0.025			
1st Dec 20[a] 1st Jul 21[b]	EU Stage V	< 8	8.0	7.5		0.4	-	-	NRSC Mode
		8-19	6.6	7.5		0.4			
		19-37	5.0	4.7		0.015	1×10^{12}	10	
		37-56	5.0	4.7		0.015	1×10^{12}	10	
		56-130	5.0	0.4	0.19	0.015	1×10^{12}	10	NRSC & NRTC Modes
		130-560	3.5	0.4	0.19	0.015	1×10^{12}	10	

Footnotes:
[a] For construction machinery.
[b] For agricultural machinery.

CURRENTLY IN FORCE BHARAT STAGE II AND III LIMIT VALUES FOR DIESEL CONSTRUCTION EQUIPMENT (CEV) VEHICLE ENGINE (FROM 2008)

Emissions measured over NRSC (see page 177)

- ISO 8178 C1 for variable speed applications
- ISO 8178 D2 for constant speed applications

Bharat Stage Norms	Category	Effective Date	CO (g/kWh)	HC (g/kWh)	NOx (g/kWh)	HC + NOx (g/kWh)	PM (g/kWh)	80% of Full Load Smoke Opacity Value (per m)
BS-II	kW < 8	1st Oct 08	8.00	1.30	9.20	–	1.00	3.25
	8 ≤ kW < 19		6.60	1.30	9.20	–	0.85	
	19 ≤ kW < 37	1st Oct 07	6.50	1.30	9.20	–	0.85	
	37 ≤ kW < 75		6.50	1.30	9.20	–	0.85	
	75 ≤ kW < 130		5.00	1.30	9.20	–	0.70	
	130 ≤ kW < 560		5.00	1.30	9.20	–	0.54	
BS-III	kW < 8	1st Apr 11	8.00	–	–	7.50	0.80	3.25
	8 ≤ kW < 19		6.60	–	–	7.50	0.80	
	19 ≤ kW < 37		5.50	–	–	7.50	0.60	
	37 ≤ kW < 75		5.00	–	–	4.70	0.40	
	75 ≤ kW < 130		5.00	–	–	4.00	0.30	
	130 ≤ kW < 560		3.50	–	–	4.00	0.20	

Emissions Durability Period, Deterioration Factors (DF) and Ammonia limits remain unchanged from those for Bharat Stage (CEV / TREM) IV.

Deterioration factors (DF):

Determine by engine test or by application of fixed DFs.

CO	HC	NOx	PM
1.1	1.05	1.05	1.1

Emissions Durability Period

Category (Power)	Useful Life (hrs) (Emission Durability Period)
< 19 kW	3,000
19 < kW≤ 37 (constant speed)	3000
19 < kW ≤ 37 (variable speed)	5,000
> 37 kW	8,000

CURRENTLY IN FORCE BHARAT STAGE IV AND LIMIT VALUES FOR AGRICULTURAL (TREM) AND CONSTRUCTION (CEV)VEHICLES (FROM 2020)

Diesel Agricultural Tractor, Construction Equipment Vehicle and Combine Harvester

Notification GSR 201 (E) dated 5th March 18.

Bharat Stage (CEV / TREM) IV

Emissions measured over NRSC & NRTC (see page 176 & 179).

Category (kW)	Applicable With Effect From	CO (g/kWh)	HC (g/kWh)	NOx (g/kWh)	PM (g/kWh)
37 ≤ kW < 56	1st Oct 20	5.0	4.7 (HC + NOx)		0.025
56 ≤ kW < 130		5.0	0.19	0.4	
130 ≤ kW < 560		3.5	0.19	0.4	

Mean Ammonia emissions limits over the NRSC & NRTC for engines equipped with SCR are specified based on engine Power levels:

≤ 56 kW: 25 ppm

> 56 kW: 10 ppm

Emissions Durability Period

Category (Power)	Useful Life (hrs) (Emission Durability Period)
≤ 37 kW (constant speed)	3,000
≤ 37 kW (variable speed)	5,000
> 37 kW	8,000

Deterioration factors (DF):

Determine by engine test or by application of fixed DFs.

Test Cycle	CO	HC	NOx	PM
NRSC	1.3	1.3	1.15	1.05
NRTC	1.3	1.3	1.15	1.05

CURRENTLY IN FORCE TREM II, III AND IIIA LIMIT VALUES FOR DIESEL AGRICULTURAL TRACTORS (2020 TO 2024)

Diesel Agricultural Tractors Trem II, III and IIIA

Emissions measured over NRSC [ISO 8178 C1] test cycle (see page 176)

Bharat Stage Norms	Category	Effective Date	CO (g/kWh)	HC + NOx (g/kWh)	PM (g/kWh)	80% of Full Load Smoke Opacity Value (per m)
Trem II	-	1st Jun 03	9.00	15.00	1.00	
Trem III	-	1st Oct 2005	5.50	9.50	0.80	
Trem III A	kW < 8	1st Apr 2010	5.50	8.50	0.80	
	8 ≤ kW < 19		5.50	8.50	0.80	
	19 ≤ kW < 37		5.50	7.50	0.60	3.25
	37 ≤ kW < 56		5.00	4.70	0.40	
	56 ≤ kW < 75		5.00	4.70	0.40	
	75 ≤ kW < 130		5.00	4.00	0.30	
	130 ≤ kW < 560		3.50	4.00	0.20	

Emissions Durability Period and Deterioration factors are as those for Bharat (CEV) Stage III.

PLANNED BHARAT STAGE V TEST CONDITIONS AND LIMIT VALUES FOR NON-ROAD ENGINES

INDIA

Bharat Stage (CEV - Construction / TREM - Agricultural) V

Emissions measured over:

- NRSC & NRTC for engines ≥ 19 kW to < 560 kW (see page 176 & 179)
- NRSC only for engines < 19 kW and those ≥ 560 kW (see page 176)

Category (kW)	Applicable With Effect From	CO (g/kWh)	HC (g/kWh)	NOx (g/kWh)	PM (g/kWh)	PN (#/kWh)
P < 8	Delayed until 1st Jan 2025 for CEV (Construction) and 1st April 2026 for TREM (Agricultural)	8.0	7.5 (HC + NOx)		0.4	–
8 ≤ P < 19		6.6	7.5 (HC + NOx)		0.4	–
19 ≤ P < 37		5.0	4.7 (HC + NOx)		0.015	1×10^{12}
37 ≤ P < 56		5.0	4.7 (HC + NOx)		0.015	1×10^{12}
56 ≤ P < 130		5.0	0.19	0.4	0.015	1×10^{12}
130 ≤ P < 560		3.5	0.19	0.4	0.015	1×10^{12}
P ≥ 560		3.5	0.19	3.5	0.045	–

Emissions Durability Period, Deterioration Factors (DF) and Ammonia limits remain unchanged from those for Bharat Stage (CEV / TREM) IV.

