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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)<br>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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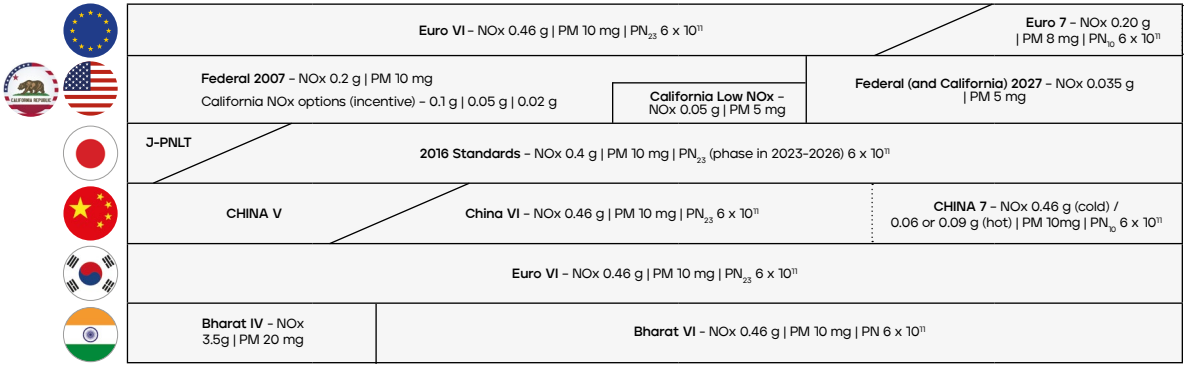
# ON-ROAD POLLUTANT EMISSIONS STANDARDS

# 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) | PNx$10^{11}$ (#/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<br>THC: 0.22<br>CO: 2<br>PM: 0.016 | CF NOx: 1.5<br>CF PN: 1.63<br>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 | $8 \times 10^{11}$ |
| WHTC (CI) | 4,000 | 160 | - | - | 460 | 10 | 10 | $6 \times 10^{11}$ |
| WHTC (PI) | 4,000 | - | 160 | 500 | 460 | 10 | 10 | $6 \times 10^{11}$ |

**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.

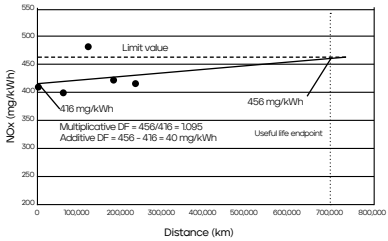
For each pollutant, a multiplicative DF (min 1.0) or additive DF (min 0.00) can then be determined by comparing the pollutant value at the beginning of the process and at the end of the normal useful life period (extrapolated value), resulting in a ratio or a difference, depending on the manufacturer's 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<br>THC: 0.22<br>CO: 2.0<br>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:**

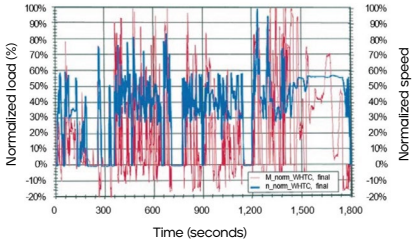
Global Technical Regulation Nr 4 (GTR 4) introduces two representative test cycles, created to cover typical driving conditions in the European Union, USA, Japan and Australia:

- 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:

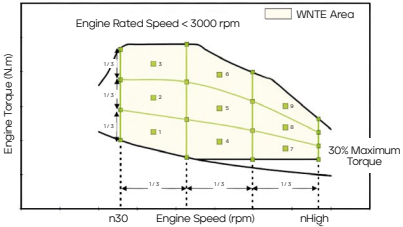
- For Engines, OCE (Off-Cycle Emissions) in a stationary engine test cycle with the measurement of 15 random modes – not applicable for spark-ignition engines
- For Vehicles, during certification and any in-service conformity procedure, RDE (Real Driving Emissions) test, using PEMS

**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**

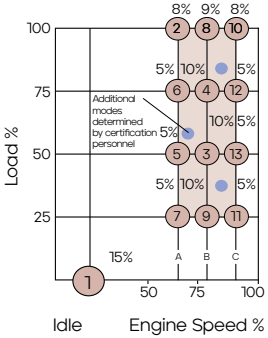
The test cycle consists of a number of speed and load points which cover the typical operating range of diesel engines.

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

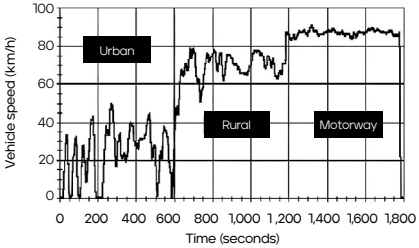
# EURO V AND EARLIER ENGINE TEST CYCLES

**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.

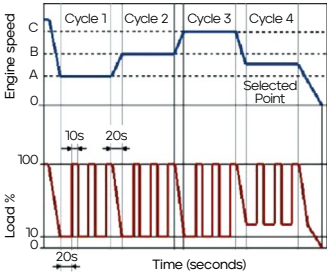



**3) European Load Response - ELR**

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.

