Delphi Technologies

Worldwide emissions standards

On and off-highway commercial vehicles

2018 | 2019

2018 | 2019

Delphi Technologies ultra-high pressure F3 fuel injection system: meeting the next generation of emission standards in the toughest applications.

At the forefront of high pressure commercial vehicle Diesel fuel injection technology, Delphi Technologies has now developed a new generation of fuel injectors which can deliver fuel at 3,000 bar with extremely high operating efficiency, improved multiple injection performance and tighter packaging.

2018 | 2019

Our drive

We are one of the world's leading pioneers of vehicle propulsion systems. With more than 5,000 technologists, our advanced solutions are integral to powering better vehicle performance. We are committed to driving forward the future of a sustainable automotive industry. Together with the world's leading manufacturers, we help make vehicles that are cleaner, more reliable, more efficient and that people are passionate about driving.

Driven to make a difference

Delphi Technologies

2018 | 2019

Delphi Technologies SCR-CV, on and off-road solutions today for the clean planet of tomorrow.

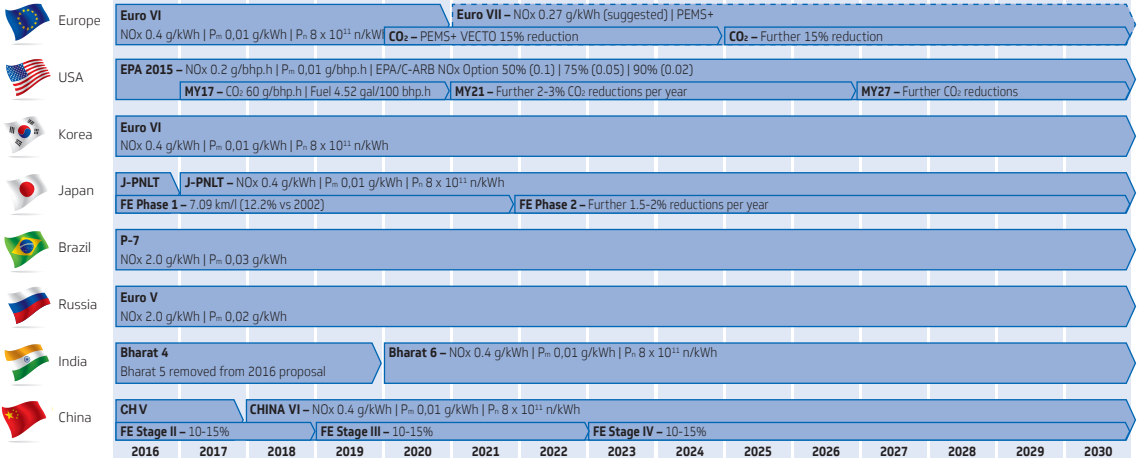
SCR dosing system solutions for clean exhaust for the toughest of conditions.

The Delphi Technologies system includes dosers which spray a finely atomized mist of an aqueous urea solution into the exhaust to the smart pump supply module which delivers clean pressurized fluid while controlling and diagnosing the system.

Delphi Technologies

HD – EXHAUST EMISSIONS STANDARDS

ON ROAD – EXHAUST EMISSIONS STANDARDS – ROADMAP

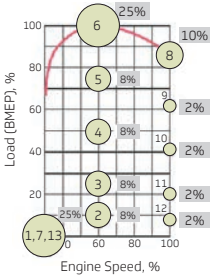


EUROPEAN UNION

Test cycles Euro I and II / ECE R49 or 13 Mode Cycle

It is a steady-state diesel engine test cycle used for TA emission testing of HD highway engines up to Euro II standards. Effective October 2000, the R49 cycle was replaced by the ESC cycle.

This cycle is operated through a sequence of 13 speed and load conditions. The final result is a weighted average of the 13 modes.



Mode	Speed	Load [%]	Weight Factor
1	Idle	–	0.25/3
2	Max Torque Speed	10	0.08
3		25	0.08
4		50	0.08
5		75	0.08
6		100	0.25
7	Idle	–	0.25/3
8	Rated Power Speed	100	0.10
9		75	0.02
10		50	0.02
11		25	0.02
12		10	0.02
13	Idle	–	0.25/3

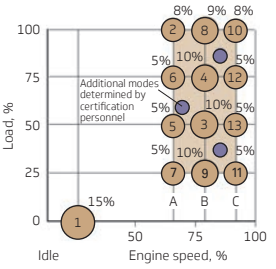
EUROPEAN UNION

Test cycles Euro III and later defined by Dir 88/77/EC as amended by Dir 2001/27/EC

3 cycles are accepted:

1) European Steady-State Cycle – ESC

The test cycle consists of a number of speed and power modes which cover the typical operating range of diesel engines.
It is so determined by 13 steady and 3 random modes.
Emission values are obtained with the weighted mean of emissions on each of the 13 modes. The 3 random points are random-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 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

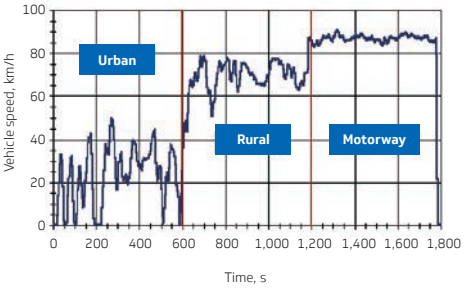
Speed A = n_{lo} + 25% (n_{hi} - n_{lo})
Speed B = n_{lo} + 50% (n_{hi} - n_{lo})
Speed C = n_{lo} + 75% (n_{hi} - n_{lo})

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

EUROPEAN UNION

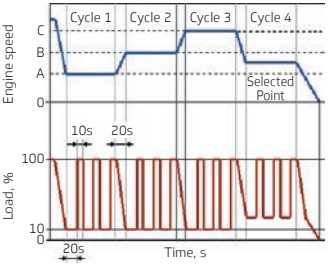
2) European Transient Cycle – ETC

This cycle consists of a second-by-second sequence of transient modes.
It is based on-road-type-specific driving patterns of HD engines installed in trucks and buses.
It is divided in 3 parts: 1/3 urban roads, 1/3 rural roads, 1/3 motorways.



3) European Load Response – ELR

Only diesel smoke is measured. ELR cycle is defined by fixed speed sampling and a random sampling.
The random sampling is represented by a random speed and by a random initial load.
Smoke measurements during the sampling must not exceed 20% of the highest value of close speeds or more than 5% of limit value. The biggest one is selected.



ECE

The ECE R49 series of regulations are similar to EU directives. A base regulation is updated in a consecutive series of amendments. Dates of implementation differ from country, depending on the approval status of the respective amendment in that country.

TEST CYCLES

WWHD – Worldwide Harmonised Heavy Duty

Emissions Certification Procedure: Global Technical Regulation Nr 4 (GTR 4)

2 representative test cycles have been created covering typical driving conditions in the European Union, USA, Japan and Australia:

– WHTC: Transient Test Cycle
– WHSC: Steady-State Test Cycle

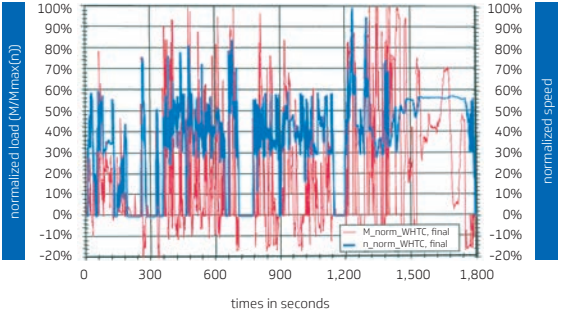
The GTR does not contain emission limit values.

Exhaust Emissions to be measured: CO, HC, NMHC, NOx, PM, CO_2, expressed in g/kWh.

If GTR applied in a national legislation, the limit values should represent at least the same level of severity as its existing regulations.

WHTC – World Heavy Duty Transient Cycle

It is a second by second sequence of normalized speed and torque values.



EUROPEAN UNION

VEHICLE CATEGORIES

Category	Description	Subcategory	Number of Persons	Mass Limit	
M	Transportation of Passengers Min. 4 wheel	M1	Up to 9 Persons	GVW ≤ 3,500 kg[1]	
		M2	Over 9 Persons	GVW ≤ 5,000 kg	
		M3		GVW > 5,000 kg	
N	Transportation of Goods Min. 4 wheel	N_1 Cl 1	N.A.	Max GVW ≤ 3,500 kg	RM ≤ 1,305 kg
		N_1 Cl 2			1,305 kg < RM ≤ 1,760 kg
		N_1 Cl 3			1,760 kg < RM ≤ 3,500 kg
		N_2		3,500 kg < GVW ≤ 12,000 kg	
		N_3		12,000 kg > GVW	

[1] Until Euro IV: 2 subgroups: M1 with GVW ≤ 2,500 kg and M1 with 2,500 kg < GVW ≤ 3,500 kg.

Euro I – Dir 88/77/EEC amended by Dir 91/542/EEC

Exhaust emissions of C.I. engines for vehicles > 25 km/h

Test Cycle	Emissions TA (1992) – FR (1993)	Unit	Engine Power (kW)	
			P ≤ 85[1]	P > 85[1]
ECE 49	CO	g/kWh	4.5 (4.9)	4.5 (4.9)
	HC		1.1 (1.23)	1.1 (1.23)
	NOx		8.0 (9.0)	8.0 (9.0)
	PM		0.612 (0.68)	0.36 (0.40)

[1] In brackets: COP values

Euro II - Dir 88/77/EEC as amended by Dir 91/542/EEC and Dir 96/1/EEC

Test Cycle	Emissions TA (Oct 1995) – FR (Oct 1996)	Unit	Euro II TA – FR[2]
ECE R49-02	CO	g/kWh	4.0
	HC		1.1
	NOx		8.0
	PM		0.15[1]

[1] 0.25 g/kWh for engines with a cylinder swept volume < 0.7 liters and rated power speed > 3,000 rpm and engine power < 85 kW until 30 Sep 97 for TA and 30 Sep 98 for FR.

[2] COP Limits = TA limits.

EUROPEAN UNION

Euro III – Dir 88/77/EC as amended by Dir 1999/96/EC and Dir 2001/27/EC

- Diesel engines are tested on ESC and ELR cycles (see pages 7&8). NOx can be tested on ETC cycle (6.5 g/kWh) if required by TA authority
- Diesel engines fitted with aftertreatment devices (PM filters, De-NOx) are tested on ESC, ELR and ETC cycles.
- Gas engines are tested only on ETC cycle

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

Specific requirements for diesel from Euro III

- NOx measured at the random check points within the control area of the ESC test 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 2 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 – Euro III

Emissions TA: 10/2000 – FR: 10/2001	Unit	Euro III		Euro III – EEV	
		ESC/ELR	ETC	ESC/ELR	ETC
		Diesel only	Diesel / Gas	Diesel only	Diesel / Gas
CO	g/kWh	2.1	5.45	1.5	3.0
HC		0.66	–	0.25	–
NMHC		–	0.78	–	0.40
CH_4 [2]		–	1.6	–	0.65
NOx		5.0	5.0	2.0	2.0
PM		0.1/0.13 [1]	0.16/0.21 [1][3]	0.02	0.02 [3]
Smoke	m^{-1}	0.8	–	0.15	–

[1] 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
[2] For natural gas engines only
[3] Not applicable for gas engines – Euro III stage

EUROPEAN UNION

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: OCT05 – FR: OCT06	Unit	Euro IV		Euro IV – EEV	
		ESC/ELR	ETC	ESC/ELR	ETC
		Diesel only	Diesel / Gas	Diesel only	Diesel / Gas
CO	g/kWh	1.5	4.0	1.5	3.0
HC		0.46	–	0.25	–
NMHC		–	0.55	–	0.40
CH_4 [2]		–	1.1	–	0.65
NOx		3.5	3.5	2.0	2.0
PM		0.02	0.03 [2]	0.02	0.02 [2]
Smoke	m^{-1}	0.5	–	0.15	–

– Diesel engines are tested on ESC, ELR and ETC cycles if required (see pages 7&8)
– Gas engine are tested on ETC cycle

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

Emissions TA: 01OCT08 – FR: 01OCT09	Unit	Euro V		Euro V – EEV	
		ESC/ELR	ETC	ESC/ELR	ETC
		Diesel only	Diesel / Gas	Diesel only	Diesel / Gas
CO	g/kWh	1.5	4.00	1.5	3.0
HC		0.46	–	0.25	–
NMHC		–	0.55	–	0.40
CH_4 [2]		–	1.1	–	0.65
NOx		2.0	2.0	2.0	2.0
PM		0.02	0.03 [2]	0.02	0.02 [2]
Smoke	m^{-1}	0.5	–	0.15	–

For TA and for EEV's, ETC and ESC/ELR tests are applicable (see pages 7&8)

[1] For natural gas engines only
[2] Not applicable for gas fuelled engines – Euro IV Stage

EUROPEAN UNION

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 01Oct05 for new type approvals
- from 01Oct06 for all type approvals

Vehicle Category	Useful Life
N1 - M2	100,000 km or 5 yrs
N2, N3 < 16 tons – M3 > 7.5 tons	200,000 km or 6 yrs
N3 > 16 tons – M3 > 7.5 tons	500,000 km or 7 yrs

Deterioration Factors

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

1) DF's based on service accumulation schedule

DF's 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 and ETC tests.

Vehicle Category	Minimum service accumulation period
N1	100,000 km
N2	125,000 km
N3 w / permissible mass ≤ 16 tons	125,000 km
N3 w / permissible mass > 16 tons	167,000 km
M2	100,000 km
M3 w / permissible mass ≤ 7.5 tons	125,000 km
M3 w / permissible mass > 7.5 tons	167,000 km

2) Alternative: DF's defined in Directive 2005/78/EC

Engine type	Test cycle	CO	HC	NMHC	CH_4	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	–

EUROPEAN UNION

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

Scope: M1, M2, N1, N2 with RM > 2.610 kg
Application dates: TA 31DEC12 - FR 31DEC13

	CO	THC	NMHC	CH4	NOx[1]	NH_3	PM Mass	PM[2] Number
	mg/kWh					ppm	mg/kWh	#/kWh
WHSC (C.I.)	1,500	130			400	10	10	8.0×10^{11}
WHTC (C.I.)	4,000	160			460	10	10	6.0×10^{11}
WHSC (P.I.)	4,000		160	500	460	10	10	[3]

Regulation covers:
- Only world harmonized driving cycles (WHTC, WHSC) are applicable as defined in ECE Regulation Annex 4B.
- Reference fuel specifications for Diesel (B7); Ethanol (ED95) (see page 103&105).
- Access to vehicle OBD and vehicle repair and maintenance information.
- Off-cycle laboratory testing and vehicle testing of engines at type approval.