OTHER AREAS OF THE WORLD

<table>
<tr><td rowspan="8">Brazil</td><td colspan="3">PROCONVE MAR-I Limitation on CO, HC, NOx & PM.</td><td></td><td>Introduction date</td></tr>
<tr><td colspan="3" rowspan="2">Construction machinery:</td><td>≥37 kW</td><td>1st January 2015</td></tr>
<tr><td>All</td><td>1st January 2017</td></tr>
<tr><td colspan="3" rowspan="2">Farm machinery:</td><td>≥75 kW</td><td>1st January 2017</td></tr>
<tr><td>All</td><td>1st January 2019</td></tr>
<tr><td></td><td>Power (kW)</td><td>CO (g/kWh)</td><td>HC+NOx (g/kWh)</td><td>PM (g/kWh)</td></tr>
<tr><td></td><td>130 ≤ P < 560</td><td>3.5</td><td>4.0</td><td>0.2</td></tr>
<tr><td></td><td>75 ≤ P < 130</td><td>5.0</td><td>4.0</td><td>0.3</td></tr>
<tr><td></td><td>37 ≤ P < 75</td><td>5.0</td><td>4.7</td><td>0.4</td></tr>
<tr><td></td><td>19 ≤ P < 37</td><td>5.5</td><td>7.5</td><td>0.6</td></tr>
<tr><td>Canada</td><td colspan="5">Canadian emissions regulations for CI engines are aligned with the US EPA Tier 4 standards applicable from 2015MY.
For large SI engines, US Tier 2 standards apply from June 2021.
For small SI engines, US EPA Phase 3 standards are in place from 2019MY.</td></tr>
<tr><td rowspan="5">Russia & Eurasian Economic Union (EAEU)</td><td colspan="5">European emissions standards adopted for mobile non-road engines.
Standard targeted from 2014 & 2015 introduction have not been officially confirmed / published.</td></tr>
<tr><td>Date</td><td colspan="2">Standard</td><td colspan="2">EU Equivalent</td></tr>
<tr><td>2000</td><td colspan="2">GOST R41 96-99</td><td colspan="2">Stage I (Dir 77/537/EC and
Dir 97/68/EC, ECE R24 test)</td></tr>
<tr><td>Jan 2014[a]</td><td colspan="2">GOST R41 96-2011</td><td colspan="2">Stage III</td></tr>
<tr><td>Feb 2017[a]</td><td colspan="2">TR-TS 031-2012[b]</td><td colspan="2">Stage IIIA for engines < 37kW;
Stage IIIB > 37 kW</td></tr>
</table>

Footnotes:

[a] Dates not officially confirmed [b] Standard not officially published [c] EAEU standard for Agricultural and Forestry tractors

OTHER AREAS OF THE WORLD

Singapore	Imports of new and rebuilt non-road diesel engines must meet US Stage II, Tier II or Japan Tier I off-road engine emission standards since 1st July 2012.		
Switzerland	New engines for off-road vehicles and machinery must meet current EU standards. Particulate Filters are mandatory for diesel equipment use for underground (SUVA) construction.		
Turkey	Diesel non-road engines Faz I, II, IIIA, IIIB and IV.		
	Standard harmonised with EU regulations but with different implementation dates.		
	Stage	Power (kW)	Date[d]
	Stage I (Faz I)	37 ≤ P ≤ 560	April 2003
	Stage II (Faz II)	18 ≤ P ≤ 560	Jan 2007
	Stage IIIA (Faz IIIA)	19 ≤ P ≤ 560	Jan 2011
	Stage IIIB (Faz IIIB)	37 ≤ P ≤ 56	July 2021
	Stage IV (Faz IV)	56 ≤ P < 130	Oct 2021
		130 ≤ P ≤ 560	Jan 2021
	Stage V (Faz V)	EU NRMM categories	Oct 2021[a]

Footnotes:

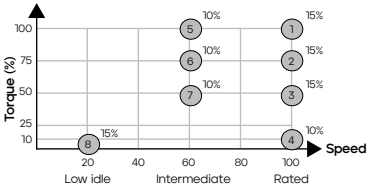
[a] January 2023 for agricultural and forestry equipment

TEST CYCLES (GLOBAL)

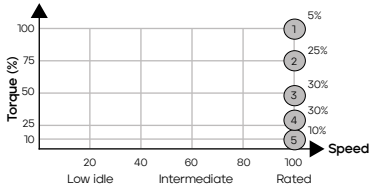
NRSC Test (Non-Road Steady-State Cycle) ISO 8178 categories C (off-road vehicles) and D (constant speed)

With a warm engine, raw exhaust emissions are measured during a prescribed sequence of operating conditions. The test cycle consists of a number of speed and load modes. Intermediate speed is the maximum torque speed if it occurs between 60% and 75% of rated (max power) speed or 60% of rated speed
if this is higher or 75% if this is lower.