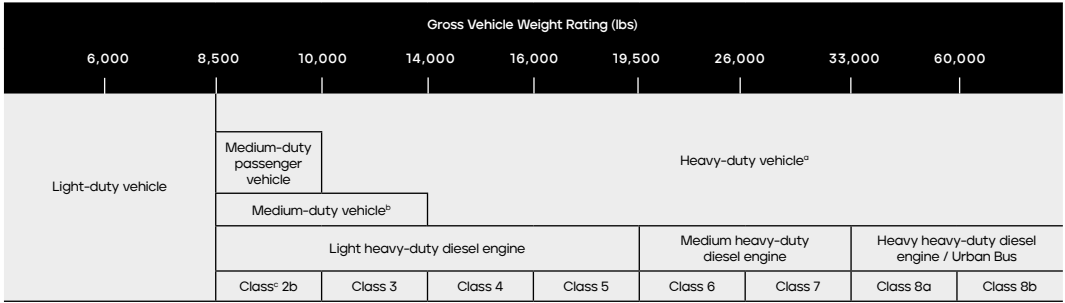
| Vehicle Category | Minimum Service Accumulation Period |
|---|---|
| $N_1$ | 100,000 km |
| $N_2$ | 125,000 km |
| $N_3$ with permissible mass ≤ 16 tons | 125,000 km |
| $N_3$ with permissible mass > 16 tons | 167,000 km |
| $M_2$ | 100,000 km |
| $M_3$ with permissible mass ≤ 7.5 tons | 125,000 km |
| $M_3$ 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<br>MHDDE: – / 8 / 185,000<br>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:<br>LHDDE: – / 8 / 110,000<br>MHDDE: – / 8/ 185,000<br>HHDDE: – / 8 / 290,000<br>1994+ urban buses for PM only:<br>LHDDE: – / 10 / 110,000<br>MHDDE: – / 10 / 185,000<br>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]<br>LHDDE: –/ 10 / 110,000<br>MHDDE: –/ 10 / 185,000<br>HHDDE: 22,000 / 10 / 435,000 | LHDDE: 5 / 50,000<br>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<br>MHDDE: – / 10 / 185,000<br>HHDDE: 22,000 / 10 / 435,000 | LHDDE: – / 5 / 110,000<br>MHDDE: – / 5 / 155,000<br>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<br>MHDDE 17,000 / 12 / 350,000<br>HHDDE: 32,000 / 11 / 650,000 | LHDDE: 10,000 / 10 /210,000<br>MHDDE: 14,000 / 10 / 280,000<br>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<br>> 14,000 | 1.1<br>1.9 | – | 10.6<br>10.6 | – | –<br>– | 14.4<br>37.1 | | – |
| | 1988-90 | ≤ 14,000<br>> 14,000 | 1.1<br>1.9 | –<br>– | 6.0<br>6.0 | – | –<br>– | 14.4<br>37.1 | | –<br>– |
| | 1990 | ≤ 14,000<br>> 14,000 | 1.1<br>1.9 | – | 6.0<br>6.0 | – | –<br>– | 14.4<br>37.1 | - / 8 / 110,000[h] | 5 / 50,000 |
| | 1991-97 | ≤ 14,000<br>> 14,000 | 1.1[f]<br>1.9[g] | –<br>– | 5.0<br>5.0 | – | –<br>– | 14.4<br>37.1 | | |
| | 1998-2004 | ≤ 14,000<br>> 14,000 | 1.1[f]<br>1.9[g] | –<br>– | 4.0 | – | – | 14.4<br>37.1 | | |
| | 2005-07 | ≤ 14,000<br>> 14,000 | 1.1[f]<br>1.9[g] | –<br>– | –<br>– | 1.0 | –<br>– | 14.4<br>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<br>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<br>MHDDE - / 10 / 185,000<br>HHDDE 22,000 / 10 / 435,000 | LHDDE 5 / 50,000<br>MHDDE 5/ 100,000<br>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<br>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<br>MHDDE 8 / 185,000<br>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 / -<br>MHDD 185,000 / 10 / -<br>HHDD 435,000 / 10 / 22,000 | LHDD 110,000 / 5<br>MHDD 150,000 / 5<br>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<br>15 years<br>13,000 hours | 350,000<br>12 years<br>17,000 hours | 650,000<br>11 years<br>32,000 hours | 200,000<br>15 years<br>10,000 hours |
| Emissions Warranty | 210,000<br>10 years<br>10,000 hours | 280,000<br>10 years<br>14,000 hours | 450,000<br>10 years<br>22,000 hours | 160,000<br>10 years<br>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<br>15 years<br>13,000 hours | 350,000<br>12 years<br>17,000 hours | 650,000<br>11 years<br>32,000 hours | 200,000<br>15 years<br>10,000 hours |
| Emissions Warranty | 210,000<br>10 years<br>10,000 hours | 280,000<br>10 years<br>14,000 hours | 450,000<br>10 years<br>22,000 hours | 160,000<br>10 years<br>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.