C.I. Compression Ignition
P.I. Positive Ignition
WHSC, WHTC (see pages 7&9)

[1] Admissible level of NO_2 may be defined later
[2] Measurement procedure to be introduced at a later date
[3] Particle number limit and date of implementation not confirmed yet

EUROPEAN UNION

Conformity of Production; Durability of pollution control devices; In-service conformity

Reference Time Periods and Mileages

Vehicle Category	Ref. Mileage or Duration
M1, N1, M2	160,000 km / 5 years
N2, N3 with a max. technically permissible mass not exceeding 16 tonnes; M3 Class I, Class II, Class A, Class B with a max. technically permissible mass not exceeding 7.5 tonnes	300,000 km / 6 years
N3 with a max. technically permissible mass exceeding 16 tonnes; M3 Class III, Class B with a max. technically permissible mass exceeding 7.5 tonnes	700,000 km / 7 years

Determination of Deterioration Factors (DFs)

Minimum service accumulation distances must be applied to determine the evolution of the different pollutants over mileage. These values are extrapolated to reflect the respective reference mileages.

Minimum service accumulation period	
Category N 1 vehicles	160,000 km
Category N 2 vehicles	188,000 km
Category N 3 vehicles with a max. technically permissible mass not exceeding 16 tonnes	188,000 km
Category N 3 vehicles with a max. technically permissible mass exceeding 16 tonnes	233,000 km

Multiplicative DFs (min 1.0) or additive DFs (min 0.00) can be determined based on this method. Mixing of multiplicative and additive DFs within one set of pollutants is not permitted. Alternatively the assigned mulitiplicative deterioration factors in the table here below can be applied.

Test Cycle	CO	THC[1)]	NMHC	CH4	NOx	NH_3	PM Mass	PM[2)] Number
WHTC	1.3	1.3	1.4	1.4	1.15	1.0	1.05	1.0
WHSC	1.3	1.3	1.4	1.4	1.15	1.0	1.05	1.0

The engines shall meet the respective emission limits for each pollutant, as given in the table of Annex I to Regulation (EC) No 595/2009, after application of the deterioration factors to the test result as measured.

1) Applies in case of a C.I. engine.
2) Applies in case of a P.I. engine.

EUROPEAN UNION

TEC/2018/000516 – Publication – Commission Regulation on HDV fuel consumption and CO_2 emissions

A new European Regulation requiring manufacturers to calculate and declare Heavy Duty Vehicle fuel consumption and CO_2 emissions entered into force on 18 January 2018.

Commission Regulation (EU) 2017/2400 requires vehicle manufacturers to determine the CO_2 emissions and fuel consumption of each new truck before it can be sold, registered or put into service in the EU using the VECTO simulation software. This shall be recorded in a customer information file by the manufacturer and accompany each new vehicle when sold.

Obligations enter force from 1 January 2019 for certain classes, as per Art.2 and Art.24. In summary:

1 July 2019[1)] – for 4x2's over 16t, and 6x2's all weights [see note below];
1 January 2020 – for 4x2's from 7,5t to 16t;
1 July 2020 – for 6x4's and 8x4's all weights.

[1)] This date shall be 1 January 2019 for those vehicles with a production date on or after 1 January 2019. The production date is the date of signature on the CoC or the date of issue of the individual approval certificate. In the case of multi-stage approvals, the Regulation only applies to base vehicles equipped at least with a chassis, engine, transmission, axles and tyres. Supplementary legislation is currently being discussed in Brussels on VECTO monitoring and reporting requirements.

COM(2018)284/976483 – Proposal for a regulation – Commission update on HDV fuel consumption and CO_2 emissions

Following on from the EU statement in January 2018 they have now updated the on-going plan for Truck fuel consumption reduction.

Using the VECTO monitoring tool data in 2019 the EU will regulate each OEM to reduce fuel consumption by 15% by 2025 compared to 2019 levels and a further 15% by 2030.

This is following a similar strategy to Passenger Car legislation / regulation.

The EU expects the transport market will grow by 9% between 2020 and 2030 so it is important to reduce truck fuel consumption in line with this Trucks are the main way in which goods are moved around the EU and IoT is also driving this growth. The EU needs to remain competitive in Truck design and innovation – EU OEM's are strong global players and they need to remain so.

The EU is introducing credits and fines for OEMs' exceeding or beating limits – OEMS can look at their fleet performance and argue where a truck is performing better than the requirement and one that is not – the fleet average needs to be lower.

The EU is also incentivising Low Emission (LEV) and Zero Emission Vehicles (ZEV) – want to push natural gas LNG / CNG or Hydrogen or Electric trucks.

US FEDERAL (EPA)

California and US Environmental Protection Agency (EPA) HD Standards become close to convergence from 2004.

Vehicle Weight Definitions

<table>
<tr><th colspan="2">MY</th><th colspan="6">GVWR (lbs)</th></tr>
<tr><th colspan="2"></th><th colspan="2">6,000</th><th colspan="2">8,500</th><th>14,000</th><th>19,500</th><th>33,000</th></tr>
<tr><td rowspan="2">Federal</td><td rowspan="2"></td><td colspan="2">LDT ≤ 8,500</td><td colspan="4">HDV > 8,500</td></tr>
<tr><td>LLDT ≤ 6,000</td><td>6,000 < HLDT ≤ 8,500</td><td colspan="2">8,500 < LHDDE ≤ 19,500</td><td>19,500 ≤ MHDDE ≤ 33,000</td><td>HHDDE / Urban Bus > 33,000</td></tr>
<tr><td rowspan="5">California</td><td rowspan="2">1994 and earlier</td><td rowspan="4">LDT ≤ 6,000</td><td colspan="5">HDV > 6,000</td></tr>
<tr><td colspan="2">6,000 < HLDT ≤ 8,500</td><td colspan="2">8,500 < LHDDE ≤ 19,500</td><td>19,500 ≤ MHDDE ≤ 33,000</td><td>HHDDE / Urban Bus > 33,000</td></tr>
<tr><td rowspan="2">1995+</td><td colspan="3">6,000 < MDV ≤ 14,000</td><td>8,500 < LHDE-S.I. ≤ 14,000</td><td colspan="2">HDDE-Slcd > 14,000</td></tr>
<tr><td colspan="3">6,000 < MDV ≤ 14,000</td><td>14,000 < LHDDE ≤ 19,500</td><td>19,500 ≤ MHDDE ≤ 33,000</td><td>HHDDE / Urban Bus > 33,000</td></tr>
<tr><td>1995+[1]</td><td colspan="3">6,000 < MDV ≤ 14,000</td><td colspan="3">HDDE-S.I. > ddd14,000</td></tr>
</table>

[1] LEVs, ULEVs, SULEVs, ZEVs only

Testing

Emission testing is generally engine dynamometer based. Chassis certification is available in place of HD Federal Test Procedure (FTP) Transient cycle. 3 sets of tests are required: Transient FTP Test and from MY 2007 (1998 for Consent Decree Manufacturers), Supplemental Emission Test, Not to Exceed standards.

US FEDERAL (EPA)

COMPRESSION IGNITION HD HIGHWAY – Engines & Urban Buses Exhaust Emissions Standards

Year	HC	NMHC	NMHC + NOx	NOx	PM	CO	Idle CO (% exhaust gas flow)	Smoke[1] (%)	Useful Life (hrs / yrs / miles)	Warranty Period (yrs / miles)
	(g/bhp-hr)									
1974-78	–	–	16	–	–	14	–	20 / 15 / 50	–	–
1979-84	1,5	–	10	–	–	25	–	20 / 15 / 50	–	–
1985-87	1,3	–	–	10.7	–	15.5	–	20 / 15 / 50	LHDDE: – / 8 / 110,000 MHDDE: – / 8 / 185,000 HHDDE: – / 8 / 290,,000	–
1988-89	1,3[4]	–	–	10.7	0.6	15.5	0.5[3]	20 / 15 / 50	1990-97 and 1998+ for HC, CO and PM: LHDDE: – / 8 / 110,000 MHDDE: – / 8 / 185,000 HHDDE: – / 8 / 290,000 1994+ urban buses for PM only: LHDDE: – / 10 / 110,000 MHDDE: – / 10 / 185,000 HHDDE: – / 10 / 290,000	5 / 100,000[17]
1990	1,3[4]	–	–	6.0	0.6	15.5	0.5[3]	20 / 15 / 50		
1991-93	1,3	–	–	5.0 [ABT]	0.25 [ABT] 0.10[5]	15.5	0.5[3]	20 / 15 / 50		
1994-97	1,3	–	–	5.0 [ABT]	0.1 [ABT] 0.07[6] 0.05[7]	15.5	0.5[3]	20 / 15 / 50		
1998-2003	1,3	–	–	4.0 [ABT]	0.1 [ABT] 0.05[7]	15.5	0.5[3]	20 / 15 / 50		
2004-2006[8]	–	–	2.4 (or 2.5 with a limit of 0.5 on NMHC)[15] [ABT[9,10]]	–	0.1 0.05[7]	15.5	0.5	20 / 15 / 50	For all pollutants:[16] LHDDE: – / 10 / 110,000 MHDDE: – / 10 / 185,000 HHDDE: 22.000 / 10 / 435,000	LHDDE: 5 / 50,000 All other HDDE: 5 / 100,000[17]
2007 [8,11,12,13,14]	–	0.14[15]	2.4 (or 2.5 with a limit of 0.5 on NMHC)	0.2[15]	0.1 0.01	15.5	0.5	20 / 15 / 50		

US FEDERAL (EPA)

Notes:

The test procedures are the EPA Transient Test Procedure and the EPA Smoke Test Procedure.

1) Percentages apply to smoke opacity at acceleration/lug/peak modes.
2) Standards for 1990 apply only to diesel-fueled heavy-duty engines (HDE). Standards for 1991+ apply to both diesel- and methanol-fueled HDEs. Standards that apply to urban buses specifically are footnoted.
3) This standard applies to the following fueled engines for the following model yrs: methanol – 1990+, natural gas and liquefied petroleum gas (LPG) – 1994+.
4) For petroleum-fueled engines, the standard is for hydrocarbons (HC). For methanol-fueled engines, the standard is for total hydrocarbon equivalent (THCE).
5) Certification standard for urban buses for 1993.
6) Certification standard for urban buses from 1994-95.
7) Certification standard for urban buses from 1996 and later. The in-use standard is 0.07.
8) Load Response Test certification data submittal requirements take effect for heavy-duty diesel engines beginning in model year 2004. The following requirements take effect with the 2007 model year: steady-state test requirement and Not-to-Exceed (NTE) test procedures for testing of in-use engines. On-board diagnostic requirements applicable to heavy-duty diesel vehicles and engines up to 14,000 pounds gross vehicle weight rating (GVWR) phase in from the 2005 through 2007 model yrs.
9) The modified averaging, banking, and trading program for 1998 and later model year engines applies only to diesel cycle engines. Credits generated under the modified program may be used only in 2004 and later model yrs.
10) For heavy-duty diesel engines, there are three options to the measurement procedures currently in place for alternative fueled engines: (1) use a THC measurement in place of an non-methane hydrocarbon (NMHC) measurement; (2) use a measurement procedure specified by the manufacturer with prior approval of the Administrator; or (3) subtract two percent from the measured THC value to obtain an NMHC value. The methodology must be specified at time of certification and will remain the same for the engine family throughout the engines' useful life. For natural gas vehicles, EPA allows the option of measuring NMHC through direct quantification of individual species by gas chromatography.
11) Starting in 2006, refiners must begin producing highway diesel fuel that meets a maximum sulphur standard of 15 parts per million (ppm).
12) Subject to a Supplemental Emission Test (1.0 x Federal Test Procedure [FTP] standard (or Family Emission Limit [FEL]) for nitrogen oxides [NOx], NMHC, and particulate matter [PM]) and a NTE test (1.5 x FTP standard [or FEL] for NOx, NMHC, and PM).
13) EPA adopted the lab-testing and field-testing specifications in 40 CFR Part 1065 for heavy-duty highway engines, including both diesel and Otto-cycle engines. These procedures replace those previously published in 40 Code of Federal Regulations (CFR) Part 86, Subpart N. Any new testing for 2010 and later model yrs must be done using the 40 CFR Part 1065 procedures.
14) Two-phase in-use NTE testing program for heavy-duty diesel vehicles. The program begins with the 2007 model year for gaseous pollutants and 2008 for PM. The requirements apply to diesel engines certified for use in heavy-duty vehicles (including buses) with GVWRs greater than 8,500 pounds. However, the requirements do not apply to any heavy-duty diesel vehicle that was certified using a chassis dynamometer, including medium-duty passenger vehicles with GVWRs of between 8,500 and 10,000 pounds.
15) NOx and NMHC standards will be phased in together between 2007 and 2010. The phase-in will be on a percent-of-sales basis: 50 percent from 2007 to 2009 and 100 percent in 2010.
16) Note that for an individual engine, if the useful life hours interval is reached before the engine reaches 10 yrs or 100,000 miles, the useful life shall become 10 yrs or 100,000 miles, whichever occurs first, as required under Clean Air Act section 202(d).
17) Yrs or miles, whichever comes first but never less than the basic mechanical warranty for the engine family.

US FEDERAL (EPA)

Smoke Test Limits

Mode	Acceleration (A)	Lugging (B)	Peak (C)
Opacity %	20	15	50

Family Emissions Limits GVW ≥ 8.500 lbs (g/bhp.h)

	NOx + NMHC	PM
Before 2007	4.5 or 4.5 w/a limit of 0.5 NMHC (ABT)	0.25
2007 and later	2.4 or 2.5 w/a limit of 0.5 NMHC (ABT)	0.25

Crankcase emissions added to tailpipe level prior to comparison to standard. Under Tier 2, PC, LDV and MDV up to 10.000 lbs used for personal transportation have to be type approved following LDV legislation.