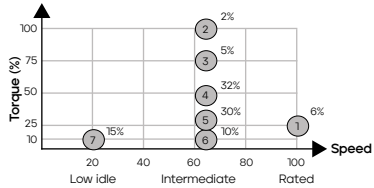
CI engines ISO 8178-C1 intermittent



CI engines ISO 8178-D2 constant speed



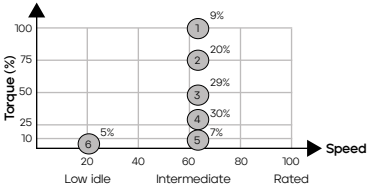
ISO 8178-C2 SI engines > 20 kw



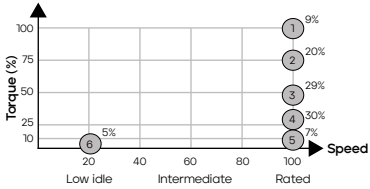
TEST CYCLES (GLOBAL)

NRSC Test (ISO 8178) for Utility, Lawn & Garden applications)

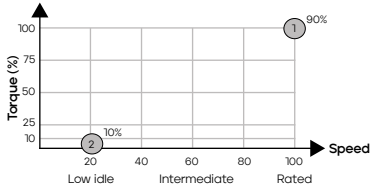
ISO 8178-G1
Non-handheld intermediate speed applications



ISO 8178-G2
Non-handheld rated speed applications



ISO 8178-G3
Handheld rated speed applications



Intermediate speed is the maximum torque speed if it occurs between 60% and 75% of rated (max power) speed
· or 60% of the rated speed if this is higher
· or 75% of the rated speed if this is lower

TEST CYCLES (GLOBAL)

Steady-State Ramped Model Testing

9-Mode Test Cycle

RMC Mode	Time in Mode (sec)	Engine Speed [a,c]	Torque [b,c] (%)
1a Steady-state	126	Warm idle	0
1b Transition	20	Linear transition	Linear transition
2a Steady-state	159	Intermediate	100
2b Transition	20	Intermediate	Linear transition
3a Steady-state	160	Intermediate	50
3b Transition	20	Intermediate	Linear transition
4a Steady-state	162	Intermediate	75
4b Transition	20	Linear transition	Linear transition
5a Steady-state	246	Rated	100
5b Transition	20	Rated	Linear transition
6a Steady-state	164	Rated	10
6b Transition	20	Rated	Linear transition
7a Steady-state	248	Rated	75
7b Transition	20	Rated	Linear transition
8a Steady-state	247	Rated	50
8b Transition	20	Linear transition	Linear transition
9 Steady-state	128	Warm idle	0

5-Mode Test Cycle

RMC Mode	Time in Mode (sec)	Engine Speed [a][c]	Torque [b,c] (%)
1a Steady-state	53	Engine governed	100
1b Transition	20	Engine governed	Linear transition
2a Steady-state	101	Engine governed	10
2b Transition	20	Engine governed	Linear transition
3a Steady-state	277	Engine governed	75
3b Transition	20	Engine governed	Linear transition
4a Steady-state	339	Engine governed	25
4b Transition	20	Engine governed	Linear transition
5a Steady-state	350	Engine governed	50

For variable-speed engines, the following 9-Mode Duty Cycle applies:

[a] Speed terms as per footnote of the steady-state discrete mode test

[b] The percent torque is relative to the maximum torque at the commanded engine speed

[c] Advance from one mode to the next within a 20 second transition phase. During the transition phase, command a linear progression from the torque setting of the current mode to the torque setting of the next mode, and simultaneously command a linear progression for engine speed if there is a change in speed setting

For constant-speed engines, the following 5-Mode Duty Cycle applies:

[a] The percent torque is relative to maximum test torque

[b] Advance from one mode to the next within a 20 second transition phase. During the transition phase, command a linear progression from the torque setting of the current mode to the torque setting of the next mode

TEST CYCLES (GLOBAL)

NRTC Test (Non-Road Transient Cycle)
Emissions Test Run

Engine preparation, pre-test measurements and calibration

▼

NRTC

▼

Generate engine map (maximum torque curve)
Generate reference test cycle

▼

Run one or more practice cycles as necessary to check engine/test cell/emission systems

▼

Natural or forced cool-down

▼

Ready all systems for sampling (analyzer calibration included) and data collection

▼

Cold start cycle exhaust emissions phase

▼

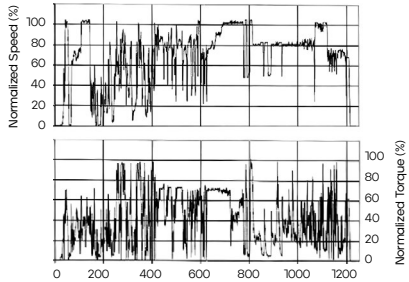
Hot soak

▼

Hot start cycle exhaust emissions phase

The NRTC is run twice (cold start/hot start) with the weighted PM being an

- average of the hot (90%) and cold (10%) cycles from EU Stage III
- average of the hot (95%) and cold (5%) cycles for US Tier 4



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FUELS

EU REFERENCE TEST FUELS

Diesel for Heavy-Duty Road Vehicles

This section contains only selected reference test fuel definitions for EU, US, Japan and India markets.

Diesel fuel for compression-ignition (CI) engines

If the manufacturer permits the engine to run on market fuels not included in the EN 590 CEN standard, such as running on B100, the manufacturer shall:

- demonstrate the capability of the parent engine to meet the requirements of this regulation on the fuels declared and
- be liable to meet the requirements of in-service conformity on the fuels declared including any blend between the declared fuels and the market fuels included in the relevant CEN standards.

Parameter	Unit	Euro I/II/III		Euro IV/V		Euro VI		Test Method[b]
		88/77/EEC Annex IV[a]		2005/55 EC Annex IV		EU 582/2011 Annex IX		
		Min	Max	Min	Max	Min	Max	
Cetane number	–	52	54	52	54	52	56	EN ISO 5165
Density at 15°C	kg/m³	833	837	833	837	833	837	EN ISO 3675
Distillation 50%	° C	245	–	245	–	245	–	EN ISO 3405
Distillation 95%	° C	345	350	345	350	345	350	EN ISO 3405
Distillation Final Boiling Point FBP	° C	–	370	–	370	–	360	EN ISO 3405
Viscosity at 40°C	mm²/s	2.5	3.5	2.5	3.5	2.3	3.3	EN ISO 3104
Sulphur content	mg/kg	–	300	–	300	–	10	EN ISO 20846
Flash point	° C	55	–	55	–	55	–	EN 22719
Cold Filter Plug-in Point CFPP	° C	–	-5	–	-5	–	-5	EN 116
Polycyclic aromatic hydrocarbons	% m/m	3.0	6.0	3.0	6.0	2.0	4.0	EN 12916
Copper Corrosion Rating	–	–	Class 1	–	Class 1	–	Class 1	EN ISO 2160
Conradson carbon residue (10% DR)	% m/m	–	0.20	–	0.20	–	0.20	EN ISO 10370
Ash content	% m/m	–	0.01	–	0.01	–	0.01	EN ISO 6245
Water content	% m/m	–	0.05	–	0.05	–	0.02	EN ISO 12937
Neutralization (strong acid) nr	mg KOH/g	–	0.02	–	0.02	–	0.10	ASTM D974
Oxidation stability (for middle distillate fuels)	mg/ml	–	0.025		0.025	–	0.025	EN ISO 12205
Oxidation stability (for FAME content > 2%)	Hours	–	–	–	–	20	–	EN 15751
Lubricity (HFRR wear scar at 60°C)	µm	–	–	–	–	–	400	EN ISO 12156
FAME content	% vol	–	–	–	–	6	7	EN 14078