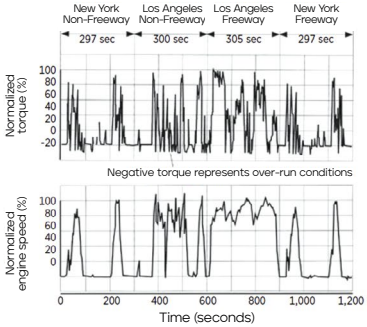
**Off-cycle NOx limit values**

| 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 |

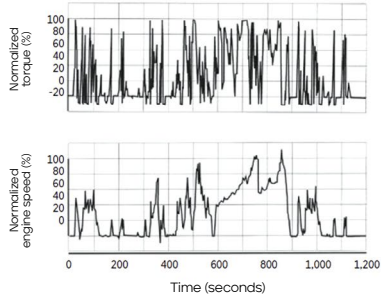
# ENGINE TEST CYCLES

## 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).

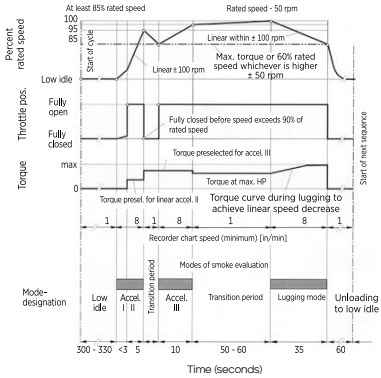
The DMC is based on the EU ESC cycle.

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:**

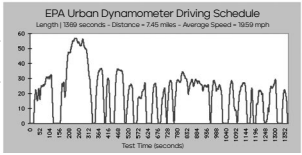
1. Federal Test Procedure (FTP) using the light-duty Urban Dynamometer Driving Schedule (UDDS, right).
2. Heavy-Duty Supplemental Federal Test Procedure (HD-SFTP) = 0.35 x FTP + 0.28 x HDSIM + 0.37 x SC03, where HDSIM is defined:
   - For Class 2b vehicles: the US06 cycle (right)
   - For Class 2b vehicles 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.

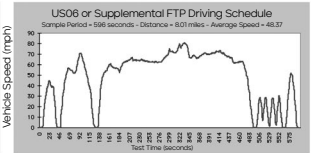
The results of both the FTP and the HD-SFTP are compared to the relevant standard.

**Test cycles**

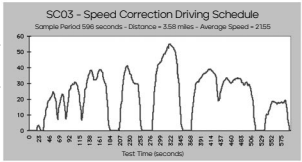
FTP - UDDS



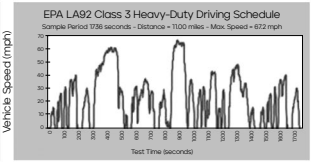

US06




SC03




LA92

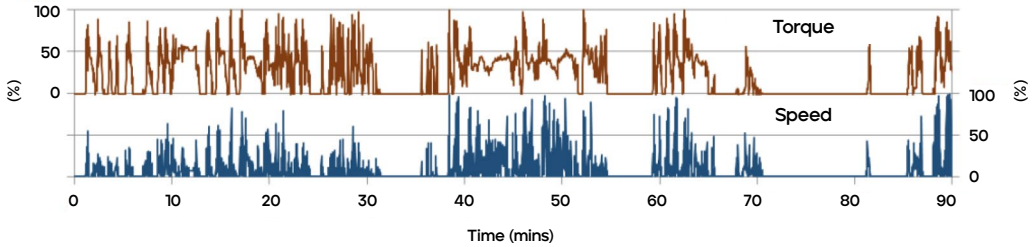


# ENGINE TEST CYCLES

## 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 ($8 \times 10^{11}$) and WHTC ($6 \times 10^{11}$)

**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

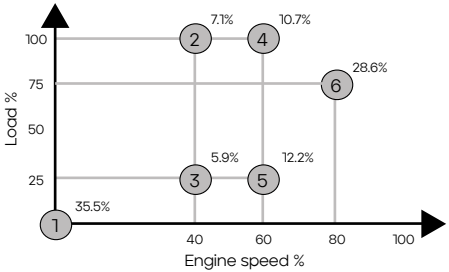
**Test cycle:** JE05 (Diesel Sulphur content: 10 ppm)

# ENGINE TEST CYCLES

**6-Mode Cycle (until 2005)**

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

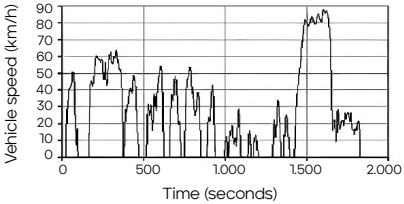
The modes are run in sequence and the duration of each mode is 3 minutes. Measurements are expressed in ppm (volumetric concentration).




**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

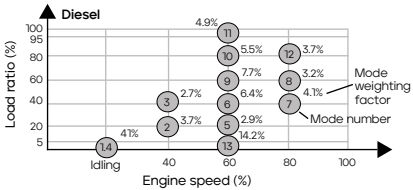
### 13-Mode Cycle

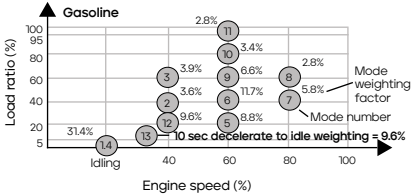
This cycle replaced the 6-Mode cycle. It includes a sequence of 13 steady-state modes. Measurements are expressed in g/kWh. The test represents low-speed driving conditions, specified by low average engine loads and low exhaust temperature.

| 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 | $6 \times 10^{11}$ |
| Hot WHTC | 200 | 50 | 350 | 60 / 90[a] | 65 | 200 | 30 | 10 | $6 \times 10^{11}$ |