MY 2007 and Later (g/bhp.h)

	Standard	Phase-In MY			
		2007	2008	2009	2010
NOx	0.20	50%	50%	50%	100%
NMHC (E)	0.14	50%	50%	50%	100%
CO	15.5	100%			
PM	0.01	100%			
Formaldehyde	0.01[1)]	100%			

Phase-In Options

For MY 2007-2009 combined NOx+NMHC is possible, as defined in EPA, MY 2004. All other requirements to comply w/ MY 2007 standards.
Max authorised 2006 NOx+NMHC TA: 50% of direct production.

ABT and FEL (g/bhp.h)

MY	Family Emissions Limits	
	NOx	PM
Before 2010	2.0	0.02
2010 and later	0.50	0.02

Supplemental Test (see page 32)

- Weighted average exhaust emissions: max 1.0 times applicable emission standards or FEL.
- If NOx FEL < 1.5 g/bhp.h, gaseous exhaust emissions ≤ steady-state interpolated values (Maximum Allowable Emission Limits MAEL).

1) CARB 1996 -> 0.05

US FEDERAL (EPA)

HD HIGHWAY S.I. ENGINES: EXHAUST EMISSION STANDARDS

Engine or Vehicle	Year	GVW	HC[1]	NMHC[2]	NOx	NOx + NMHC[3]	PM	CO	Idle CO	Formal-dehyde	Useful Life	
		(lbs)	(g/bhp-hr)						(% exhaust gas flow)		(yrs / miles)	(yrs / miles)
Heavy Duty Engines[4]	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	1.1	–	–	10.6	–	14.4	0.5	–		–
		> 14,000	1.9	–	–	10.6	–	37.1		–		–
	1988-90	≤ 14,000	1.1	–	–	6.0	–	14.4	–	–		–
		> 14,000	1.9	–	–	6.0	–	37.1	–	–		–
	1990[5]	≤ 14,000	1.1	–	–	6.0	–	14.4	0.5[10]	–	8 / 110,000[11]	5 / 50,000
		> 14,000	1.9	–	–	6.0	–	37.1		–		
	1991-97[6]	≤ 14,000	1.1[7]	–	–	5.0	–	14.4		–		
		> 14,000	1.9[8]	–	–	5.0	–	37.1		–		
	1998-2004[6]	≤ 14,000	1.1[7]	–	–	4.0[12]	–	14.4		–		
		> 14,000	1.9[8]	–	–		–	37.1		–		
	2005-07[6]	≤ 14,000	1.1[7]	–	1.0[12]	–	–	14.4		–	10 / 110,000	
		> 14,000	1.9[8]	–		–	–	37.1		–		
	2008 +	All	–	0.14	0.20	–	0.01	14.4		–		
Complete Heavy Duty Vehicles[14][17]	2005-07	8,500-10,000	–	0.280[13] g/mi	0.9 g/mi	–	–	7.3 g/mi		–	11 / 120,000	
		10,000-14,000	–	0.330[13] g/mi	1.0 g/mi	–	–	8.1 g/mi		–		
	2008 +[16]	8,500-10,000	–	0.195[15] g/mi	0.2 g/mi	–	0.02 g/mi	7.3 g/mi		0.032 g/mi		
		10,000-14,000	–	0.230[15] g/mi	0.4 g/mi	–	0.02 g/mi	8.1 g/mi		0.040 g/mi		

US FEDERAL (EPA)

1) For methanol-fueled engines the standard is for total hydrocarbon equivalent (THCE).
2) For methanol and alcohol fueled vehicles the standard is for non-methane hydrocarbon equivalent (NMHCE).
3) For methanol fueled engines the standard is for nitrogen oxides (NOx) plus NMHCE.
4) Standards for heavy duty engines are expressed in grams per brake horsepower-hour (g/bhp-hr). Starting with the 1998 model year (MY) crankcase emissions are not allowed.
5) Standards for 1990 apply to gasoline and methanol-fueled engines.
6) Standards for 1991 and later apply to gasoline and methanol engines and are optional for natural gas and Liquefied Petroleum Gas-fueled engines through the 1996 MY.
7) For Natural gas fueled engines the standard is 0.9 g/bhp-hr NMHC.
8) For natural gas fueled engines the standard is 1.7 g/bhp-hr NMHC.
9) The NOx standard is 5.0 for all natural gas-fueled engines.
10) This standard applies to the following engines utilizing aftertreatment technology (except for methanol) for the following MY gasoline/1990+, natural gas and LPG/1991+; methanol/1990+.
Starting in 2005 the engines certified to on-board diagnostics requirements are not required to meet the idle carbon monoxide (CO) standard.
11) Useful life is expressed in yrs or miles, whichever comes first.
Useful life for the 1998 and later NOx standard and for all 2004 standards is 10 yrs or 110,000 miles, whichever comes first.
12) Manufacturers can choose this standard or one of the following options: (1) a standard of 1.5 g/bhp-hr NMHC+NOx that applies to the 2004-2007 MY, with complete HD vehicle standards taking effect in 2005; or (2) a standard of 1.5 g/bhp-hr NMHC+NOx that would apply to the 2003-2007 HD engines and optionally to 2003-2006 complete HD vehicles.
13) Standard is expressed as non-methane organic gas, but compliance can optionally be shown using measurement of NMHC or total hydrocarbon (THC).
14) Complete HD vehicles have the primary load-carrying container or device attached. Incomplete HD vehicles are optionally certified to HD engine or HD chassis standards.
Standards for complete or incomplete HD vehicles are expressed in gram per mil (g/mi). Starting in 2005 (or 2003 or 2004 depending on the selected phase in option; see footnote l), complete HD vehicles under 14,000 lbs gross vehicle weight are tested on chassis-based procedures and must meet these complete HD vehicle standards.
15) Although expressed as NMHC, compliance can optionally be shown using measurement of NMOG or THC.
16) At least 50% of manufacturer's sales must meet these standards in 2008, with 100% required in 2009.
17) Gross vehicle weight ranges are more accurately specified as follows: 8,500 ≤ GVW ≤ 10,000 and 10,000 ≤ GVW < 14,000.
18) Warranty period is expressed in yrs or miles, whichever comes first, but not less than the basic mechanical warranty for the engine family.

US FEDERAL (EPA)

HD HIGHWAY ENGINE: CLEAN FUEL FLEET EXHAUST EMISSION STANDARDS

	Emissions Category	NMHC + NOx	CO	PM	Formaldehyde
		g/bhp-hr			
Federal [1]	LEV (Federal Fuel)	3.8	[2]	[2]	[2]
	LEV (California Fuel)	3.5	[2]	[2]	[2]
	ILEV	2.5	14.4	0.10	0.05
	ULEV	2.5	7.2	0.05	0.025
	ZEV	0	0	0	0

[1] These standards have in effect been superseded by newer, more stringent ones in 40 Code of Federal Regulations (CFR) Part 86. See EPA manufacturer guidance letter on Clean-Fuel Vehicle Standards (CCD-05-12, July 21, 2005), which provides guidance on determining the equivalency of vehicle and engine emissions standards in the CFR Part 86 and Part 88 standards for Clean-Fuel Vehicles.

[2] Exhaust emissions from engines used in heavy-duty low emission vehicles shall meet conventional vehicle standards set forth in Part 86 for total hydrocarbon, carbon monoxide, particulate and organic material hydrocarbon equivalent.

US FEDERAL (EPA)

HD HIGHWAY C.I. and S.I. ENGINES: EVAPORATIVE EMISSION STANDARDS

Engine Type	Year	GVW	Conventional Diurnal + Hot Soak[1]	Three-Diurnal Test Sequence[2]	Supplemental Two-Diurnal Test Sequence[2]	Running Loss[3]	Spitback[3]	Useful Life[4]
		(lbs)	(g/test)			(gpm)	(g/test)	(yrs/miles)
SI	1991-95	≤ 14,000	3.0	–	–	–	–	8 / 110,000
		> 14,000[5]	4.0	–	–	–	–	
	1996-2007 (Enhanced)	≤ 14,000	–	3.0	3.5	0.05	1.0	10 / 120,000
		> 14,000[5]	–	4.0	4.5		–	
	2008+ (Enhanced)	8,500 – 14,000	–	1.4	1.75		1.0	11 / 110,000
		> 14,000[5]	–	1.9	2.3		–	
CI	1996-97	≤ 14,000	–	3.0	–	–	–	LHDDE: 8 / 110,000 MHDDE: 8 / 185,000 HHDDE: 8 / 290,000
		> 14,000[5]	–	4.0	–	–	–	
	1998+[7]	≤ 14,000	–	3.0	3.5	0.05	1.0	
		> 14,000[5]	–	4.0	4.5		–	

1) Applies to gasoline and methanol engines. Standard is hydrocarbon (HC) for gasoline engines, total hydrocarbon equivalent (THCE) for methanol engines.

2) For SI engines, standard applies to gasoline, methanol, natural gas, and liquefied petroleum gas engines. For CI engines, standard applies to methanol, natural gas, and liquefied petroleum gas engines. Standard is THCE for methanol engines, HC for others.

3) 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 for others.

4) Useful life is expressed in years or miles, whichever comes first.

5) Vehicles over 26,000 pounds gross vehicle weight may demonstrate compliance with an engineering design evaluation in lieu of testing.

6) A new enhanced evaporative test procedure applies, which is considerably more stringent than the previous one despite the fact that the standard values do not change from prior years. Gasoline and methanol engines are phased in at the following rates of a manufacturer's sales for the specified MY: 1996: 20% 1997: 40%; 1998: 90%; 1999: 100%.

7) A new enhanced evaporative test procedure applies, which is considerably more stringent than the previous one despite the fact that the standard values do not change from prior years. Methanol-fueled vehicles are phased in at a rate of 90% of a manufacturer's production in 1998 and 100% in 1999.

STATEMENT ON EPA MD & HD GHG PHASE 2 – FROM INFORMATION AVAILABLE AT THE TIME OF PUBLICATION

Portions of the EPA Phase 2 GHG – Currently in a period of Review:

Aug 17, 2017, *The U.S. Environmental Protection Agency (EPA) announced today its intent to revisit provisions of the Phase 2 Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines following concerns raised by stakeholders in the trailer and glider industry.*[1)]

Trailers: After U.S. EPA finalized their Phase 2 rule, the Truck Trailer Manufacturers Association filed a petition with the U.S. Court of Appeals requesting the rescission of the federal Phase 2 trailer standards. This has resulted in a stay of those standards.

Gliders: U.S. EPA has proposed to repeal the glider restrictions contained in the Phase 2 rulemaking. U.S. EPA's final Phase 2 regulations included limits on the number of high-emitting gliders that could be produced. Those limits took effect beginning on January 1, 2018, but in response to a petition from the largest glider manufacturer, U.S. EPA has now proposed rolling back these limits.

The final phase two program promotes a new generation of cleaner, more fuel efficient trucks by encouraging the development and deployment of new and advanced cost-effective technologies. The product of four years of extensive testing and research, the vehicle and engine performance standards would cover **model years 2018-2027** for certain trailers and **model years 2021-2027** for semi-trucks, large pickup trucks, vans, and all types and sizes of buses and work trucks. The final standards are expected to:

- Lower CO_2 emissions by approximately 1.1 billion metric tons;
- Save vehicle owners fuel costs of about $170 billion; and
- Reduce oil consumption by up to two billion barrels over the lifetime of the vehicles sold under the program.

1) www.epa.gov/newsreleases/epa-announces-intent-revisit-provisions-phase-2-heavy-duty-rules
2) www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-greenhouse-gas-emissions-commercial-trucks

CALIFORNIA (CARB)

HD Idling Emissions Reduction Program

- 2008+ GVWR > 14 k lbs must have automatic engine shutoff if.
  a) after 5 min if park. brake on; 15 min if park. brake off.
  b) cert. to 30 g/hr NOx over SET/FTR.
- Sleeper equipped trucks no longer exempted from idling reduction requirement.
- Delay of shutoff for < 30 min allowed for emission dev. performance (dash light requir.).
- Override allowed by PTO (Power Take Off) operation.
  As portion of idling reduction program, auxiliary power supplies are regulated.
- Primary engine certified 2007+:
  APU (Auxiliary Power Unit) to be certified off-road (w/ Level 3 DPF) or routed ahead of primary engine DPF.
- Primary engine 2006 or earlier: APU engine needs to be off-road certified (no DPF required).
  5 min still applies w/in 100 ft of restricted areas.
- Scan tool allowed to extend idling to 60 min for service.
- Fuel fired heaters: must comply w/ LEV requirements for fuel fired heaters
  LEV requirement for shutoff above 40F does NOT apply.

Foreign Trucks required to meet emission limits when entering the State from outside the US.

Modification to Urban Bus Engines and Vehicles Rules

NOx standard for Diesel Hybrid-Electric Buses: 1.8 g/bhp.h MY 2004-2005
PM standard 0.01 g/bhp.h Test Procedure: SAE J2711
Further information can be found in section 1956.1 of title 13, California code of regulations.

ZEB (Zero Emission Bus) Regulation: Modified Nov 07

- Requires operators of fleets ≥ 200 buses on the diesel path to begin Advanced. Demonstration Project with required ZEBs to be placed in revenue service by 01Jan09.
- Delays purchase requirements to 2011 for operators on the diesel path and 2012 for operators on the alternative fuelled bus path.
- Extends the date to fulfill the full purchase requirements to 2026 for all fleets.
- Requires technical review in 2009 by Board.
- Credits available to fleet operators for early deployment of ZEBs.

Portable Emission Measurement Systems (PEMS)

PEMS required since 2009.

CALIFORNIA (CARB)

On-Road Heavy Duty Diesel (In-use) Regulation

The regulation requires diesel trucks and buses to be upgraded to reduce emissions. Heavier trucks must be retrofitted with PM filters beginning 01 Jan 12, and older trucks must be replaced starting 01 Jan 15. By 01 Jan 23 nearly all trucks and buses will need to have 2010 MY engines or equivalent. The regulation applies to nearly all diesel fueled trucks and buses with a gross vehicle weight rating (GVWR) greater than 14,000 pounds. Exemptions to this regulation can be applied to several (13) categories of vehicles.