Footnotes:

[a] Including amendments to 2004

[b] Test methods are as specified in EU 582/2011

EU REFERENCE TEST FUELS

Natural Gas for Heavy-Duty Road Vehicles

Natural Gas / Biomethane

The parent engine shall meet the requirements of this regulation on the reference fuels. At the manufacturer's request the engine may be tested on a third fuel when fuel 3 is a market fuel. The results of this test may be used as a basis for the evaluation of the conformity of the production.

Parameter	Unit	Euro IV, V and VI – 2005/55 EC Annex IV, EU 582/2011 Annex IX			
		Basis	Minimum	Maximum	Test method
Reference fuel G_R					
Methane	%mole	87	84	89	ISO 6974
Ethane	%mole	13	11	15	ISO 6974
Balance	%mole	-	-	1	ISO 6974
Sulphur content	mg/m³	-	-	10	ISO 6326-5
Reference fuel G_{23}					
Methane	%mole	92.5	91.5	93.5	ISO 6974
Balance	%mole	-	-	1	ISO 6974
N_2	%mole	7.5	6.5	8.5	ISO 6974
Sulphur content	mg/m³	-	-	10	ISO 6326-5
Reference fuel G_{25}					
Methane	%mole	86	84	88	ISO 6974
Balance	%mole	-	-	1	ISO 6974
N_2	%mole	14	12	16	ISO 6974
Sulphur content	mg/m³	-	-	10	ISO 6326-5

EU REFERENCE TEST FUELS

Ethanol for Heavy-Duty Road Vehicles and Non-Road Mobile Machinery

Ethanol for diesel engines / dedicated compression-ignition engines (ED95)[a]

Parameter	Unit	Euro IV/V 2005/55/EC Annex IV		Euro VI (HD) and Stage V (NRMM) EU 582/2011 Annex IX, EU/2017/654 Annex IX		
		Minimum	Maximum	Minimum	Maximum	Test method
Total alcohol	% m/m	92.4	–	92.4	–	EN 15721
Other higher saturated mono-alcohols (C_3 - C_5)	% m/m	–	2	–	2	EN 15721
Methanol	% m/m	–	-	–	0.3	EN 15721
Density at 15°C	kg/m³	795	815	793	815	EN-ISO 12185
Ash content	% m/m	–	0.001	-	-	ISO 6245
Acidity (calculated as acetic acid)	% m/m	–	0.0025	–	0.0025	EN 15491
Flash point	°C	10	–	10	–	EN 3679
Dry residue	mg/kg	–	15	–	15	EN 15691
Water content	% m/m	–	6.5	–	6.5	EN 15489
Aldehydes calc. as acetaldehyde	% m/m	–	0.0025	–	0.005	ISO 1388-4
Neutralization (strong acid) number	KOH mg/l	–	1	–	-	
Esters calc. as Ethylacetate	% m/m	–	0.1	–	0.1	ASTM D1617
Sulphur content	mg/kg	–	10	–	10	EN 15485 / EN 15486
Sulphates	mg/kg	–	-	–	4.0	EN 15492
Particle contamination	mg/kg	–	-	–	24	EN 12662
Phosphorus	mg/l	–	-	–	0.2	EN 15487
Inorganic chloride	mg/kg	–	-	–	1.0	EN 15484 or EN 15492
Copper	mg/kg	–	-	–	0.1	EN 15488
Electrical Conductivity	µS/cm	–	-	–	2.5	DIN 51627-4 or prEN 15938
Appearance	–	–		Bright and clear		–
Colour	To scale	–	10	-	-	ASTM D1209

Footnotes: [a] Additives, such as cetane improver as specified by the engine manufacturer, may be added to the ethanol fuel, as long as no negative side effects are known. If these conditions are satisfied, the maximum allowed amount is 10 % m/m.

EU REFERENCE TEST FUELS

Diesel for Non-Road Mobile Machinery

Parameter	Unit	Stage I/II 97/68/EC Annex IV		Stage IIIA 2004/26/EC Appx. 5 (3)		Stage IIIB/IV 2004/26/EC Appx. 5 (3)		Stage V EU 2017/654 Annex IX		Test Method
		Min	Max	Min	Max	Min	Max	Min	Max	
Cetane Number	-	45	50	52	54	-	54	45	56	EN ISO 5165
Density at 15°C	kg/m³	835	845	833	837	833	837	833	865	EN ISO 3675
Distillation T50	°C	-	-	245	-	245	-	245	-	EN ISO 3405
Distillation T95	°C	-	370	345	350	345	350	345	350	EN ISO 3405
Distillation Final Boiling Point FBP	°C	-	-	-	370	-	370	-	370	EN ISO 3405
Viscosity at 40°C	mm²/s	2.5	3.5	2.5	3.5	2.3	3.3	2.3	3.3	EN ISO 3104
Sulphur content	mg/kg	1,000	2,000	-	300	-	10	-	10	ASTM D5453
Flash point	°C	55	-	55	-	55	-	55	-	EN 22719
Cold Filter Plug-in Point CFPP	°C	-	+5	-	-5	-	-5	-	-5	EN 116
Polycyclic aromatic hydrocarbons	% m/m	-	-	3.0	6.0	3.0	6.0	2.0	6.0	IP 391
Copper Corrosion Rating	-	-	Class 1	-	Class 1	-	Class 1	-	Class 1	EN ISO 2160
Conradson carbon residue (10% DR)	% m/m	-	0.3	-	0.2	-	0.2	-	0.2	EN ISO 10370
Ash content	% m/m	-	0.01	-	0.01	-	0.01	-	0.01	EN ISO 6245
Total Contamination	mg/kg	-	-	-	-	-	-	-	24	EN 12662
Water content	% m/m	-	0.05	-	0.05	-	0.02	-	0.02	EN ISO 12937
Neutralization (strong acid) nr	mg KOH/g	-	0.2	-	0.02	-	0.02	-	0.01	ASTM D974
Oxidation stability (for middle distillate fuels)[a]	Mass	-	2.5 mg/100ml	-	0.025 mg/ml	-	0.025 mg/ml	-	0.025 mg/ml	EN ISO 12205
Oxidation stability (for FAME content > 2%)	Hours	-	-	-	-	-	-	20	-	EN 15751
Lubricity (HFRR wear scar at 60°C)	µm	-	-	-	-	-	400	-	400	CEC F-06-A-96
FAME content	% vol	-	-	-	-	Prohibited		-	7.0	EN 14078