**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<br>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 | - | $8 \times 10^{11}$ | WHSC |
| | 4.0 | 0.46 | 0.16 | | | $6 \times 10^{11}$ | WHTC |
| 1st Oct 2017[b,c] | 1.50 | 0.40 | 0.13 | 0.01 | - | $8 \times 10^{11}$ | WHSC |
| | 4.0 | 0.46 | 0.16 | | | $6 \times 10^{11}$ | 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 | $8.0 \times 10^{11}$ |
| WHTC (CI) | 4,000 | 160 | - | - | 460 | 10 | 10 | $6.0 \times 10^{11}$ |
| WHTC (PI) | 4,000 | - | 160 | 500 | 460 | 10 | 10 | $6.0 \times 10^{11}$ |

**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)<br>US 07 or Japanese 05 Long Term as alternative<br>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<br>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<br>1st September 2015 Urban bus – Euro V<br>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<br>Transitional (phase AA) standards equivalent to US EPA 2007 or Euro V from 1st January 2019<br>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) |

PHINIA

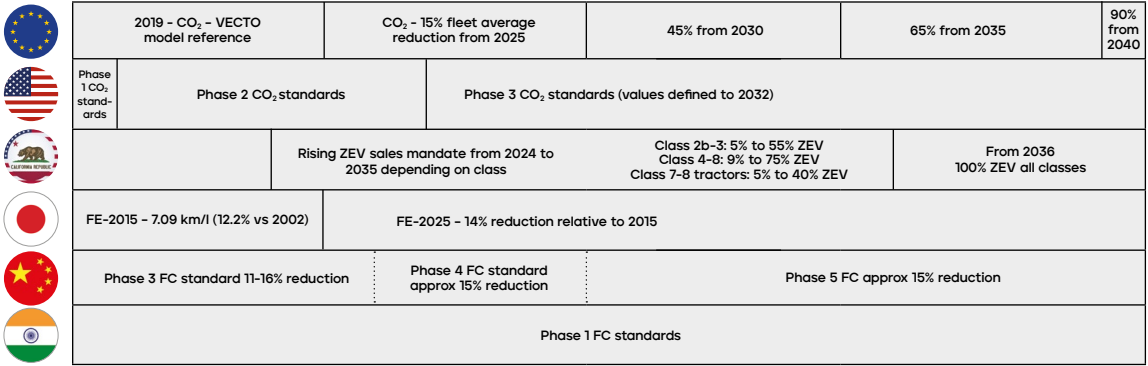
# ADVANCING SUSTAINABILITY TODAY, POWERING A CARBON-FREE TOMORROW

PHINIA

# $CO_2$ / 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 |

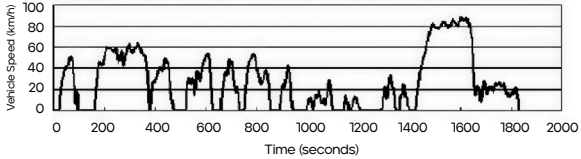
# FUEL ECONOMY TEST METHODS AND CYCLES

**Test method**

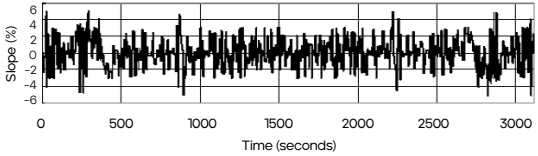
The fuel economy (in km/liter) of heavy-duty trucks and buses is calculated by a computer simulation procedure using data inputs from engine dynamometer tests.