Compliance Schedule by Engine MY for Vehicles with GVWR 26,000 lbs or less

Compliance Date as of 01 Jan	Existing Engine MY	Requirements
2015	1995 + older	2010 MY emission equivalent
2016	1996	
2017	1997	
2018	1998	
2019	1999	
2020	2003 + older	
2021	2004 – 2006	
2022	N/A	
2023	All Engines	

Compliance Schedule by Engine MY for Vehicles with GVWR > 26.000 lbs

Engine MY	Compliance Date Install PC Filter by	Compliance Date 2010 Engine by
1993 + older	N/A	01 Jan 15
1994-1995	N/A	01 Jan 16
1996-1999	01 Jan 12	01 Jan 20
2000-2004	01 Jan 13	01 Jan 21
2005-2006	01 Jan 14	01 Jan 22
2007 or newer	01 Jan 14 if not OEM equipped	01 Jan 23

Vehicles with GVWR > 26,000 lbs can alternatively opt to comply to BM ACT (Best Available Control Technology) requirements.

CALIFORNIA (CARB)

Phase-In Compliance Schedule for Vehicles with GVWR > 26,000 lbs

Compliance Deadline as of 01 Jan	% of Fleet Complying with PM Bact
2012	30%
2013	60%
2014	90%
2015	90%
2016	100%
2020	All vehicles must comply with section 2025 (g)

There are credits foreseen for: fleets that have downsized, early PM retrofit, hybrid vehicles, early addition of newer vehicles.

School Buses (section 2025(d)(48)) Log Trucks (Section 2025 G)

Compliance Schedule for School Buses

Compliance Deadline as of 01 Jan	% of Fleet Complying with PM Bact
2012	33%
2013	66%
2014	100%

Compliance Schedule for Log Truck Phase-in Option

Compliance Deadline as of 01 Jan	% of Total Fleet with 2010 MY Emissions Equivalent Engines
2012	0%
2013	0%
2014	10%
2015	20%
2016	30%
2017	40%
2018	50%
2019	60%
2020	70%
2021	80%
2022	90%
2023	100%

CALIFORNIA (CARB)

Emission Standards for 2004 and subsequent model Otto-Cycle Medium and Heavy-Duty vehicles [1] (g/bhp.hr)

MY	Emission Cat	NMHC + NOx	NMHC	NOx	CO[8]	HCHO	PM
MD > 8,501 – 14,000 lbs GVW[2][3]							
2004	ULEV	2.4 or 2.5 w / 0.5 NMHC cap[4]	–	–	14.4	0.05	–
	SULEV	2.0	–	–	7.2	0.025	–
2005-2007[6]	ULEV	1.0[4][6]	–	–	14.4	0.05	–
	SULEV	0.5[4][6]	–	–	7.2	0.025	–
2008+[7]	ULEV	–	0.14[6]	0.20[6]	14.4	0.01	0.01
	SULEV	–	0.07[6]	0.10[6]	7.2	0.005	0.005
MD > 14,000 lbs GVW							
2004	–	2.4 or 2.5 w / 0.5 NMHC cap[4]	–	–	37.1	0.05[5]	–
2005-2007	–	1.0	–	–	37.1	0.05[5]	–
2008-2015	–	–	0.14[6]	0.20[6]	14.4	0.01	0.01
2015+[9]	Optional	–	0.14		14.4	0.01	0.01

1) These standards apply to petroleum-fueled, alcohol-fueled, liquefied petroleum gas-fueled and natural gas-fueled Otto-cycle engines. Alcohol-fueled engines have the option of certifying to the organic material hydrocarbon equivalent (OMHCE) or organic material non-methane hydrocarbon equivalent (OMNMHCE) standard.

2) For the 2020 and subsequent MY, MD vehicles 8,501 to 10,000 pounds GVW must certify to the primary emission standards and test procedures for complete vehicles specified in section 1961.2, title 13, CCR.

3) A manufacturer of engines used in incomplete MD vehicles may choose to comply with these standards as an alternative to the primary emission standards and test procedures for complete vehicles specified in section 1961 or 1961.2, title 13, CCR. A manufacturer that chooses to comply with these optional HD engine standards and test procedures shall specify, in the Part I application for certification, an in-use compliance test procedure, as provided in section 2139(c), title 13 CCR.

4) A manufacturer may request to certify to the Option 1 or Option 2 federal NMHC + NOx standards as set forth in 40 CFR 86.005-10(f). However for engines used in MD vehicles the formaldehyde level must meet the standard specified above.

5) This standard only applies to methanol-fueled Otto-cycle engines.

6) A manufacturer may elect to include any or all its MD and HD Otto-cycle engine families in any or all the emissions ABT programs for HDEs, within the restrictions described in section I.15 of these test procedures. For engine families certified to Option 1 or 2 federal standards the FEL must not exceed 1.5 g/bhp-hr. If a manufacturer elects to include engine families certified to the 2005 and subsequent MY standards, the NOx plus NMHC FEL must not exceed 1.0 g/bhp-hr. For engine families certified to the 2008 and subsequent MY standards, the FEL is the same as set forth in 40 CFR 86.008-10(a)(1).

7) A manufacturer may elect to include any or all of its MD or HD Otto-cycle engine families in any or all of the emissions ABT programs for HDEs, within the restrictions described in section I.15 of these test procedures.

8) Idle carbon monoxide: for all Otto-cycle HD engines utilizing aftertreatment techology, and not certified to the on-board diagnostics requirements of title 13, CCR, 1968, et seq, as applicable, the CO emissions shall not exceed 0.50% of exhaust gas flow at curb idle.

9) Optional Low NOx Emission Standards from HD Engines. Manufacturers may choose to produce HD engines that emit less NOx emissions than standard 0.20g/bhp-hr engines. A manufacturer may not include an engine family certified to the optional NOx emission standards in the ABT programs for NOx but may include it for NMHC.

STATEMENT ON CALIFORNIA AIR RESOURCES BOARD MD & HD GHG PHASE 2 – FROM INFORMATION AVAILABLE AT THE TIME OF PUBLICATION

- The U.S. EPA and NHTSA adopted the Phase 2 GHG standards in 2016. The proposed Phase 2 GHG rule for California, including the amendments to the Tractor-Trailer GHG regulation, were approved for adoption by CARB on February 8, 2018, along with a few areas where staff followed up with proposed minor changes on 03 Jul 2018. **The CARB Phase 2 GHG rulemaking will be final in late 2018.**
- Increases to the emissions system warranty period and other related changes to are expected to be finalized and released by May 2019, and go into effect with the 2022 model year.

Overview of Planned CARB and EPA MD & HD GHG Phase 2[1)]

EPA and the National Highway Traffic Safety Administration (NHTSA) are taking coordinated steps to enable the production of a new generation of clean vehicles, through reduced greenhouse gas (GHG) emissions and improved fuel use from onroad vehicles and engines.

Building on the success of the Phase I standards, in August 2016, EPA and NHTSA jointly finalized Phase 2 standards for medium- and heavy-duty vehicles through model year 2027 that will improve fuel efficiency and cut carbon pollution to reduce the impacts of climate change, while bolstering energy security and spurring manufacturing innovation.

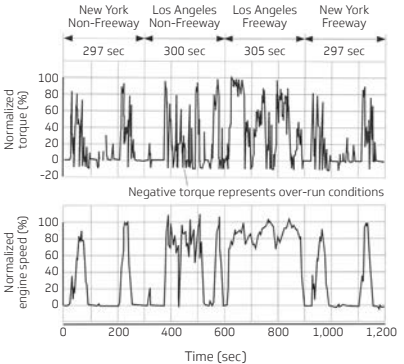
The final phase two program promotes a new generation of cleaner, more fuel efficient trucks by encouraging the development and deployment of new and advanced cost-effective technologies. The product of four years of extensive testing and research, the vehicle and engine performance standards would cover model years 2018-2027 for certain trailers and **model years 2021-2027** for semi-trucks, large pickup trucks, vans, and all types and sizes of buses and work trucks. The final standards are expected to:

- Lower CO_2 emissions by approximately 1.1 billion metric tons;
- Save vehicle owners fuel costs of about $170 billion; and
- Reduce oil consumption by up to two billion barrels over the lifetime of the vehicles sold under the program.

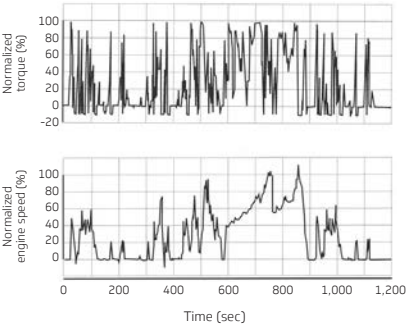
1) www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-greenhouse-gas-emissions-commercial-trucks

FTP TEST CYCLES

Heavy Duty Diesel Transient Cycle (HDDTC)



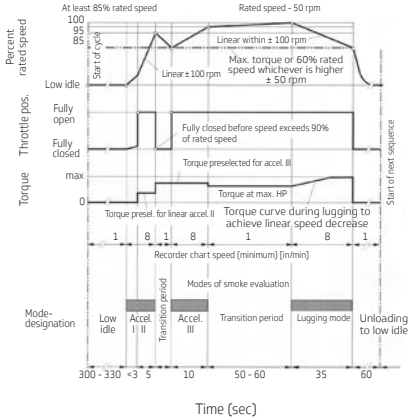
Heavy Duty Gasoline Transient Cycle (HDGTC)



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 min soak and then a repeat of the test cycle.

FTP TEST CYCLES

Diesel Smoke



Supplemental Test Cycles 2004 & 2007

Steady-State Test discrete – Mode Cycle up to MY 2009

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

Supplement Steady-State test (SSS) is based on the EU ESC cycle (see page 7).

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

The alternate procedure for Steady-State test may be used through MY 2009.

The ramped modal test is mandatory in MY 2010 (see page 33).

FTP TEST CYCLES

Ramped Modal test 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 (sec)	Engine Speed	Torque (%)
1a Steady-State	170	Warm Idle	0
1b Transition	20	Linear Transition	Linear Transition
2a Steady-State	170	A	100
2b Transition	20	A	Linear Transition
3a Steady-State	102	A	25
3b Transition	20	A	Linear Transition
4a Steady-State	100	A	75
4b Transition	20	A	Linear Transition
5a Steady-State	103	A	50
5b Transition	20	Linear Transition	Linear Transition
6a Steady-State	194	B	100
6b Transition	20	B	Linear Transition
6a Steady-State	219	B	25
6b Transition	20	B	Linear Transition
8a Steady-State	220	B	75
8b Transition	20	B	Linear Transition
9a Steady-State	219	B	50
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
14a Steady-State	168	Warm Idle	0

Load Response Test 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 a HD diesel engine as it is suddenly loaded, with its fuelling lever, at a given engine operating speed. Results of this test are not compared to emission standards.

FTP TEST CYCLES

Not To Exceed Test (NTE)

As a result of the Consent Decree of 1998, most engine 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.

Limit increases to 1.5 x FTP standard in MY 2007.

No specific drive cycle.

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

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

Evaporative Emission Limits

EPA g/test

MY	GVWR (Lbs)	3 Diurnal + Hot Soak	2 Diurnal + Hot Soak	Running Loss	Refuelling spitback[2)]
1998 MY, +	≤ 14,000	3.0	3.5	0.05	1.0
	> 14,000	4.0	4.5	0.05	–
2008 MY, +	≤ 14,000	1.4	1.75	0.05	1.0
	> 14,000	1.9	2.30	0.05	–

CARB – From 2004 MY, > 8,500 lbs g/test

3 Diurnal + Hot Soak	Running Loss	2 Diurnal + Hot Soak
1.00	0.05	1.25

Phase-in schedule: MY 2004: 40% - MY 2005: 80% - MY 2006, Y: 100%

1) Evaporative emissions limits for NG and LPG fuelled HDDC engines.
2) Methanol – Gas fuelled engines only.

JAPAN

EMISSIONS STANDARDS

Vehicle Categories – Original weight category: vehicles (trucks, buses) > 2.5t GVW
From 2001 standards: gasoline vehicles > 3.5t GVW
From 2005 long term standards: diesel vehicles > 3.5t GVW
Initial Standards

Diesel Engines		CO		HC		NOx		PM		Smoke[3]
		Std[1]	Others[2]	Std[1]	Others[2]	Std[1]	Others[2]	Std[1]	Others[2]	
Japan 88/89 6-Mode test (pm)	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[4] (g/kWh)		7.4	9.2	2.9	3.8	4.5	5.8	2.25	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	–	–	–

1) TA emission standard for type assigned vehicle and vehicle with TA equipment.
2) Emission standard for the vehicles other than defined above.
3) Smoke measured under 3 full load conditions (at 40, 60 or 100% of rated speed) and under free load acceleration.
4) 2.5t-3.5t: introduction in 1997; 3.5t-12t in 1998; > 12t in 1999.

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New Short Term Standards (13-Mode)

Diesel Engines Implementation dates:		2.5t < GVW ≤ 12t		GVW > 12t				
New vehicles		from Oct 03 to Oct 05		from Oct 04 to Oct 05				
Existing and Import vehicles		from Sep 04 to Sep 07		from Sep 05 to Sep 07				
CO (g/kWh)		HC (g/kWh)		NOx (g/kWh)		PM (g/kWh)		Smoke
Std[1]	Others[2]	Std[1]	Others[2]	Std[1]	Others[2]	Std[1]	Others[2]	
3.46	2.22	1.47	0.87	4.22	3.38	0.35	0.18[1]	25%

Implementation dates: GVW > 3,5t								
Domestic new vehicles				from Oct 05				
Existing and Import vehicles				from Sep 07				
	CO		NMHC		NOx		PM		Smoke
(g/kWh)	Std[1]	Others[2]	Std[1]	Others[2]	Std[1]	Others[2]	Std[1]	Others[2]	–
Diesel	2.95	2.22	0.23	0.17	2.7	2.0	0.036	0.027	25%
Gasoline	21.3	16.0	0.31	0.23	0.9	0.7	–	–	–

Evaporative Emissions

Running	25 sec idle 4 x 11-Mode + 3x (24 sec idle + 10-15 Mode)
Hot Soak Loss (HSL)	1 hr 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

Implementation dates: GVW > 3.5t									
Domestic new vehicles					from Oct 05				
Existing and Import vehicles					from Sep 07				
	CO		NMHC		NOx		PM		Smoke
(g/kWh)	Std[1]	Others[2]	Std[1]	Others[2]	Std[1]	Others[2]	Std[1]	Others[2]	–
Diesel	2.95	2.22	0.23	0.17	2.7	2.0	0.036	0.027	25%
Gasoline	21.3	16.0	0.31	0.23	0.9	0.7	–	–	–

Test cycle: New JE05 transient cycle (see page 38)

[1] TA emissions standard for type assigned vehicle and vehicle with TA equipment.
[2] Emissions standard for the vehicles other than defined above.