Footnotes: [a] Even though oxidation stability is controlled, it is likely that shelf life will be limited. Advice should be sought from the supplier as to storage conditions and life

EU REFERENCE TEST FUELS

Petrol (E10) for Non-Road Mobile Machinery

Parameter	Unit	Stage V - EU 2017/654 Annex IX		Test Method
		Minimum	Maximum	
Research Octane Number RON		91	98	EN ISO 5164:2005
Motor Octane Number MON		83	89	EN ISO 5163:2005
Density at 15°C	kg/m³	743	756	EN ISO 3675 / EN ISO 12185
Vapour pressure	kPa	45	60	EN ISO 13016-1 (DVPE)
Water content	%v/v	-	0.05	EN 12937
Distillation Evaporated at 70°C	%v/v	18	46	EN-ISO 3405
Distillation Evaporated at 100°C	%v/v	46	62	EN-ISO 3405
Distillation Evaporated at 150°C	%v/v	75	94	EN-ISO 3405
Final boiling point	°C	170	210	EN-ISO 3405
Residue	%v/v	-	2.0	EN-ISO 3405
HC analysis - olefins	%v/v	3	18	EN 14517 / EN 15553
HC analysis - aromatics	%v/v	19.5	35	EN 14517 / EN 15553
HC analysis - benzene	%v/v	-	1	EN 12177 / EN 238 / EN 14517
Induction period	minutes	480	-	EN-ISO 7536
Oxygen content	%m/m	3.3	3.7	EN 1601 / EN 13132 / EN 14517
Existent gum	mg/ml	-	0.04	EN-ISO 6246
Sulphur content	mg/kg	-	10	EN ISO 20846 / EN ISO 20884
Copper corrosion	rating	-	Class 1	EN-ISO 2160
Lead content	mg/l	-	5.0	EN 237
Phosphorus content	mg/l	-	1.3	ASTM D 3231
Ethanol	%v/v	9.0	10.2	EN 22854

EU REFERENCE TEST FUELS

Natural Gas (NG) for Non-Road Mobile Machinery

Natural Gas / Biomethane

EU 2017/654 Annex IX section 3.2.2 permits an alternative reference NG fuel supplied from a pipeline with an admixture of other gases with gas properties determined by on-site measurement. The basis of each pipeline reference fuel (GR, G20) shall be gas drawn from a utility gas distribution network, blended, where necessary to meet the corresponding lambda-shift (Sλ) specification in Table 9.1, with an admixture of one or more of the following commercially available gases: (a) Carbon dioxide; (b) Ethane; (c) Methane; (d) Nitrogen; (e) Propane.

Parameter	Unit	Stage V - EU 2017/654 Annex IX			
		Basis	Minimum	Maximum	Test Method
Reference fuel G_R					
Methane	%mole	87	84	89	
Ethane	%mole	13	11	15	
Balance	%mole	–	–	1	ISO 6974
Sulphur content[a]	mg/m³	–	–	10	ISO 6326-5
Reference fuel G_{23}					
Methane	%mole	92.5	91.5	93.5	
Balance	%mole	–	–	1	ISO 6974
N_2	%mole	7.5	6.5	8.5	
Sulphur content[a]	mg/m³	–	–	10	ISO 6326-5
Reference fuel G_{25}					
Methane	%mole	86	84	88	
Balance	%mole	–	–	1	ISO 6974
N_2	%mole	14	12	16	
Sulphur content[a]	mg/m³	–	–	10	ISO 6326-5
Reference fuel G_{20}					
Methane	%mole	100	99	100	ISO 6974
Balance	%mole	–	–	1	ISO 6974
N_2	%mole	–	–	–	ISO 6975
Sulphur content[a]	mg/m³	–	–	10	ISO 6326-5
Wobbe Index (net)[b]	mg/m³	48.2	47.2	49.2	

Footnotes:

[a] Value to be determined at standard conditions 293.2 K (20°C) and 101.3 kPa.

[b] Value to be determined at 273.2 K (0°C). and 101.3 kPa

US REFERENCE TEST FUELS

Diesel for Heavy-Duty Road Vehicles and Non-Road Mobile Machinery

EPA CFR 40 Part 1065.703 - Test Fuel Specifications for Distillate Diesel Fuel from model year 2010

Fuels with sulfur levels no greater than 0.2 wt% (2.000 ppm) were used for certification testing of Tier 1-3 engines. From 2011 all Tier 4 engines are tested using fuels of 7-15ppm sulfur content. The transition from 2,000 ppm specification to the 7-15 ppm specification took place 2006-2010 (see Certification Diesel Fuel).

Parameter	Unit	Ultra Low Sulfur		Low Sulfur		High Sulfur		Test Method
		Min	Max	Min	Max	Min	Max	
Cetane Number	-	40	50	40	50	40	50	ASTM D613
Distillation range: Initial boiling point	°C	171	204	171	204	171	204	ASTM D86
Distillation range: 10%	°C	204	238	204	238	204	238	ASTM D86
Distillation range: 50%	°C	243	282	243	282	243	282	ASTM D86
Distillation range: 90%	°C	293	332	293	332	293	332	ASTM D86
Distillation range: Endpoint	°C	321	366	321	366	321	366	ASTM D86
Gravity	°API	32	37	32	37	32	37	ASTM D4052
Total sulfur, ultra-low sulfur	mg/kg	7	15	-	-	-	-	See 40 CFR 80.580
Total sulfur, low and high sulfur	mg/kg	-	-	300	500	800	2500	ASTM D2622 or alternates as allowed under 40 CFR 80.580
Aromatics, min. (remainder shall be paraffins, naphthenes, and olefins)	g/kg	100	-	100	-	100	-	ASTM D5186
Flashpoint, min.	°C	54	-	54	-	54	-	ASTM D93
Kinematic Viscosity	cSt	2.0	3.2	2.0	3.2	2.0	3.2	ASTM D445