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

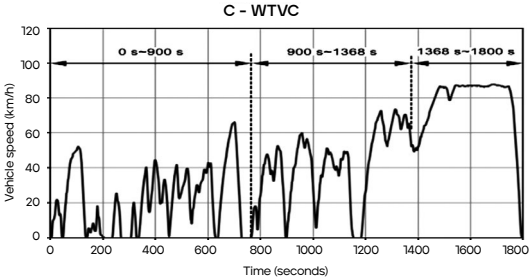
# VEHICLE TEST CYCLES

**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 |

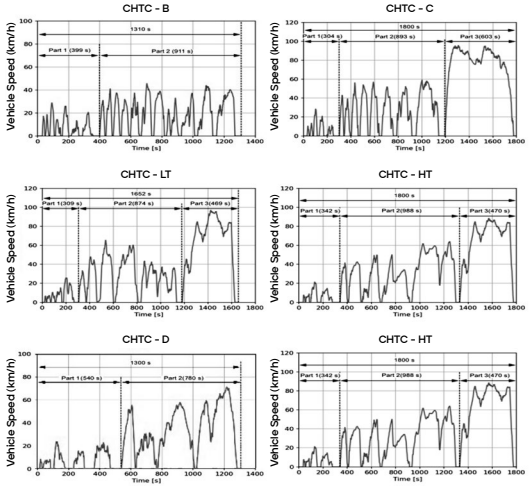
# TEST CYCLES

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
  - $N_2$ > 16 tons
  - $M_2$, $M_3$/III and
  - $M_3$/B > 7.5 tons
· Maximum 75% of maximum torque for
  - $N_1$, $N_2$, $N_3$ ≤ 16 tons
  - 3.5 < $M_1$ < 7.5 tons
  - $M_2$, $M_3$/I, $M_3$/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<br>Engine misfire monitoring<br>EGR system monitoring<br>Turbo boost control system monitoring<br>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<br>Engine misfire monitoring<br>Exhaust gas recirculation system monitoring<br>Cold start emission reduction strategy monitoring<br>Secondary air system monitoring<br>Exhaust gas sensor monitoring<br>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<br>B. Fuel system injection quantity<br>C. Fuel system injection timing<br>D. Combined monitor for 2, 3 in case of common rail system<br>E. Fuel system feedback control | A. Emission threshold monitor<br>B. Adaptive feedback control has used up all of the adjustment<br>C. Feedback control reached limit of emission threshold<br>D. Unable to enter closed loop |
| | Monitoring conditions | · Continuously for A and E<br>· 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<br>· Detect misfire occurring in one or more cylinders if > 5% misfire | A. Misfire causing catalyst damage.<br>B. Misfire causing emissions to exceed thresholds |
| | Monitoring conditions | · During engine idle conditions at least once per drive cycle<br>· 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<br>B. EGR high flow<br>C. EGR slow response<br>D. EGR system feedback control<br>E. EGR cooler performance | A. Decrease in EGR flow rate that could reach emission threshold<br>B. Increase in EGR flow rate that could reach emission threshold |
| | Monitoring conditions | · Continuously for A, B and D<br>· Occurs every time the monitoring conditions are met for C<br>· 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<br>B. Turbo over boost<br>C. VGT slow response<br>D. Turbo boost feedback control<br>E. Charge air undercooling | Not applicable |
| | Monitoring conditions | · Continuously for A, B and D.<br>· 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<br>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<br>B. SCR and lean NOx catalyst active/intrusive reductant delivery performance<br>C. SCR and lean NOx catalyst active/intrusive reductant quantity<br>D. SCR and lean NOx catalyst active/intrusive reductant quality<br>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<br>· Continuously for B, C and E | -- |
| NOx absorber system monitoring | Malfunction criteria | A. NOx adsorber system capability<br>B. NOx adsorber system active/intrusive reductant delivery performance<br>C. NOx adsorber system feedback control | Not applicable |
| | Monitoring conditions | · At least once per drive cycle when monitoring conditions are met for A<br>· Continuously for B and C | -- |
| Diesel particulate filter (DPF) system monitoring | Malfunction criteria | DPF filtering performance<br>DPF regeneration frequency<br>DPF incomplete regeneration<br>DPF missing substrate<br>DPF system active/intrusive injection<br>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<br>1) upstream,<br>2) downstream,<br>3) NOx Sensors of aftertreatment devices<br>A. Sensor performance.<br>B. Circuit integrity.<br>C. Feedback function<br>D. Monitoring function<br>4) Other Exhaust Gas sensors : evaluation and demonstration<br>5) Exhaust gas Heaters:<br>A. Performance when the current or voltage drop outside manufacturer limits<br>B. Open or short circuits | 1. Primary exhaust gas sensor malfunction criteria<br>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<br>B. Detect malfunctions due to lack of circuit continuity or out-of-range values.<br>C. Sensor failure or deterioration causes the fuel system to stop using that sensor as a feedback input (Open-loop operation)<br>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<br>2. Secondary exhaust gas sensor malfunction criteria<br>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<br>B. Detect malfunctions of the exhaust gas sensor caused by a lack of circuit continuity<br>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<br>D. Detect malfunctions of the exhaust gas sensor caused by out-of-range values<br>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<br>3. Exhaust gas sensor heater malfunction criteria<br>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<br>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<br>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<br>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<br>3. Exhaust gas sensor heater:<br>· At least once per DCY every time monitoring conditions are met for A<br>· 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<br>B. VVT slow response<br>C. VVT Improper functional response of the system | A. VVT system target error<br>B. VVT slow response<br>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<br>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<br>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<br>· 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<br>· May disable temporarily the evaporative purge system to run an evaporative system leak monitor |