JAPAN

Post New Long Term Emission Standards

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

PM for diesel vehicle > 12t: 0.5m^{-1} (Opacity meter)

PM for gasoline vehicle apply only to DI vehicles equipped w/ NOx absorber cat

Application date: New domestic vehicles
Diesel: HD > 3,500 kg and ≤ 12,000 kg: 01 Oct 10
Gasoline: 01 Oct 09
Imported vehicles and existing domestic vehicles:
11 months later

Test cycle: JE05 Diesel Sulphur content: 10 ppm

NOx (Std) is planned to be reduced to 0.4 (g/kWh)
for GVW > 7.5 vehicles from 2016
for tractors from 2017
for GVW > 7.5 vehicles from 2018

Trucks and Buses GVW > 3,5t								
	PM		NOx		NMHC		CO	
(g/kWh)	Std	Others	Std	Others	Std	Others	Std	Others
Diesel	0.010	0.013	0.4	0.7	0.17	0.23	2.22	2.95
Gasoline/LPG	0.010	0.013	0.4	0.7	0.23	0.31	16.0	21.3

Implementation date:
GVW > 7.5t (except for tractor): Oct 2016
GVW > 7.5t (tractor): Oct 2017
3.5t < GVW < 7.5t: Oct 2018
Imported vehicles and existing domestic vehicles: 11 month later
Test cycle: WHTC and WHSC mode (Diesel Sulphur content: 10 ppm)

2015 Fuel Efficiency Standards for Diesel Truck and Bus

GVW (t)	3,5-7,5				7,5-8	8-10	10-12	12-14	14-16	16-20	>20
Max load cap (t)	< 1,5	1,5-2	2-3	> 3	–						
2015 FE (km/l)	10.83	10.35	9.51	8.12	7.24	6.52	6.00	5.69	4.97	4.15	4.04

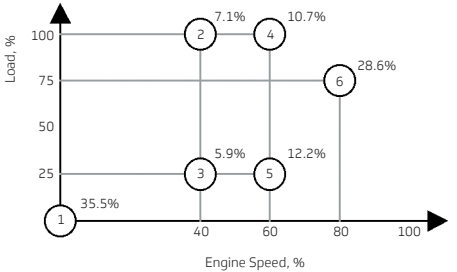
Test mode: Heavy Vehicle Test Mode

JAPAN

TEST CYCLES

6-Mode Cycle (until 2005)

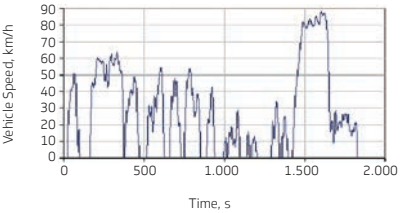
The engine is tested over 6 different speed and load conditions.
The modes are run in sequence and the duration of each mode is 3 main.
Measurements are expressed in ppm (volumetric concentration).



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, that's requiring conversion to engine conditions.

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

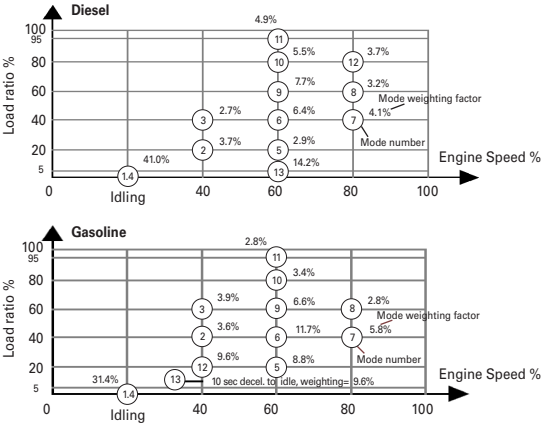


JAPAN

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[1)]	5	20[1)]	0.142	0.096



[1)] Deceleration to idle

PR OF CHINA

- Applicable Standards GB 17691-2005 (equivalent to EU standards).
- CN4 has been implemented nationwide 1st Jan 15 (FR 1.1.2015).
- Regarding HD CN5 implementation, there will be several steps:
  - From 1st Apr 16 (FR), HD diesel CN5 vehicles (only city bus, sanitation and Postal vehicle) are mandatory for China eastern 11 provinces and cities (Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan).
  - From 1st Jan 17 (FR), HD diesel CN5 vehicles (only city bus, sanitation and Postal vehicle) are mandatory for China national wide.
  - From 1st Jul 17 (FR), all HD diesel CN5 vehicles are mandatory for China national wide.
- WHTC is required nationwide for urban vehicles including city bus, postal vehicle and environment/sanitation vehicle as per HJ 689-2014. HJ 437-2008 is the technical specification for on-board diagnostic (OBD) system of compression ignition and gas fueled positive ignition engines of vehicles.

WHTC Limits (g/kWh)										
HJ 689-2014 (Nationwide)					DB 11/694-2013 (Bejing Area)					
	CO	NMHC	NOx	PM		CO	NMHC	CH4[1]	NOx	PM[2]
IV	4.0	0.55	4.20	0.03	IV	4.0	0.55	1.1	3.70	0.03
V	4.0	0.55	2.80	0.03	V	4.0	0.55	1.1	2.80	0.03

[1] Only for gas fuelled PI engines.
[2] Only for CI engines.

BEIJING AREA

- Beijing 5 stage was implemented 1st Jun 15.
- Applicable Regulations DB 11/964-2013 and DB 11/965-2013.
- DB 11/964-2013 is about limits and measurement methods of engines (bench mode methods).
- DB 11/965-2013 is about limits and measurement methods of HD vehicles usings PEMS equipment.

SOUTH KOREA

Euro VI (HD/MD) Start from Jan 15

Test Mode	CO	HC	NOx	PM	NH_3	Nr of Nano Particle [#/kWh]
	[g/kWh]				ppm	
WHSC	1.5	0.13	0.4	0.01	10	$8x10^{11}$
WHTC	5	0.16	0.46	0.01	10	$6x10^{11}$

Euro VI vs Euro V: NOx reduced 80%; PM reduced 50%

New Features	EU	Korea
Introduce Euro VI	New vehicle 01 Jan 13	New vehicle 01 Jan 14
Added number of nano particle	Produced vehicle 01 Jan 14	Produced vehicle 01 Jan 15
Added NH3		

OTHER AREAS OF THE WORLD

Argentina	From 2016 for new models, 2018 for all vehicles Euro V.			
Australia	ADR 80/03 Euro V (Diesel)	from 01 Jan 10 for new vehicles. from 01 Jan 11 for all produced vehicles.		
	US 07 or Japanese 05 Long Term as alternative.			
Brazil	Proconve P-7, equiv Euro V: from 01 Jan 12			
Canada	Canada Tier 2 requirements, similar to US Tier 2 are applicable. No emission averaging, banking and trading option. Fuel consumption and greenhouse gas limits introduced in 2014 and become more stringent until 2018 aligned with US standards.			
Chile	10.2014	New models exc. Urban buss	Metropolitan area	Euro V
	09.2015	Urban buss	–	Euro V
	10.2015	All models	–	US 2004/US 2007 PM
India	From 2010	BS III (Euro III)	ESC / ETC	Nationwide
		BS IV (Euro IV)	ESC / ETC	13 Metropolitan areas
	From 2020	BS VI (Euro VI)	WHSC (CI)/ WHTC (CI/PI)	(Proposal)
	Draft includes adoption of more stringent WHSC & WHTC test cycles, off-cycle emissions testing requirements and specs for PEMS demonstration.			

Indonesia	From 09.2010 Euro II	
Mexico	Diesel	2008 US 2004 or Euro IV
	Regulation	In 2018 a final revision of NOM-044 was adopted, requiring compliance with US 2010 or Euro VI from 2021, with a transition period allowing US 2007/Euro V
	Gasoline	2012 US 2004
	Regulation	NOM-076 since 1995 with amendments in 2012
		Test cycle: FTP (alternately for CNG vehicles: ETC)
Peru	From 2007	Euro III
Russia	From Jan 10/3 Euro IV for new type/all vehicle From Jan 14/6 Euro V for new type/all vehicle	
Singapore	From Jan 14 Euro V or Japan 2009 From Jan 18 Euro VI or Japan 2009 + Euro VI PN	
Switzerland	EU standards adopted	
Thailand	From 2012	Diesel HDV Euro IV (TIS 2315-2551)
Turkey	From 01.2011 Euro V	From Jan 15 Euro VI
Vietnam	From 2018 Euro IV (diesel)	

High precision and closed loop feedback allows real time control of engine gases that impact engine emissions.

Delphi Technologies smart remote actuators are an integral part of our customers' emissions control strategies, covering applications that include variable-geometry and wastegate turbocharger controls, exhaust gas recirculation, exhaust brakes and more.

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EMISSIONS RELATED REQUIREMENTS

EUROPEAN ON-BOARD DIAGNOSTICS

OBD permits rapid detection of failure of emission critical components and systems on vehicles. **EOBD from Euro IV** OBD tests are made over the ESC test cycle where the length of each mode is reduced to 60 seconds.

Condition for malfunction Emissions increase above total threshold	NOx (g/kWh)	PM (g/kWh)
Row A (2005) Euro IV	7.0	0.1
Row B (2008) Euro V		
Row C (EEV)		

OBD Stage I (Euro IV) (Diesel engines only)
TA: from 01 Oct 05 FR: from 01 Oct 06

Monitoring Area
- Reduction in the efficiency of the catalyst
- Complete removal of a catalyst
- 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
TA: from 01 Oct 08 FR: from 01 Oct 09

Monitoring Area: Stage I monitoring area, except monitor for MFF (Major Functional Failure) only not enough + 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 (air flow, EGR, etc) if a malfunction causes increase above threshold.
- Check of circuit continuity of any other emission related component connected to computer, unless monitored otherwise.
- In case of after treatment system using a consumable reagent, monitoring of lack of any required reagent.

General Requirements
- Standardisation of emission related fault codes, data transfer, diagnostic tools and connector according to ISO standards.
- Repair information to be provided, excluding information covered by intellectual rights or that constitutes specific know-how of manufacturers/suppliers.

EUROPEAN ON-BOARD DIAGNOSTICS

Requirements for Correct Operation of NOx Control Measures

Application date: TA from 09 Nov 06 FR from 01 Oct 07

1) In case of engine systems requiring a reagent, NH3 emissions over the applicable emissions test cycle, do not exceed 25 ppm (mean value).
2) Engine NOx control
   - Incorrect operation of the NOx control monitored => MIL (Malfunction Indicator Light)
   - NOx level > 1.5 g/kWh above the applicable NOx limit => MIL
   - NOx level exceed OBD (7.0 g/kWh) => torque limiter activation
   - Record of the fault for at least 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 w/ the fuel reserve level
   - Reagent consumption to be monitored
   - Consumption deviated by > 50% => torque limiter activation
   - Reagent indicator on dashboard
   - Reagent tank empty => torque limiter activation
   - Wrong reagent quality/concentration => torque limiter activation
   - Interruption in reagent dosing activity => torque limiter activation
4) Torque limiter value of:
   - Max 60% of max torque for N3 > 16 tons, M1, M3/III and M3/B > 7.5 tons
   - Max 75% of max torque for N1, N2, N3 ≤ 16 tons, 3.5 < M1 < 7.5 tons M2, M3/I, M3/II, M3/A, M3/B ≤ 7.5 tons

   Deactivation of the torque lim. not feasible by switch or maintenance tool
5) Operating conditions of the emission control monitoring system
   - Ambient temperature: -7°C –> 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

Euro VI OBD (Reg EC N° 595/2009 and (EU) N° 582/2011)

Implementation dates: NEW Types	Implementation dates: ALL Types	OBD Limits (mg/kWh)					
		P.I. Engines	C.I. Engines	All Engines			
		CO	PM	NOx	IUPR[2)]	Reagent quality & consumption monitoring	Additional OBD requirements
31 DEC 12 (phase-in)	31 DE C13		Performance monit.[1)]	1.500	Phase-in[3)]	Phase-in[3)]	N/A
01 SEP 14	01 SEP 15	7.500	–	1.500	Phase-in[3)]	Phase-in[3)]	N/A
31 DEC 15 (gen. req.)	31 DEC 16	7.500	25	1.200	General[4)]	General[4)]	Yes (5)

1) Performance monitoring requirements applies for particulate aftertreatment device.
2) IUPR – In-use performance ratio.
3) Phase-in requirements shall apply.
4) General requirements shall apply.

US ON-BOARD DIAGNOSTICS

EPA HD OBD

Identifies deteriorations and malfunctions to exceed the defined threshold values according to HDDTC or HDGTC procedures.

Driver is notified upon detection (MIL).

Standardization of emission related fault codes, data transfer, diagnostic tools and connector according to ISO standards.

Monitoring Area

- Catalysts and particulate traps
- Engine misfire
- Oxygen sensors
- Evaporative leak
- Other emission control systems (EGR)
- Other emission related engine components

California OBD II compliance as an option.

Note: CARB OBD II compliance is required (i.e. not optional) for many states.