US REFERENCE TEST FUELS

Gasoline (E10) for Heavy-Duty Road Vehicles and Non-Road Mobile Machinery

EPA CFR 40 Part 1065.710 Test Fuel Specifications for a Low-Level Ethanol-Gasoline Blend (E10)

Property	Unit	Specification			Reference Procedure
		General Testing	Low-Temp Testing	High-Altitude Testing	
Antiknock Index (R + M)/2			87.0 - 88.4	87.0 Minimum	ASTM D2699 and D2700
Sensitivity (R-M)		7.5 Minimum	7.5 Minimum	7.5 Minimum	ASTM D2699 and D2700
Dry Vapor Pressure Equivalent (DVPE)	kPa	60.0 - 63.4	77.2 - 81.4	52.4 - 55.2	ASTM D5191
Distillation: 10% evaporated	°C	49 - 60	43 - 54	49 - 60	ASTM D86
Distillation: 50% evaporated	°C		88 - 99		
Distillation: 90% evaporated	°C		157 - 168		
Distillation: Evaporated final boiling point	°C		193 - 216		
Residue	ml	2.0 Maximum	2.0 Maximum	2.0 Maximum	
Total Aromatic Hydrocarbons	volume %		21.0 - 25.0		ASTM D5769
C6 Aromatics (benzene)	volume %	0.5 - 0.7	0.5 - 0.7	0.5 - 0.7	
C7 Aromatics (toluene)	volume %	5.2 - 6.4	5.2 - 6.4	5.2 - 6.4	
C8 Aromatics	volume %	5.2 - 6.4	5.2 - 6.4	5.2 - 6.4	
C9 Aromatics	volume %	5.2 - 6.4	5.2 - 6.4	5.2 - 6.4	
C10 + Aromatics	volume %	4.4 - 5.6	4.4 - 5.6	4.4 - 5.6	
Olefins	mass %	4.0 - 10.0	4.0 - 10.0	4.0 - 10.0	ASTM D6550
Ethanol blended	volume %	9.6 - 10.0	9.6 - 10.0	9.6 - 10.0	
Ethanol confirmatory	volume %	9.4 - 10.2	9.4 - 10.2	9.4 - 10.2	ASTM D4815 or D5599
Total Content of Oxygenates Other than Ethanol	volume %	0.1 Maximum	0.1 Maximum	0.1 Maximum	ASTM D4815 or D5599
Sulfur	mg/kg	8.0 - 11.0	8.0 - 11.0	8.0 - 11.0	ASTM D2622, D5453 or D7039
Lead	g/l	0.0026 Maximum	0.0026 Maximum	0.0026 Maximum	ASTM D3237
Phosphorus	g/l	0.0013 Maximum	0.0013 Maximum	0.0013 Maximum	ASTM D3231
Copper Corrosion		No. 1 Maximum	No. 1 Maximum	No. 1 Maximum	ASTM D130
Solvent-Washed Gum Content	mg/100 ml	3.0 Maximum	3.0 Maximum	3.0 Maximum	ASTM D381
Oxidation Stability	minute		1000 Minimum		ASTM D525

US REFERENCE TEST FUELS

Gasoline (E0) and Natural Gas for Heavy-Duty Road Vehicles and Non-Road Mobile Machinery

EPA CFR 40 Part 1065.710 — Test Fuel Specifications for Neat (E0) Gasoline

Property	Unit	Specification		Reference Procedure
		General Testing	Low-Temp Testing	
Distillation Range: Evaporated IBP	°C	24 - 35	24 - 36	ASTM D86
Distillation Range: 10% evaporated	°C	49 - 57	37 - 48	
Distillation Range: 50% evaporated	°C	93 - 110	82 - 101	
Distillation Range: 90% evaporated	°C	149 - 163	158 - 174	
Distillation Range: Evaporated FBP	°C	Maximum 213	Maximum 212	
Hydrocarbon composition: Olefins	volume %	Maximum 10	Maximum 17.5	ASTM D1319
Hydrocarbon composition: Aromatics	volume %	Maximum 35	Maximum 30.4	
Hydrocarbon composition: Saturates	volume %	Remainder	Remainder	
Lead	g/l	Maximum 0.013	Maximum 0.013	ASTM D3237
Phosphorus	g/l	Maximum 0.0013	Maximum 0.005	ASTM D3231
Total sulfur	mg/kg	Maximum 80	Maximum 80	ASTM D2622
Dry vapor pressure equivalent	kPa	60.0 - 63.4	77.2 - 81.4	ASTM D5191

EPA CFR 40 Part 1065.715 — Test Fuel Specifications for Natural Gas

Property	Unit	Specification	
		Minimum	Maximum
Methane, CH_4	mol/mol	0.87	–
Ethane, C_2H_6	mol/mol	–	0.055
Propane, C_3H_8	mol/mol	–	0.012
Butane, C_4H_{10}	mol/mol	–	0.0035
Pentane, C_5H_{12}	mol/mol	–	0.0013
C_6 and higher	mol/mol	–	0.001
Oxygen	mol/mol	–	0.001
Inert gases (sum of CO_2 and N_2)	mol/mol	–	0.051

JAPAN REFERENCE TEST FUELS

Automotive fuel quality regulations

Type of Fuel	Fuel Property	Limit	JIS
Gasoline	Lead	Not detected	K 2255
	Sulphur	Maximum 0,001 (mass %)	
	Benzene	Maximum 1 (vol %)	
	MTBE	Maximum 7 (vol %)	
	Oxygen[a]	Maximum 1,3 (mass %)	K 2536

Type of Fuel	Fuel Property	Limit	JIS
Diesel	Sulphur	Maximum 0,001 (mass %)	
	Cetane Index	Minimum 45	K 2280
	Distillation at 90%	Maximum 360 (deg C)	K 2254

Footnotes: [a] Min 1.3 % and Maximum 3.7 % for E10 and ETBE22 Fuel

CHINA REFERENCE DIESEL FUELS

Below diesel fuel specification used for China On-Road HD CN6 and Non-Road Stage IV type approval test