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# 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<br>(h)(4.2.3)(F): NOx mass emission rate -engine out and NOx mass emission rate -tailpipe<br>(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:<br>Engine and vehicle parameters<br>Diesel oxidation catalyst parameters<br>Particulate filter parameters<br>EGR parameters<br>SCR parameters<br>Derating parameters | Spark-Ignition:<br>Air-fuel enrichment parameters |
| In-cab display of diagnostic information | Inducement-related fault code<br>Derate and speed restrictions<br>DEF Consumption<br>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**<br>· Pressure Control<br>· Injection Quantity<br>· Injection Timing | a) NMHC, NOx, CO: 2.0 x standard<br>b) PM: Standard + 0.02 grams/bhp-hr<br>Note: Failure modes incl. both single & all injectors equally deteriorated |
| · Feedback Control | a) Fails to begin control within manufacturer-defined time<br>b) Failure or deterioration causes open loop or default operation<br>c) Control maximum authority reached & cannot achieve control target |
| **Misfire**<br>Monitoring during idle (systems without combustion sensor)<br>Continuous monitoring for all positive engine torque/speed/loads (systems with combustion sensor) | Misfire detection level:<br>· 2018+ MY: 100%. Applies low-level misfire detection to ALL vehicles (must detect 5% misfire)<br>Monitoring conditions:<br>· Monitoring required under ALL positive torque engine speed conditions, except:<br>1) Positive torque line to 50% maximum engine speed @ positive torque line<br>2) 100% maximum engine speed & (+10%) torque above positive torque line |
| **Exhaust Gas Recirculation (EGR)**<br>· Low Flow Rate<br>· High Flow Rate (incl. leaking EGR valve bypass flow)<br>· Slow response (both increasing and decreasing directions)<br>· EGR Cooler Performance (monitoring of multiple coolers requires Executive Officer approval) | a) NMHC, NOx, CO: 2.0 x standard<br>b) PM: Standard + 0.02 grams/bhp-hr<br>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<br>b) Failure or deterioration causes open loop or default operation<br>c) Control maximum authority reached & cannot achieve control target<br>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**<br>· Underboost - Overboost<br>· Slow Response Boost System)<br>· Charge Air Undercooling (monitoring of multiple coolers requires Executive Officer approval) | If no emission impact under driving condition where impact is most likely<br>a) NMHC, NOx, CO: 2.0 x standard<br>b) PM: Standard + 0.02 grams/bhp-hr |
| · Feedback Control | a) Fails to begin control within manufacturer-defined time<br>b) Failure or deterioration causes open loop or default operation<br>c) Control maximum authority reached and cannot achieve control target<br>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**<br>(exl. downstream or PM filter for regeneration)<br>· Conversion Efficiency<br>· Other Aftertreatment<br>· Assistance Function | a) NMHC: 2.0 x standard<br>b) NOx: standard + 0.2 g/bhp-hr<br><br>**Exotherm generation (PM Filter regeneration assistance):**<br>· Catalyst unable to generate sufficient exotherm for regeneration Feedgas constituency (SCR assistance):<br>· Catalyst unable to generate sufficient feedgas for proper SCR operation, with no monitoring required if < 15% emission increase and < std. under test cycle<br><br>**NMHC conversion downstream of PM filter for use during regeneration:**<br>· No detectable amount of NMHC conversion Converter downstream of SCR system<br>· No detectable amount of NMHC, CO, NOx or PM conversion capability |