CALIFORNIA (CARB) ON-BOARD DIAGNOSTICS

CARB HD OBD

CCR Title 13, sec. 1971.1: MY 2013+ (OAL Approved by 13 Jul 2013) DIESEL VEHICLES

Monitor Area	Condition for Malfunction
Fuel System - Pressure Control - Injection Quantity - Injection Timing	a) NMHC, NOx, CO: 2,0 x standard b) PM: Standard + 0.02 grams/bhp-hr Note: Failure modes incl. both single & all injectors equally deteriorated
- Feedback Control	a) Fails to begin control within manufacturer-defined time b) Failure or deterioration causes open loop or default operation c) Control max. authority reached & cannot achieve control target
Misfire monitoring during idle (systems w/o combustion sensor) Continuous monitoring for all positive engine torque speed/loads (systems with combustion sensor)	Misfire detection level: - 2013-2015 MY: (Veh. w/comb. Sensor) 5% misfire detection - 2016 MY: 20%; 2017 MY: 50%; 2018+ MY: 100%. Applies low-level misfire detection to ALL vehicles (must detect 5% misfire) - Vehicles w/o comb. Sensor and not part of above phase-in: one or more cylinders continuous misfire Monitoring conditions: - (volumes not incl. in phase-in below): monitoring region restricted by 20-75% of peak torque and up to 75% max engine speed - 2019 MY: 20%; 2020 MY: 50%; 2021 MY: 100%. Monitoring required under ALL positive torque engine speed conditions, except: 1) Positive torque line to 50% max engine speed @ positive torque line 2) 100% max engine speed & (+10%) torque above positive torque line
Exhaust Gas Recirculation (EGR) - Low Flow Rate - High Flow Rate (incl. leaking EGR valve bypass flow) - Slow response (both increasing and decreasing directions) - EGR Cooler Performance (monitoring of multiple coolers requires Executive Officer approval)	a) NMHC, NOx, CO: 2,0 x standard b) PM: Standard + 0.02 grams/bhp-hr

Monitor Area	Condition for Malfunction
- Feedback Control	a) Fails to begin control within manufacturer-defined time. b) Failure or deterioration causes open loop or default operation. c) Control max. authority reached & cannot achieve control target. Note: a) and b) may be met by monitoring of EGR input parameters instead of system, if all equivalent failure modes are detectable
- EGR Catalyst Performance	No detectable amount of constituent oxidation (monitoring not required if no emission impact under driving condition where impact is most likely)
Boost Pressure Control System - Underboost - Overboost - Slow Response (Boost System) - Charge Air Undercooling (monitoring of multiple coolers requires Executive Officer approval)	a) NMHC, NOx, CO: 2,0 x standard b) PM: Standard + 0.02 grams/bhp-hr
- Feedback Control	a) Fails to begin control within manufacturer-defined time b) Failure or deterioration causes open loop or default operation c) Control max. authority reached and cannot achieve control target Note: a) and b) may be met by monitoring of Boost pressure input parameters instead of system, if all equivalent failure modes are detectable
NMHC Converting Catalyst (exl. downstream or PM filter for regen) - Conversion Efficiency - Other Aftertreatment Assistance Function	a) NMHC: 2,0 x standard b) NOx: standard + 0.2 g/bhp-hr Exotherm generation (PM Filter regen assistance): - Catalyst unable to generate sufficient exotherm for regen. Feedgas constituency (SCR assistance): - Catalyst unable to generate sufficient feedgas for proper SCR operation, with no monitoring required if < 15% emission increase and < std. under test cycle NMHC conversion downstream of PM filter for us during regen: - No detectable amount of NMHC conversion Converter downstream of SCR system - No detectable amount of NMHC,CO, NOx or PM conversion capability

CALIFORNIA (CARB) ON-BOARD DIAGNOSTICS

Monitor Area	Condition for Malfunction
NOx Converting Catalyst - Conversion Efficiency	- 2013-2015 MY (not part of below phase-in volume): standard +0.4 g/bhp-hr NOx, 2,0 x standard NMHC - Phase-In Requirement (2014 MY: 20%; 2015 MY: 50%): standard +0.3 g/bhp-hr NOx, 2,0 x standard NMHC - 2016 + MY: standard + 0,2 g/bhp-hr NOx, 2,0 x standard NMHC (Note: carry-over allowed from previous 2014 or 2015 phase-in volume certification for 2016 MY only)
- Selective Catalytic Reduction (SCR)	Reductant Other than engine's fuel: - Insufficient reductant for proper operation - Improper reductant in reservoir/tank - 2013-2015 MY (not part of below phase-in volume): standard +0.4 g/bhp-hr NOx, 2,0 x standard NMHC - Phase-In Requirement (2014 MY: 20%; 2015 MY: 50%): standard +0.3 g/bhp-hr NOx, 2,0 x standard NMHC - 2016 + MY: standard + 0,2 g/bhp-hr NOx, 2,0 x standard NMHC (Note: carry-over allowed from previous 2014 or 2015 phase-in volume certification for 2016 MY only)
- Feedback Control	a) Fails to begin control within manufacturer-defined time b) Failure or deterioration causes open loop or default operation c) Control max. authority reached and cannot achieve control target Notes a) and b) may be met by monitoring of NOx catalyst input parameters instead of system, if all equivalent failure modes are detectable
NOx Adsorber	
- Capability	- NOx: standard + 0.2 g/bhp-hr, 2,0 x standard NMHC
- Active/Intrusion Injection	- Unable to achieve desorption of the NOX adsorber
- Feedback Control	a) Fails to begin control within manufacturer-defined time b) Failure or deterioration causes open loop or default operation c) Control max. authority reached and cannot achieve control target Notes a) and b) may be met by monitoring of NOx adsorber input parameters instead of system, if all equivalent failure modes are detectable
Particulate Matter Filtering Filtering Performance	- 2013-2015 MY (not part of below phase-in volume): higher of 0.05 OR standard + 0.04 g/bhp-hr PM, & maintain relief for certain failure mode exemptions - 2014-2016 MY: 2 options for manufacturers to "phase-in":

Monitor Area	Condition for Malfunction
Option 1	- 2014-2015 MY: 20% higher of 0.05 OR std. + 0.04 g/bhp-hr PM, with NO failure mode relief. Remaining vol. same as 2013 MY - 2016 MY: 20% phase-in volume will carry-over, while remaining vol. must meet higher of 0.03 OR std. + 0.02 g/bhp-hr PM, with NO failure mode relief - 2017+ MY: 100% higher of 0.03 OR std. + 0.02 g/bhp-hr PM, with NO failure mode relief
Option 2	- 2014 MY: carry-over 2013 MY requirements - 2015 MY: 50% higher or 0.03 OR std. + 0.02 g/bhp-hr PM, with NO failure mode relief. Remaining vol. carry-over from 2014 MY - 2016+ MY: 100% higher of 0.03 OR std. + 0.02 g/bhp-hr PM, with NO failure mode relief
- Frequent Regeneration	a) NMHC: 2,0 x standard b) NOx: standard + 0.2 g/bhp-hr
- Incomplete Regeneration	Improper regeneration where regeneration is designed to occur under manufacturer-defined conditions
- NMHC Conversion	NMHC: 2,0 x standard, with no monitoring required if < 15% emission increase AND < standard under test cycle
- Missing Substrate	a) PM filter substrate completely destroyed, removed, or missing b) PM filter assembly replaced with a muffler or straight pipe
- Active/Intrusion Injection	(fuel injected to achieve regen. of the PM): unable to achieve regen.
- Feedback Control	a) Fails to begin control within manufacturer-defined time b) Failure or deterioration causes open loop or default operation c) Control max. authority reached and cannot achieve control target Notes a) and b) may be met by monitoring of PM changes input parameters instead of system, if all equivalent failure modes are detectable
Feedgas Constituency (SCR assistance)	- 2016+ MY: PM Filter unable to generate sufficient feedgas for proper SCR operation, with no monitoring required if < 15% emission increase AND < standard under test cycle.

CALIFORNIA (CARB) ON-BOARD DIAGNOSTICS

Monitor Area	Condition for Malfunction
Exhaust Gas Sensors - All Sensors	a) Lack of circuit continuity b) Out of "normal" range
- A/F Sensors - Upstream of Exhaust Treatment	- Sensor Performance: a) NMHC, CO, NOx: 2,0 x standard b) PM: standard + 0.02 g/bhp-hr - Feedback: failure or deterioration causes an emission control system to stop using that sensor as an input (default or open loop) - Monitoring capability: any characteristic no longer sufficient for use as input to other monitoring strategy
- A/F Sensors - Downstream of Exhaust Treatment	- Sensor Performance: a) NMHC: 2,0 x standard b) NOx: standard + 0.2 g/bhp-hr c) PM: 0.03 g/bhp-hr (FTP or SET), OR std. + 0.02 g/bhp-hr whichever is higher - Feedback: failure or deterioration causes an emission control system to stop using that sensor as an input (default or open loop) - Monitoring capability: any characteristic no longer sufficient for use as input to other monitoring strategy
- NOx & PM Sensor Performance	- 2013-2015 MY (not part of below phase-in volume): std. +0.4 g/bhp-hr NOx, higher of 0.03 g/bhp-hr OR std. +0.02 g/bhp-hr PM - Phase-In Requirement (2014 MY: 20%; 2015 MY: 50%): std. + 0.3 g/bhp-hr NOx, higher of 0.03 g/bhp-hr OR std. + 0.02 g/bhp-hr PM - 2016+ MY: 100%: std. + 0.2 g/bhp-hr NOx, 2,0 x std. NMHC, higher of 0.03 g/bhp-hr OR std. + 0.02 g/bhp-hr PM. Note that manufacturer is allowed to carry-over from previous 2014 or 2015 phase-in volume certification for the 2016 MY only. - Feedback: failure or deterioration causes an emission control system to stop using that sensor as an input (default or open loop) - Monitoring capability: any characteristic no longer sufficient for use as input to other monitoring strategy

Monitor Area	Condition for Malfunction
- Other Exhaust Sensors	Manufacturer to submit plan and obtain approval of Exec. Officer
- Exhaust Gas Sensor Heaters	a) Current or voltage drop no longer with sensor manufacturer's limits for normal operation b) Faults that result in conflict between commanded & actual state of the heater
Variable Valve Timing and/or Control - Target Error (outside crank angle and/or lift tolerance) - Slow Response	a) NMHC, CO, NOx: 2,0 x standard b) PM: standard + 0.02 g/bhp-hr
Cold Start Emission Reduction Strategy	a) Any single commanded element does not respond properly: - By a robustly measurable amount - In the commanded direction - By an amount that is greater than otherwise would have been commanded without the cold start strategy activated b) Deterioration: - NMHC, NOx, or CO: 2,0 x standard - PM: standard + 0.02 g/bhp-hr c) Cold Start System Capability: - Desired effect not achieved (as feasible) - Individual elements/components (when desired effect method is NOT feasible) Note: Fault codes must isolate cold start related failures

CALIFORNIA (CARB) ON-BOARD DIAGNOSTICS

CARB HD OBD – Gasoline Vehicles

Monitor Area	Condition for Malfunction
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 max. authority reached (if based on secondary oxygen sensor, allowed to also verify if control target is achieved prior to failure) b) Fails to begin control within manufactured-define time (time period requires Exec. Officer approval). Engine off strategies must monitor every engine start.
Misfire Continuous monitoring for all positive engine torque speed/loads from the 2nd crankshaft revolution after engine start (150 rpm below normal, warmed-up idle speed)	a) 1,5 x std. (all constituents) - single detection of misfire rate in 1st 1000 engine revolutions - 4 detections of misfire rate in 1000 engine revolution blocks b) Misifre rate that causes temperature to reach catalyst damaging level Specific cylinder DTC required for > 90% misfire occurring on a single cylinder
Exhaust Gas Recirculation (EGR) - Low Flow Rate - High Flow Rate (incl. leaking EGR valve bypass flow)	1,5 x std. (all constituents)
Cold Start Emission Reduction Strategy	a) Any single commanded element does not respond properly: - By a robustly measurable amount - In the commanded direction - By an amount that is greater than otherwise would have been commanded without the cold start strategy activated b) Deterioration and Cold Start System Capability (desired effect not achieved OR individual elements/components not achieved):
	- 1,5 x std. (all constituents) Note: fault codes must isolate cold start related failures
Secondary Air System	1,5 x standard (all constituents) - Both reduction in secondary flow and excessive secondary flow must be monitored - Monitoring required while control strategy is normally activated - When < 1,5 x standard due to failure, must monitor control system for being at the limit of authority to reduce air delivery
Catalyst	Conversion capability: a) NMHC, NOx: 1,75 x standard b) NMHC conversion efficiency below 50% For threshold testing purposes, the catalyst system is to be aged simultaneously (full catalyst volume) - If fuel is shut off for misfiring cylinder, the monitored volume catalyst(s) must be aged simultaneously to the threshold limit, while unmonitored volume must be aged to the end of the vehicle's full useful life
Evaporative System	a) No purge flow (must monitor all purge flow paths) b) Cumulative evaporative system leak ≥ 0.150" orifice (may be revised upward for techn. incapability or < 1,5 x std. with Exec Officer approval) Note: MIL illumination not required for approved alternate indicator for fuel cap missing or improperly secured. Alternate fuel engines require Executive Officer approval of a strategy equating to gasoline
Exhaust Gas Sensor - Primary & Secondary Exhaust Gas Sensors	a) Sensor Performance: - 1,5 x standard (all constituents) - (Primary sensors only): symmetric and asymmetric delay to respond and response rates, lean-to-rich and rich-to-lean (certification data/analysis required) b) Lack of circuit continuity c) Out of "normal" range

CALIFORNIA (CARB) ON-BOARD DIAGNOSTICS

Monitor Area	Condition for Malfunction
	d) Feedback: Failure or deterioration causes fuel system to stop using that sensor as an input (default or open loop) - (Primary sensors only): delayed entry to closed loop e) Monitoring Capability: Any charcteristic no longer sufficient for use as input to other monitoring strategy
- Exhaust Gas Sensor Heaters	a) Current or voltage drop no longer within sensor manufacturer's limit for normal operation b) Faults that result in conflict between commanded and actual state of the heater
Variable Valve Timing and/or Control - Target Error (outside crank angle and/or lift tolerance) - Slow Response	1,5 x std. (all constituents)

CARB HD OBD – ALL Vehicles

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

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

CALIFORNIA (CARB) ON-BOARD DIAGNOSTICS

Monitor Area	Condition for Malfunction
	– Hybrid monitoring requires Exec Officer approval: at a min, 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.
- Vehicle Speed (when received by OBD system from another controller, such as transmission control unit)	a) Monitoring as Input Component, as feasible (refer to "Input Components" below) b) Unable to properly receive vehicle speed information (communication failure) c) If other controller monitors the vehicle speed info & provides "invalid" determination, must handle as default mode of operation (with MIL illumination) for the OBD systems
- Input Components	a) Lack of circuit continuity b) Out of "normal" range c) Irrational sensor value (2-sided monitoring) d) Alternate Strategy Activation (that can affect emissions): – Malfunctions that cause the system to erroneously activate or deactivate – Failures that invoke erroneous control, as feasible (rationality) e) Components used for emission control strategies not specifically addressed by CARB regulations. – Failures that cause the strategy to not operate in its intended manner (delayed enable, erroneous exit, authority limit) f) Camshaft/Crankshaft Position Sensors: – Engines requiring precise cam/crank alignment: improper alignment – Engines equipped with VVT and belt/chain: one or more tooth improper alignment (larger if no emission impact for single tooth)
- Output Components	a) Improper functional response, as feasible b) Circuit continuity faults c) Idle Control System (Gasoline engines w/monitoring strategies based on deviation from target idle speed): – Speed control cannot maintain within 200 rpm above or 100 rpm below the target idle speed – Speed control cannot maintain within the smallest engine speed tolerance range for any other monitor's enable d) Idle Control System (Diesel Engines): – Speed control cannot maintain within +/- 50% of target speed – Speed control cannot maintain within the smallest engine speed tolerance range for any other monitor's enable Idle control cannot achieve the target idle speed with fuel injection quantity within (smallest quantity tolerance range for enabling other monitors) OR (+/- 50% of properly functioning quantity) e) Glow Plugs/Intake Air Heaters: – Improper functional response – Circuit continuity faults – Proper current and voltage drop – Single glow plug no longer operates in manufacturer's limits f) "Wait to Start" Lamp: failures that prevent illumination g) Components used for emission control strategies not specifically addressed by CARB regulations: - Failures that cause the strategy to not operate in its intended manner (delayed enable, erroneous exit, authority limit) h) "Tolerance Compensation": Improper compensation being applied by controller for connected hardware, with no monitoring required if < 15% emission increase AND < std. under test cycle (Executive Officer review/approval required).