Items	Unit	Requirements	Specifications	Test Method
Oxidative stability (calculated as total insoluble matter)	mg/100mL	≤	2.5	SH/T 0175
Sulphur content	mg/kg	≤	10	SH/T 0689
Acidity (calculated as KOH)	mg/100mL	≤	7	GB/T 258
10% Residual carbon from steam residue (mass fraction)	%	≤	0.3	GB/T 17144
Ash content	%	≤	0.01	GB/T 508
Copper corrosion (50°C, 3h)	level	≤	1	GB/T 5096
Water content (volume fraction)	%	≤	0.02	GB/T 260
Lubricity: corrected wear scar diameter at 60°C	μm	≤	460	SH/T 0765
Polycyclic aromatic hydrocarbon content (mass fraction)	%	≤	4	SH/T 0806
Total pollutant content	mg/kg	≤	24	GB/T 33400
Kinematic viscosity (20°C)	mm^2/s		2.0~7.5	GB/T 265
Cold filter plugging point	°C	Lower than	-10	SH/T 0248
Flash point (closed)	°C	Higher than	55	GB/T 261
Cetane number		≥	52~54	GB/T 386
Distillation range: 50% recovery temperature 90% recovery temperature 95% recovery temperature	°C	Within range	 245~300 315~335 325~350	GB/T 6536
Density (20°C)	kg/m^3		824~834	GB/T 1884 GB/T 1885
Fatty acid methyl ester content (volume fraction)	%	≤	0.5	NB/SH/T 0916

INDIA REFERENCE TEST FUELS

Diesel fuel For Heavy-Duty and Non-Road Mobile Machinery

Source: ARAI

Property	Units	Heavy-Duty BS III		Heavy-Duty BS IV		EU 582/2011 Annex IX Heavy-Duty BS VI and NRMM BS IV and V		
		Min	Max	Min	Max	Min	Max	Test Method
Cetane Index	-	-	-	-	-	46	-	EN ISO 4264
Cetane Number	-	52	54	52	54	52	56	EN ISO 5165
Density at 15°C	kg/m³	833	837	833	837	833	837	EN ISO 12185
Distillation Range, 50%	°C	245	-	245	-	245	-	EN ISO 3405
Distillation Range, 95%	°C	345	350	345	350	345	360	EN ISO 3405
Distillation Range, Final Boiling Point (FBP)	°C	-	370	-	370	-	370	EN ISO 3405
Viscosity (at 40°C)	mm²/s	2.5	3.5	2.5	3.3	2.3	3.3	EN ISO 3104
Sulphur Content	mg/kg	-	300	-	10	-	10	EN ISO 20846 / 20884
Flash Point	°C	55	-	55	-	55	-	EN ISO 2719
CFPP	°C	-	-5	-	-5	-	-	EN 116
Cloud Point	°C	-	-	-	-	-	-10	EN 23015
Polycyclic Aromatic Hydrocarbons	%m/m	3	6	3	6	2	4	EN 12916
Copper Corrosion Rating (3hrs at 50°C)	-	-	Class 1	-	Class 1	-	Class 1	EN ISO 2160
Conradson Carbon Residue (10%DR)	%m/m	-	0.2	-	0.2	-	0.2	EN ISO 10370
Ash Content	%m/m	-	0.01	-	0.01	-	0.01	EN ISO 6245
Water Content	mg/kg	-	500	-	200	-	200	EN ISO 12937
Acid Number	mgKOH/g	-	-	-	-	-	0.1	EN ISO 6618
Neutralization Number	mgKOH/g	-	0.02	-	0.02	-	-	ASTM D974
Oxidation Stability at 110°C	hours	-	-	-	-	20	-	EN 15751
Oxidation Stability	mg/ml	-	0.025	-	0.025	-	-	EN ISO 12205
Lubricity (HFRR Wear Scar at 60°C)	µm	-	-	-	400	-	400	EN ISO 12156
FAME Content	%v/v	-	-	Prohibited		6	7	EN 14078
Total Contamination	mg/kg	-	-	-	-	-	24	EN 12662

INDIA REFERENCE TEST FUELS

Petrol (E5) – BS VI ED95 is same as EU

Source: ARAI

Parameter	Unit	BS III		BS IV		BS VI		Test Method
		Min	Max	Min	Max	Min	Max	
Research Octane Number (RON)	-	95	-	95	-	95	-	EN ISO 5164:2005
Motor Octane Number (MON)		85	-	85		85	-	EN ISO 5163:2005
Density at 15°C	kg/m³	748	762	740	754	743	756	EN ISO 3675 / EN ISO 12185
Vapour Pressure	kPa	56	60	56	60	56	60	EN ISO 13016-1 (DVPE)
Water Content	% v/v					-	0.015	ASTM 1064
Distillation: Evaporated at 70°C	% v/v	24	40	24	40	24	44	EN ISO 3405
Distillation: Evaporated at 100°C	% v/v	49	57	50	58	48	60	EN ISO 3405
Distillation: Evaporated at 150°C	% v/v	81	87	83	89	82	90	EN ISO 3405
Final Boiling Point	% v/v	190	215	190	210	190	210	EN ISO 3405
Residue	% v/v	-	2.0	-	2.0	-	2.0	EN ISO 3405
HC Analysis: Olefins	% v/v	-	10	-	10	3	13	ASTM D 1319
HC Analysis: Aromatics	% v/v	28	40	29	35	29	35	ASTM D 1319
HC Analysis: Benzene	% v/v	-	1	-	1	-	1	EN 12177
Saturates	%v/v	Balance		Report		Report		ASTM 1319
Carbon/Hydrogen Ratio	-	Report		Report		Report		
Carbon/Oxygen Ratio	-	-	-			Report		
Induction Period	minutes	480	-	480	-	480	-	EN ISO 7536
Oxigen Content	% m/m	-	2.3		1.0	Report		EN 1601
Existent Gum	mg/ml	-	0.04		0.04		0.04	EN ISO 6246
Sulphur Content	mg/kg	-	100	-	10	-	10	EN ISO 20846 / EN ISO 20884
Copper Corrosion	rating	-	Class 1	-	Class 1	-	Class 1	EN ISO 2160
Lead Content	mg/l		5.0		5.0	-	5.0	EN 237
Phosphorus Content	mg/l	-	1.3	-	1.3	-	1.3	ASTM D 3231
Ethanol	%v/v	-	-	-	-	4.7	5.3	EN 1601 / EN 13132