# CALIFORNIA (CARB) ON-BOARD DIAGNOSTICS (DIESEL)

| Monitoring Area | Malfunction Criteria |
|---|---|
| **NOx Converting Catalyst**<br>· Conversion Efficiency | · 2016 + MY: standard + 0.2 g/bhp-hr NOx, 2.0 x standard NMHC<br>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:<br>· Insufficient reductant for proper operation<br>· Improper reductant in reservoir/tank<br>· 2016 + MY: standard + 0.2 g/bhp-hr NOx, 2.0 x standard NMHC<br>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<br>b) Failure or deterioration causes open loop or default operation<br>c) Control maximum authority reached and cannot achieve control target<br>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**<br>· 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<br>b) Failure or deterioration causes open loop or default operation<br>c) Control maximum authority reached and cannot achieve control target<br>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**<br>· 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<br>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<br>if < 15% emission increase AND < standard under test cycle |
| · Missing Substrate | a) PM filter substrate completely destroyed, removed, or missing<br>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<br>b) Failure or deterioration causes open loop or default operation<br>c) Control maximum authority reached and cannot achieve control target<br>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<br>b) Out of "normal" range |
| **A/F Sensors - Upstream of Exhaust Treatment** | Sensor Performance:<br>a) NMHC, CO, NOx: 2.0 x standard<br>b) PM: standard + 0.02 g/bhp-hr<br>· Feedback: failure or deterioration causes an emission control system to stop using that sensor as an input (default or open loop)<br>· Monitoring capability: any characteristic no longer sufficient for use as input to other monitoring strategy |
| **A/F Sensors - Downstream of Exhaust Treatment** | Sensor Performance:<br>a) NMHC: 2.0 x standard<br>b) NOx: standard + 0.2 g/bhp-hr<br>c) PM: 0.03 g/bhp-hr (FTP or SET), OR std. + 0.02 g/bhp-hr whichever is higher<br>· Feedback: failure or deterioration causes an emission control system to stop using that sensor as an input (default or open loop)<br>· 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.<br>Note: The manufacturer is allowed to carry-over from previous 2014 or 2015 phase-in volume certification for the 2016 MY only<br>· Feedback: failure or deterioration causes an emission control system to stop using that sensor as an input (default or open loop)<br>· 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<br>b) Faults that result in conflict between commanded and actual state of the heater |
| **Variable Valve Timing and/or Control**<br>· Target Error (outside crank angle and/or lift tolerance)<br>· Slow Response | a) NMHC, CO, NOx: 2.0 x standard<br>b) PM: standard + 0.02 g/bhp-hr |
| **Cold Start Emission Reduction Strategy** | a) Any single commanded element does not respond properly:<br>· By a robustly measurable amount<br>· In the commanded direction<br>· By an amount that is greater than otherwise would have been commanded without the cold start strategy activated<br>b) Deterioration:<br>· NMHC, NOx, or CO: 2.0 x standard<br>· PM: standard + 0.02 g/bhp-hr<br>c) Cold Start System Capability:<br>· Desired effect not achieved (as feasible)<br>· Individual elements/components (when desired effect method is NOT feasible)<br>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)<br>b) Fails to begin control within manufacture-defined time (time period requires Executive Officer approval). Engine-off strategies must monitor every engine start |
| **Misfire**<br>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)<br>· single detection of misfire rate in 1st 1000 engine revolutions<br>· 4 detections of misfire rate in 1,000 engine revolution blocks<br>b) Misfire rate that causes temperature to reach catalyst damaging level<br>Specific cylinder diagnostic trouble code (DTC ) required for > 90% misfire occurring on a single cylinder |
| **Exhaust Gas Recirculation (EGR)**<br>· Low Flow Rate<br>· 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:<br>· By a robustly measurable amount<br>· In the commanded direction<br>· 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):<br>· 1.5 x std. (all constituents)<br>Note: fault codes must isolate cold start related failures |
| **Secondary Air System** | 1.5 x standard (all constituents)<br>· Both reduction in secondary flow and excessive secondary flow must be monitored<br>· Monitoring required while control strategy is normally activated<br>· 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:<br>a) NMHC, NOx: 1.75 x standard<br>b) NMHC conversion efficiency below 50%<br>For threshold testing purposes, the catalyst system is to be aged simultaneously (full catalyst volume)<br>· 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)<br>b) Cumulative evaporative system leak ≥ 0.150 inch diameter orifice<br>(may be revised upward for technical incapability or < 1.5 x std. with Executive Officer approval)<br>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**<br>· Primary & Secondary Exhaust Gas Sensors | a) Sensor Performance:<br>· 1.5 x standard (all constituents)<br>· (Primary sensors only): symmetric and asymmetric delay to respond and response rates, lean-to-rich and rich-to-lean (certification data/analysis required)<br>b) Lack of circuit continuity<br>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<br>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<br>b) Faults that result in conflict between commanded and actual state of the heater |
| **Variable Valve Timing and/or Control**<br>· Target Error (outside crank angle and/ or lift tolerance)<br>· 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<br>· Within 20 deg F of normal operating temp (may use higher threshold if < 50% emissions increase; may disable when ambient temp < 20 deg F)<br>· Highest temp required by the OBD system to enable other monitors<br>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<br>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<br>b) Time to reach closed-loop/feedback enable temp<br>c) Stuck in range below the highest minimum enabled temperature required by other monitors<br>d) Stuck in range above the lowest maximum enabled temperature required by other monitors<br>(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):<br>a) Between Crankcase and CV Valve<br>b) Between CV Valve and Intake Ducting<br>Exemptions may apply (with Executive Officer approval) for:<br>· Systems where vehicle operator is certain to respond or where disconnection of an unmonitored portion first requires disconnection of a monitored portion<br>· 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<br>· 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.)<br>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<br>· 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<br>· 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)<br>b) Unable to properly receive vehicle speed information (communication failure)<br>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<br>b) Out of "normal" range<br>c) Irrational sensor value (2-sided monitoring)<br>d) Alternate Strategy Activation (that can affect emissions):<br>· Malfunctions that cause the system to erroneously activate or deactivate<br>· Failures that invoke erroneous control, as feasible (rationality)<br>e) Components used for emission control strategies not specifically addressed by CARB regulations.<br>· Failures that cause the strategy not to operate in its intended manner (delayed enable, erroneous exit, authority limit)<br>f) Camshaft/Crankshaft Position Sensors:<br>· Engines requiring precise cam/crank alignment: improper alignment<br>· 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<br>b) Circuit continuity faults<br>c) Idle Control System (Gasoline engines with monitoring strategies based on deviation from target idle speed):<br>· Speed control cannot maintain within 200 rpm above or 100 rpm below the target idle speed<br>· Speed control cannot maintain within the smallest engine speed tolerance range for any other monitor's enable<br>d) Idle Control System (Diesel Engines):<br>· Speed control cannot maintain within +/- 50% of target speed<br>· Speed control cannot maintain within the smallest engine speed tolerance range for any other monitor's enable<br>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)<br>e) Glow Plugs/Intake Air Heaters:<br>· Improper functional response<br>· Circuit continuity faults<br>· Proper current and voltage drop<br>· Single glow plug no longer operates in manufacturer's limits<br>f) "Wait to Start" Lamp: failures that prevent illumination<br>g) Components used for emission control strategies not specifically addressed by CARB regulations:<br>· Failures that cause the strategy to not operate in its intended manner (delayed enable, erroneous exit, authority limit)<br>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)<br>· OBD requirements from 1971.1 applies to all engine ratings in all engine families.<br>· Tracking requirements:<br>Option-1:<br>· MY 22+ to meet all tracking requirements and<br>· Demonstration testing of 15 Executive officer selected monitors for MY 22/23<br>Option-2:<br>· MY 22-23 to meet tracking requirements with some exemptions (active and stored 100-hour array) and<br>· MY 24+ to meet all tracking requirements |
| **In-Use Performance Ratio (IUPR)** | MY 24+<br>· 0.100 for the diesel catalyst warm-up strategy<br>· 0.500 for the gasoline CSER cold start catalyst heating monitor<br>· 0.100 for crankcase ventilation (CV) system monitors (interim 2024-31)<br>· 0.300 for all other monitors<br>Interim lower ratios allowed for:<br>· Alternate fueled engines: 0.100 for all (2024-25) monitors.<br>· 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).<br>b) Disabling at (ambient temperature < 20 deg F or component freezing) OR (altitude > 8,000 feet): Requires Executive Officer approval.<br>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).<br>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).<br>e) Disablement for PTO activation (requires PTO activation time and IM Readiness reset at 750 minutes activation without related monitor completion).<br>f) Exemption from component monitoring if no emissions impact for any reasonable driving condition AND component is not used for other OBD purposes.<br>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

PHINIA

GET AHEAD WITH REDUCED EMISSIONS. OUR TECHNOLOGIES LEAD THE WAY.