CALIFORNIA (CARB) ON-BOARD DIAGNOSTICS

Monitor Area	Condition for Malfunction
'Other' Emission Control Systems	Executive Officer approval required for proposed strategy. Engines utilizing emission control through intake air flow or cylinder charge characteristics: may monitor the shaft (incl. all segments) instead of air flow, 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	2013-2015 MY (not including alternate fueled engines): Full OBD requirements to be met by: – ALL engine ratings within one selected family (highest weighted 2010 MY sales) – One engine rating for remaining families (highest weighted 2013 MY sales) Balance of volume to meet Extrapolated OBD (reduced monitoring requirements – Executive Officer approval required for all monitors) 2016+ MY All engine ratings & families to meet full OBD requirements Alternate Fueled Engines: 2013-2017 MY: EMD & NOx aftertreatment functional monitors 2018 + MY: Full OBD requirements apply Hybrid Vehicles: 2013 MY with base engine certification in 2013 (non-hybrid). Various relief possible, upon Executive Officer approval
In-Use Performance Ratio	Select monitors required to meet minimum ratio ≥ 0,100 2016 + MY: PM Filter/Heater Ratio calculation to be based on General Denominator
Exceptions to Monitoring Requirements	a) Executive Officer may revise emission thresholds or exempt certain PM failure modes (refer to PM monitoring). b) Disablement at (ambient temperature < 20 deg F or component freezing) OR (altitude > 8000 feet): Requires Executive Officer approval. c) Disablement at fuel level ≤ 15% full (OBD system must be capable of detecting faults at the disablement level and Executive Officer approval is required). d) Disablement at battery voltage < 11.0 V (Exec. Officer approval required for use of higher level of low voltage for disable, as well as disablement for high voltage with accompanying voltage monitor). e) Disablement for PTO activation (requires PTO activation time and IM Readiness reset at 750 minutes activation without related monitor completion). f) Exemption from component monitoring if no emissions impact for any reasonable driving condition AND component is not used for other OBD purposes. g) Small volume diesel manufacturers are allowed relaxed phase-in schedules for misfire, NOx catalyst, PM filter, and NOx sensor monitoring.

WWH ON-BOARD DIAGNOSTICS

ECE GTR5 (including Addendum 5)

- generic OBD requirements (Module A) (out of booklet scope)
- specific OBD emission related (Module B)
- in-use performance monitoring (Module C)

The OBD systems will have to

- detect malfunctions
- identify area of these malfunctions
- indicate their occurrence by means of a malfunction indicated (MI)
- store this information in computer memory
- communicate this information off-board

It applies to HD Diesel fuelled C.I. engine systems. OBD test cycle: WHTC (see page 9)

Classification of Malfunctions

Class A: malfunction when OBD threshold limits (OTL) are assumed to be exceeded

Class B1: malfunction can lead to emissions above the OTLs but for which the exact influence on emission 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 Area – Variable valve timing system

Electric, electronic components – Engine Cooling system
Lean NOx trap or NOx adsorber – Selective Catalytic Reduction System
Diesel Oxidation Catalyst – Diesel particulate filter – Exhaust Gas Sensor
Crankcase ventilation system – Fuel System – Air Handling and Turbocharger – Boost pressure control system – EGR – Engine misfire – Idle Speed Control System

Performance Requirement

If WHTC GTR is used for certification purpose, the world harmonized OBD test cycle applies. Relevant regional OTL's have to be applicable accordingly.
Harmonized OBD performance requirements will evolve with the harmonization of the test cycles, the emission limits and the process for calculating the OTL's.

	Step 1	Step 2	Step 3
Test cycles (emissions/OBD)	Non harmonized or harmonized	Harmonized	Harmonized
Emissions limits	Non harmonized	Non harmonized	Harmonized
OTL's calculation process	Non harmonized	Harmonized	Harmonized
OTL's	Regionally defined	Regionally calculated	Harmonized

FUEL CONSUMPTION – CO_2 EMISSIONS

EUROPEAN UNION

(See Page 16)

US FEDERAL

CO_2 and Fuel Consumption Standards

Both EPA's and NHTSA's joint final standards for the 3 main HD regulatory categories are summarized below:

Combination Tractors: The agencies have adopted differentiated standards for 9 sub-categories of combination tractors on 3 attributes: weight class, cab type and roof height. The standards will be in phase to the 2017 levels.

Proposed MY 2017 Combination Tractor Standards

	EPA Emissions Standards [g CO_2/ton-mile]			NHTSA Fuel Consumption Standards [gal/1,000 ton-mile]		
	Low Roof	Mid Roof	High Roof	Low Roof	Mid Roof	High Roof
Day Cab Class 7	104	115	120	10.2	11.3	11.8
Day Cab Class 8	80	86	89	7.8	8.4	8.7
Sleeper Cab Class 8	66	73	72	6.5	7.2	7.1

In addition to vehicle standards, engine-based standards must be met by heavy-heavy-duty (HHD) and medium-heavy-duty (MHD) diesel engines used in combination tractors, (MY fuel consumption standards are voluntary).

FUEL CONSUMPTION – CO_2 EMISSIONS

US FEDERAL

Engine standards for engines installed in tractors units

Engine	MY	CO_2 Emissions (g/bhp-hr)	Fuel Consumption (gallon/100 bhp-hr)
MHD	2014	502	4.93
	2017	487	4.78
HHD	2014	475	4.67
	2017	460	4.52

An optional compliance schedule is available, with more relaxed tractor engine standards to be met from 2013 and numerically identical final standards to be met from 2016.
CO2 emissions are tested on the same engine that is tested for pollutant emissions – typically the highest rated engine within an engine family. While this is the "worst case" rating for meeting pollutant emissions standards, it is typically the rating with the lowest specific CO_2 emissions within the engine family.

HD Pickup Trucks and Vans: The agencies are setting corporate average standards for HD pickup trucks and vans, similar to the approach taken for LD vehicles. Each manufacturer's standard for a MY depends on its sales mix, with higher capacity (payload and towing) having numerically less stringent target levels, and with an added adjustment for 4-wheel drive vehicles. This approach recognises both the inherently higher GHG emissions and fuel consumption of higher-capacity vehicles, and the importance of payload and towing capacity to the owners of these work trucks and vans.

EPA has established standards for this segment in the form of a set of target standard curves, based on a 'work factor' that combines a vehicle's payload, towing capabilities, and whether or not it has 4-wheel drive. The standards will phase in with increasing stringency in each MY from 2014 to 2018. The EPA standards adopted for 2018 include a separate standard to control air conditioning system leakage.

NHTSA is setting corporate average standards for fuel consumption that are equivalent to EPA's standards (though not incl. EPA's final air conditioning leakage standard). To satisfy leadtime requirements under EISA, NHTSA standards will be voluntary in 2014 and 2015. Both agencies are providing manufacturers with 2 alternative phase-in approaches that get equivalent overall reductions. One alternative phases the final standards in at 15-20-40-60-100% in MY 2014-15-16-17-18. The other phases the final standards in at 15-20-67-67-67-100% in MY 2014-25-16-17-18-19.

FUEL CONSUMPTION – CO_2 EMISSIONS

US FEDERAL

Estimated Total Vehicle CO_2 Reductions for HD Pickup Trucks & Vans for Alternative 2

GVWR Class	MY	CO_2 Reduction from 2010 MY Gasoline	CO_2 Reduction from 2010 MY Diesel
LHD 2b-3	2014	1.3%	2.0%
	2015	1.7%	2.7%
HHD	2016	3.4%	5.4%
	2017	5.0%	8.0%
	2018+	8.4%	13.4%

Vocational Vehicles: They consist of a very wide variety of truck and bus types including delivery, refuse, utility, dump, cement, transit bus, shuttle bus, school bus, emergency vehicles, motor homes, tow trucks, and many more. Vocation vehicles undergo a complex build process, with an incomplete chassis often built with an engine and transmission purchases from different manufacturers, which is then sold to a body manufacturer. In these rules, the agencies are regulating chassis manufacturers for this segment.The agencies have divided this segment into 3 regulatory subcategories: Light Heavy (Class 2b through 5), Medium Heavy (Class 6 and 7), Heavy Heavy (Class 8) which is consistent with the engine classification.

Vehicle Standards for Vocational Vehicle (MY 2017)

	CO_2 Emissions $(g/bhp-hr)	Fuel Consumption (gallon/100 bhp-hr)
LH Class 2b-5	373	36.7
MH Class 6-7	225	22.1
HH Class 8	222	21.8

The standards depicted here represent emission reductions from 6 to 9% from the 2010 baseline.

Engine Standards for Engines installed in Vocational Vehicles

Engine	MY	CO_2 Emissions (g/bhp-hr)	Fuel Consumption (gallon/100 bhp-hr)
LHD	2014	600	5.89
	2017	576	5.66
MHD	2014	600	5.89
	2017	576	5.66
HHD	2014	567	5.57
	2017	555	5.45
HH Gasoline	2016	627	7.06

FUEL CONSUMPTION – CO_2 EMISSIONS

US FEDERAL

Testing: the requirements for tractors and vocational vehicles include both engine and vehicle standards. Engine manufacturers are subject to the engine standards. Testing is conducted over one test cycle:

- Tractor engines are tested over the steady-state SET test
- Vocational engines are tested over the FTP transient test

Chassis manufacturers are subject to the vehicle standards. Vehicle standards compliance is typically determined based on a customized, sophisticated vehicle simulation model, called the Greenhouse gas Emission Model (GEM), developed by EPA specifically for this regulation. The regulation does not require chassis testing due to the large variety of vehicle configurations and the scarcity of HD chassis test facilities.

Instead of using a chassis dynamometer as an indirect way to evaluate real-world operation and performance, various characteristics of the vehicle are measured and these measurements are used as inputs to the model. These characteristics relate to key technologies applicable to a given truck category – incl. aerodynamic features, weight reductions, tire rolling resistance, presence of idle-reducing technology, vehicle speed limiters, …

Other Standards and Provisions

N_2O and CH_4 Standards: the regulation introduces emissions standards for nitrous oxide and methane.

- Engine testing (tractors and vocational):
  N_2O = 0.10 g/bhp-hr CH_4 = 0.10 g/bhp-hr
- Chassis testing (pickups and vans, FTP-75 & HFET) :
  N_2O = 0.05 g/mi CH_4 = 0.05 g/mi

Testing requirements start from MY 2015, consistently with the N_2O/CH_4 requirements for LD vehicles. The standards were designed to cap emissions at current levels to prevent N_2O/CH_4 emissions increases in future engines.

A/C Leakage: EPA has adopted standards to assure the low-leakage components are used in air conditioning systems designed for HD pickup trucks and vans, and semi trucks. The standard for larger A/C systems (capacity above 733 g) is measured in percent total refrigerant leakage per year, while the standard for smaller A/C systems (capacity of 733 g or less) is measured in grams of refrigerant leakage per year.

Useful Life: the EPA CO_2 emissions must be met over the engine's and vehicle's useful life. The useful life definitions for engines and for vehicles that use the respective engine categories are identical to those defined for criteria pollutant standards for MY 2004 and later HD engines:
LHDDE – 110,000 / MHDDE – 185,000 / HHDDE – 435,000 miles/10 yrs

FUEL CONSUMPTION – CO_2 EMISSIONS

CHINA

Implementation date from 01 Jul 14 for new certificated vehicles.
Implementation date from 01 Jul 15 for in production vehicles.
C-WTVC cycle is used for the fuel consumption (FC) test which is based on the WHVC with some of the acceleration and deceleration values reduced.

FC Limits for HD Diesel Semi-trailer Towing Vehicle, GB 30510-2014

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

FC Limits for HD Diesel Vehicles, GB 30510-2014

Gross Vehicle Weight (GVW) [kg]	FC Limits [l/100 km]	
	for Truck	for Autodumper
3,500 < GVW ≤ 4,500	13.0	15.0
4,500 < GVW ≤ 5,500	14.0	16.0
5,500 < GVW ≤ 7,000	16.0	17.5
7,000 < GVW ≤ 8,500	19.0	20.5
8,500 < GVW ≤ 10,500	21.5	23.0
10,500 < GVW ≤ 12,500	25.0	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	45.5	49.0

FC Limits for HD Diesel Vehicles, GB 30510-2014

Gross Vehicle Weight (GVW) [kg]	FC Limits [l/100 km]	
	for Bus	for City Bus
3,500 < GVW ≤ 4,500	12.5	14.0
4,500 < GVW ≤ 5,500	13.5	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

Delphi Technologies exhaust sensors enables the clean emission engines of today to stay that way tomorrow...

The core of the exhaust sensors are the ceramic elements developed and produced by Delphi Technologies which are the key to providing accurate information on parameters such as oxygen, soot, ammonia and nitrous oxides to the engine management controller.