INDIA REFERENCE TEST FUELS

Natural Gas for Heavy-Duty Road Vehicles

Parameter	Unit	BS III			BS IV Cat. M & N ≤ 3500 Kg GVW			BS IV Cat. M & N > 3500 Kg GVW			Test Method
		Basis	Min	Max	Basis	Min	Max	Basis	Min	Max	
		Reference fuel G_{20}			Reference fuel G_{20}			Reference fuel G_R			
Methane	%mole	100	99	100	100	99	100	87	84	89	ISO 6974
Ethane	%mole	–	–	–	–	–	–	13	11	15	ISO 6974
Balance [Inerts (different from N_2) + C_2 + C_{2+}]	%mole	–	–	1	–	–	1	–	–	1	ISO 6974
N_2	%mole	–	–	–	–	–	–	–	–	–	ISO 6974
Sulphur content	mg/m³	–	–	50	–	–	10	–	–	10	ISO 6326-5
Wobbe Index (net)[b]	MJ/m	–	–	–	48.2	47.2	49.2	–	–	–	–
		Reference fuel G_{23}						Reference fuel G_{23}			
Methane	%mole	92.5	91.5	93.5	–	–	–	92.5	91.5	93.5	ISO 6974
Balance [Inerts (different from N_2) + C_2 + C_{2+}]	%mole	–	–	1	–	–	–	–	–	1	ISO 6974
N_2	%mole	7.5	6.5	8.5	–	–	–	7.5	6.5	8.5	ISO 6974
Sulphur content	mg/m³	–	–	50	–	–	–	–	–	10	ISO 6326-5
		Reference fuel G_{25}			Reference fuel G_{25}			Reference fuel G_{25}			
Methane	%mole	86	84	88	86	84	88	86	84	89	ISO 6974
Balance [Inerts (different from N_2) + C_2 + C_{2+}]	%mole	–	–	1	–	–	1	–	–	1	ISO 6974
N_2	%mole	14	12	16	14	12	16	14	12	16	ISO 6974
Sulphur content[a]	mg/m³	–	–	50	–	–	10	–	–	10	ISO 6326-5
Wobbe Index (net)[b]	MJ/m	–	–	–	39.4	38.2	40.6	–	–	–	–

Footnotes: [a] Value to be determined at 293.2 K (20°C) and 101.2 kPa. [b] Value to be determined at 273.2 K (0°C) and 101.3 kPa

INDIA REFERENCE TEST FUELS

BS-VI Petrol (E10)

Source: ARAI

Parameter	Unit	Limits 1		Test Method
		Minimum	Maximum	
Research Octane number, RON[8]		95	98	EN ISO 5164
Motor Octane number, MON		85	89	EN ISO 5163
Density at 15°C	kg/m³	743	756	EN ISO 12185
Reid Vapor Pressure (RVP)	kPa	56	60	EN-13016-1
Water content	%v/v	Maximum 0.05 Appearance at -7°C: Clear and Bright		EN 12937
Distillation:				
-Evaporated at 70°C	%v/v	34.0	46.0	ENISO 3405
-Evaporated at 100°C	%v/v	54.0	62.0	ENISO 3405
-Evaporated at 150°C	%v/v	86.0	94.0	ENISO 3405
-Final Boiling Point	°C	170.0	195.0	ENISO 3405
Residue	%v/v	--	2.0	ENISO 3405
Hydro-carbon analysis:				
-Olefins	%v/v	6.0	13.0	EN22854
-Aromatics	%v/v	25.0	32.0	EN22854
-Benzene	%v/v	--	1.00	EN22854, EN238
-Saturates	%v/v	Report		EN22854
Carbon/hydrogen ratio		Report		
Carbon/oxygen ratio		Report		
Induction period	minutes	480	--	EN ISO 7536
Oxygen content	%m/m	3.3	3.7	EN22854
Solvent washed gun (existent gum content)	mg/100ml	--	0.04	EN ISO 6246
Sulphur content	mg/kg	--	10.0	EN ISO 20846, EN ISO 20884
Copper corrosion 3 hrs, 50°C	%	--	Class 1	EN ISO 2160
Lead content	mg/l	--	5.0	EN 237
Phosphorous content	mg/l	--	1.3	ASTM D 3231
Ethanol	%v/v	9.0	10.0	EN22854

INDIA REFERENCE TEST FUELS

BS-VI Petrol (E85)

Parameter	Unit	Limits 1		Test Method
		Minimum	Maximum	
Research Octane number, RON		95	-	EN ISO 5164
Motor Octane number, MON		85	-	EN ISO 5163
Density at 15°C	kg/m³	Report		ISO 3675
Vapor Pressure (RVP)	kPa	40.0	60.0	EN ISO 13016-1(DVPE)
Sulphur content	mg/kg	--	10.0	EN ISO 20846, EN ISO 20884
Oxidation Stability	minutes	360.0	--	EN ISO 7536
Existent gum content (solvent washed)	mg/100 ml	--	5	EN ISO 6246
Appearance: This shall be determined at ambient temperature or 15° whichever is higher		Clear and bright, visible free of suspended or precipitated contaminants		Visual Inspection
Ethanol and higher alcohols	%v/v	83	85	EN 1601, EN13132, EN 14517
Higher alcohols (C_3-C_8)	%v/v		2.0	
Methanol	%v/v		0.5	
Petrol	%v/v	Balance		EN 228
Phosphorous	mg/l		0.3	ASTM D 3231
Water content	%v/v		0.3	ASTM D 1064
Inorganic chloride content	mg/l	-	1	ISO 6227
pHe		6.5	9.0	ASTM D 6423
Copper strip corrosion (3h at 50°C)	Rating	Class 1		EN ISO 2160
Acidity (as acetic acid CH_3COOH)	%m/m (mg/l)		0.005(40)	ASTM D 1613
Carbon/hydrogen ratio		Report		
Carbon/oxygen ratio		Report		

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WORLDWIDE HEAVY-DUTY AND OFF-ROAD EMISSION STANDARDS

2024/2025

PHINIA is pleased to offer Worldwide Emissions Standards booklets free of charge to our customers.

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