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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 | | | |

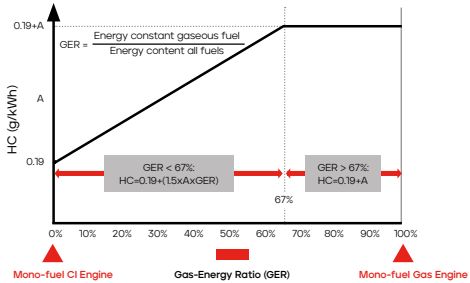
**Footnotes:**

[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 | 1.31[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<br>(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<br>(3,500 hrs or 5 yrs)</td><td rowspan="2">2.7 / 4,4[b]<br>(5,000 hrs or 7 yrs)</td><td rowspan="2" colspan="4">0.8 / 20.6<br>(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="6">-</td><td colspan="6">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 | | $5 \times 10^{12}$ |
| 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<br>0.67[a] | - | 0.045<br>0.035[a] | 25 | - |
| $130 \le P_{max} < 560$ | 3.5 | 0.19 | 0.40 | - | 0.015 | | $1 \times 10^{12}$ |
| $75 \le P_{max} < 130$ | 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]<br>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]<br>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 | $1 \times 10^{12}$ | 10 | |
| | | 37-56 | 5.0 | 4.7 | | 0.015 | $1 \times 10^{12}$ | 10 | |
| | | 56-130 | 5.0 | 0.4 | 0.19 | 0.015 | $1 \times 10^{12}$ | 10 | NRSC & NRTC Modes |
| | | 130-560 | 3.5 | 0.4 | 0.19 | 0.015 | $1 \times 10^{12}$ | 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 | $1 \times 10^{12}$ |
| 37 ≤ P < 56 | | 5.0 | 4.7 (HC + NOx) | | 0.015 | $1 \times 10^{12}$ |
| 56 ≤ P < 130 | | 5.0 | 0.19 | 0.4 | 0.015 | $1 \times 10^{12}$ |
| 130 ≤ P < 560 | | 3.5 | 0.19 | 0.4 | 0.015 | $1 \times 10^{12}$ |
| 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.<br>For large SI engines, US Tier 2 standards apply from June 2021.<br>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.<br>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<br>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;<br>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:**

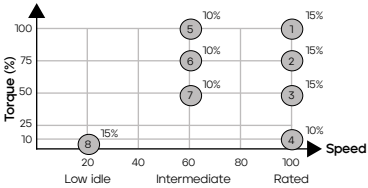
[a] January 2023 for agricultural and forestry equipment

# TEST CYCLES (GLOBAL)

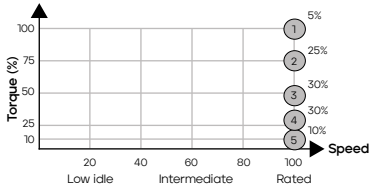
**NRSC Test (Non-Road Steady-State Cycle) ISO 8178 categories C (off-road vehicles) and D (constant speed)**

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.

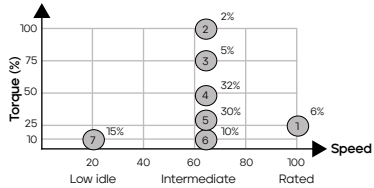
**CI engines ISO 8178-C1 intermittent**




**CI engines ISO 8178-D2 constant speed**




**ISO 8178-C2 SI engines > 20 kw**

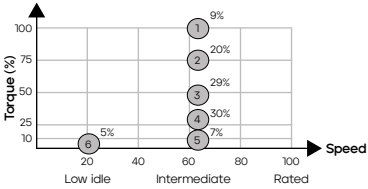


# TEST CYCLES (GLOBAL)

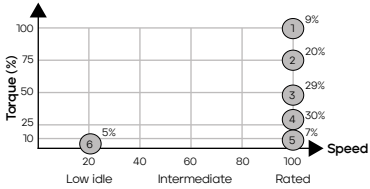


**NRSC Test (ISO 8178) for Utility, Lawn & Garden applications)**

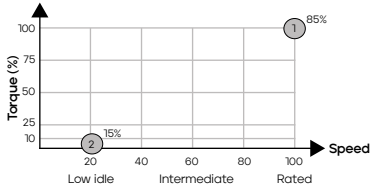
**ISO 8178-G1**
**Non-handheld intermediate speed applications**




**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**

▼

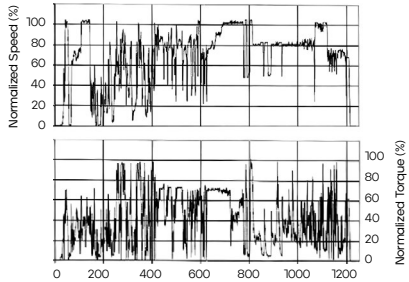
**Hot soak**

▼

**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



PHINIA

# WE GIVE NEW ENERGY TO THE FUTURE

PHINIA

# 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:<br>50% recovery temperature<br>90% recovery temperature<br>95% recovery temperature | °C | Within range | <br>245~300<br>315~335<br>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

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