Delphi Technologies

NRMM

OFF ROAD ROADMAP

EMISSION STANDARDS FOR NON-ROAD ENGINES IN THE EUROPEAN UNION AND UNITED STATES

EU

Engine Rating kW	Engine Rating hP	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
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																									

Legislation Key					
Unregulated	Tier 1 / Stage I	Tier 2 / Stage II	Tier 3 / Stage IIIA	Tier 4i / Stage IIIB	Tier 4f / Stage IV	Stage V

USA

Engine Rating kW	Engine Rating hP	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
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																									

EUROPEAN UNION

COMPRESSION IGNITION ENGINES – Euro Stage I and Stage II Dir 97/68/EC, amended by Dir 2002/88/EC

Cat	Net Power P (kW)	CO	HC	NOx	PM	TA	NR
		(g/kWh)					
Stage I (engine out emissions)							
A	130-560	5.0	1.3	9.2	0.54	01 Jul 98	01 Jan 99
B	75-130	5.0	1.3	9.2	0.70	01 Jul 98[1]	01 Jan 99[2]
C	37-75	6.5	1.3	9.2	0.85	01 Jul 98[1]	01 Apr 99[2]
Stage II[4]							
E	130-560	3.5	1.0	6.0	0.2	01 Jan 01	01 Jul 02
F	75-130	5.0	1.0	6.0	0.3	01 Jan 02	01 Jul 03
G	37-75	5.0	1.3	7.0	0.4	01 Jan 03	01 Jan 04
D	18-37	5.5	1.5	8.0	0.8	01 Jan 01[3]	01 Jan 02[3]

Test cycle: NRSC (see page 97&98).
ISO 8178-C1 for C.I. engines operated under intermittent speed.
ISO 8178-D2 for C.I. engines operated under constant speed.

[1] 01 Jan 01 for agricultural and forestry tractors.
[2] 01 Jul 01 for agricultural and forestry tractors.
[3] 1 year later for agricultural applications and forestry tractors.
[4] For constant speed engines, implementation date: 01 Jan 07.

EUROPEAN UNION

Euro Stage III and Stage IV Dir 97/68/EC as amended by Dir 2004/26/EC and Dir 2006/105/EC and Dir 2010/26/EU (01 Apr 10)

Test cycle (see pages 97-100)

NRSC: variable speed engines: Stage III A (gaseous pollutants)
NRSC: variable speed engines: Stage III B and Stage IV (gaseous & particulate emissions): ISO 8178-4: 2007 C1; constant speed engines: ISO 8178-4 D2
NRTC: variable speed engines: Stage III B and Stage IV (gaseous & particulate emissions)

Category	Net Power	CO	HC	NOx	PM	TA	NR
	(kW)	(g/kWh)					
Stage IIIA[1)]							
H	130 ≤ P < 560	3.5	NOx + HC: 4.0		0.2	30 Jun 05	31 Dec 05
I	75 ≤ P < 130	5.0	NOx + HC: 4.0		0.3	31 Dec 05	31 Dec 06
J	37 ≤ P < 75	5.0	NOx + HC: 4.7		0.4	31 Dec 06	31 Dec 07
K	19 ≤ P < 37	5.5	NOx + HC: 7.5		0.6	31 Dec 05	31 Dec 06
Stage IIIB							
L	130 ≤ P < 560	3.5	0.19	2.0	0.025	31 Dec 09	31 Dec 10
M	75 ≤ P < 130	5.0	0.19	3.3	0.025	31 Dec 10	31 Dec 11
N	56 ≤ P < 75	5.0	0.19	3.3	0.025	31 Dec 10	31 Dec 11
P	37 ≤ P < 56	5.5	NOx + HC: 4.7		0.025	31 Dec 11	31 Dec 12
Stage IV							
Q	130 ≤ P < 560	3.5	0.19	0.4	0.025	31 Dec 12	31 Dec 13
R	56 ≤ P < 130	5.0	0.19	0.4	0.025	30 Sep 13	30 Sep 14

[1)] Other than constant speed engines.

EUROPEAN UNION

EU Stage V NRMM Emissions – Compression Ignition Engines

Regulation (EU) 2016/1628 entered into force on 06 Oct 2016 and was applicable from 01 Jan 2017 [emissions limits].
Delegated Regulation (EU) 2017/654 with regard to technical and general requirements [test methods, type approval process].
Delegated Regulation (EU) 2017/655 on monitoring of gaseous pollutant emissions[1)]

Engines in category NRE				Limit values[2)]					
(emissions in g/kWh)		Speed		CO	NOx	HC	PM	PN	A
C.I. Engines	0.8 kW	Variable and constant		8	7.5		0.4/0.6	–	1.1
	8-19 kW			6.6	7.5		0.4	–	
	19-37 kW			5.0	4.7		0.015	$1x10^{12}$	
	37-56 kW				4.7				
	56-130 kW				0.4				
	130-560 kW								
P.I. Engines	> 560 kW	Variable		3.5	3.5		0.045	–	6.0
		Constant	Other than Gen-Sets					–	
			Gen-Sets		0.67		0.035	–	

- Test cycles : NRSC & NRTC (see pages 97-100)

1) In Service Monitoring (ISM)
   - Requirement to test engines installed in machines over their normal operating duty cycle using PEMS.
   - Requires ISM emissions to be monitored, reported, and made publicly available – currently there are no specified 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.

2) 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 ISC Monitoring.

EUROPEAN UNION

Agricultural and Forestry Tractors

Dir 74/150/EC, as amended by Dir 2000/25/EC and Dir 2005/13/EC and Dir 2006/96/EC
Dir 97/68/EC, as amended by Dir 2002/88/EC and Dir 2004/26/EC
Engine categories, test cycles and emissions limits: see page 64.

Agricultural and forestry vehicles are covered by EU Regulation 167/2013 which entered into force on January 2016. Article 19 paragraph 3 states the emissions test cycles and limits are set out in Directive 97/68/EC (for NRMM).

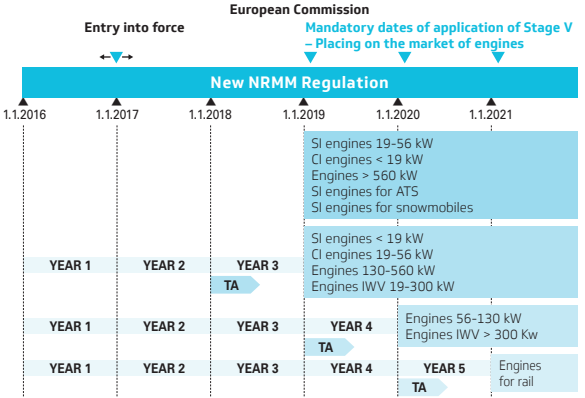
This will be updated to reference the NRMM Stage V emissions in EU Regulation 2016/1628. At the time of publication, this had not been completed but was expected before the end of 2018.

Implementation Dates

Stage	Cat.	Engine Power EP (kw)	TA	NR
Stage I	C	130 ≤ P < 560	01 Jul 98	01 Jul 01
	B	75 ≤ P < 130	01 Jan 01	01 Jul 01
Stage II	D	18 ≤ P < 37	01 Jan 01	01 Jan 02
	G	37 ≤ P < 75	01 Jan 03	01 Jan 04
	F	75 ≤ P < 130	01 Jan 02	01 Jul 03
	E	130 ≤ P < 560	01 Jan 01	01 Jul 02
Stage III A	H, I + K	75 ≤ P < 560 19 ≤ P < 37	31 Dec 05	H: 31 Dec 05 I + K: 31 Dec 06
	J	37 ≤ P < 75	31 Dec 06	31 Dec 07
Stage III B	L	130 ≤ P < 560	31 Dec 09	31 Dec 10
	M + N	56 ≤ P < 130	31 Dec 10	31 Dec 11
	P	37 ≤ P < 56	31 Dec 11	31 Dec 12
Stage IV	Q	130 ≤ P < 560	31 Dec 12	31 Dec 13
	R	56 ≤ P < 130	31 Dec 13	31 Sep 14

EUROPEAN UNION

EU STAGE V NRMM EMISSIONS – Timeplan for Stage V introduction



EU STAGE NRMM EMISSIONS

Regulations is divide into 10 categories:

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 hand-held 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

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.

EUROPEAN UNION

EU STAGE V NRMM EMISSIONS FOR SELECTED SUB-CATEGORIES OF SPARK-IGNITED ENGINES

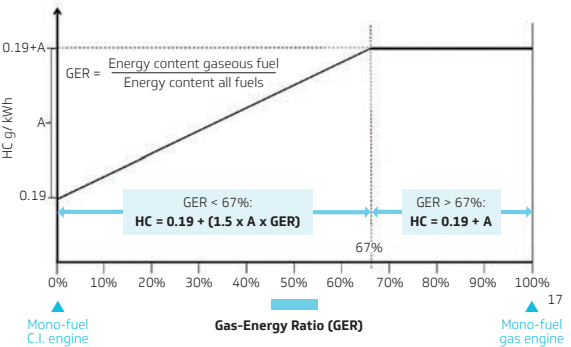
Engine Subcategory	Power Range (kW)	Engine Ignition Type	CO (g/kWh)	HC + NOx (g/kWh)
Stage V emission limits for engine category NRSh				
NRSh-v-1a	0 < P < 19	SI	805	50
NRSh-v-1b			603	72
Stage V emission limits for engine category NRS				
NRS-vr-1a	0 < P < 19	SI	610	10
NRS-vi-1a				
NRS-vr-1b			610	8
NRS-vi-1b				
NRS-v-2a	19 ≤ P ≤ 30		610	
NRS-v-2b	19 ≤ P < 56		4.40[1)]	2.70[1)]
NRS-v-3				

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

Gaseous and Dual-Fuel Engines

All engines other than S.I. < 56 kW

"A" = factor applicable to fully or partially gaseous fueled engines (see page 66).



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.

US FEDERAL (EPA)

Off-Road C.I. Engines

40 CFR part 89, covering mobile non-road diesel engines, used in construction, agricultural and industrial applications. US Non-Road regulations are in the imperial system of units, all standards expressed in g/bhp.h (metric equivalent are shown in brackets).

EPA 96 – Tier 1 Initial Schedule

Applied to engines between 175 bhp (130 kW) and 750 bhp (560 kW).
Other engine categories have been added later. Test cycle: ISO 8178.

Engine Power		MY	NOx	HC	CO	PM
hp	kW		g/bhp.h (g/kWh)			
hp ≥ 750	P ≥ 560	2000	6.9 (9.2)	1.0 (1.3)	8.5	0.40
175 ≤ hp < 130	130 ≤ P < 560	1996	6.9 (9.2)	1.0 (1.3)	8.5	0.40
100 ≤ hp < 175	75 ≤ P < 130	1997	6.9 (9.2)	–	–	–
50 ≤ hp < 100	37 ≤ P < 75	1998	6.9 (9.2)	–	–	–

Smoke: 40 CFR part 86 specifies opacity test measurements w/ limit values A (acceleration): 20% opacity; B (lugging mode): 15%; C (Peak): 50%.

EPA 98 – Final rule – Tier 1 – Tier 2 – Tier 3

Broadly similar to EU standards.

NON-ROAD C.I. ENGINES

Rated Power	Tier	MY	NMHC	NMHC + NOx	NOx	PM	CO	Smoke[1] Life	Useful Period	Warranty
(kW)			(g/kW/hr)						(%)[2]	(hrs/)[2]
< 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[3]	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[4]	3,000/5[5]
	2	2004-2007	–	7.5	–	0.60	5.5			
	4	2008-2012	–	7.5	–	0.30	5.5			
	4	2013+	–	4.7	–	0.03	5.5			
37 ≤ kW < 56	1	1998-2003	–	–	9.2	–	–		8,000/10	3,000/5
	2	2004-2007	–	7.5	–	0.40	5.0			
	3[6]	2008-2011	–	4.7	–	0.40	5.0			
	4	2008-2012	–	4.7	–	0.30	5.0			
(Option 1)	4[7]	2012	–	4.7	–	0.03	5.0			
(Option 2)	4[7]	2013+	–	4.7	–	0.03	5.0			
56 ≤ kW < 75	1	1998-2003	–	–	9.2	–	–			
	2	2004-2007	–	7.5	–	0.40	5.0			
	3	2008-2011	–	4.7	–	0.40	5.0			
	4	2012-2013[8]	–	4.7	–	0.02	5.0			
	4	2014+[9]	0.19	–	0,.40	0.02	5.0			

see footnotes on page 72.

US FEDERAL (EPA)

Rated Power (kW)	Tier	MY	NMHC	NMHC + NOx	NOx	PM	CO	Smoke[1] Life	Useful Period (%)[2]	Warranty (hrs/)[2]
			(g/kW/hr)							
75 ≤ kW < 130	1	1997-2002	–	–	9.2	–	–	20 / 15 / 50	8,000 / 10	3,000 / 5
	2	2003-2006	–	6.6	–	0.30	5.0			
	3	2007-2011	–	4.0	–	0.30	5.0			
	4	2012-2013[8]	–	4.0	–	0.02	5.0			
	4	2014+	0.19	–	0.40	0.02	5.0			
130≤kW <225	1	1996-2002	1.3[10]	–	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[8]	–	4.0	–	0.02	3.5			
	4	2014+[9]	0.19	–	0.40	0.02	3.5			
225≤kW <450	1	1996-2000	1.3[10]	–	9.2	0.54	11.4			
	2	2001-2005	–	6.6	–	0.20	3.5			
	3	2006-2010		4.0	–	0.20	3.5			
	4	2011-2013[8]	–	4.0	–	0.02	3.5			
	4	2014+[9]	0.19	–	0.40	0.02	3.5			
450≤kW <560	1	1996-2001	1.3[10]	–	9.2	0.54	11.4			
	2	2002-2005	–	6.4	–	0.20	3.5			
	3	2006-2010	–	4.0	–	0.20	3.5			
	4	2011-2013[8]	–	4.0	–	0.02	3.5			
	4	2014+[9]	0.19	–	0.40	0.02	3.5			

Rated Power (kW)	Tier	MY	NMHC	NMHC + NOx	NOx	PM	CO	Smoke[1] Life	Useful Period (%)[2]	Warranty (hrs/)[2]
			(g/kW/hr)							
560 ≤ kW < 900	1	2000-2005	1.3[10]	–	9.2	0.54	11.4	20 / 15 / 50	8,000 / 10	3,000 / 5
	2	2006-2010	–	6.4	–	0.20	3.5			
	3	2011-2014	0.40	–	3.5	0.10	3.5			
	4	2015+[9]	0.19	–	3.5[11]	0.4[12]	3.5			
kW > 900	1	2000-2005	1.3[10]	–	9.2	0.54	11.4			

Notes:

- 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 measuring 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 do 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.

US FEDERAL (EPA)

Notes:

1) Smoke emissions may not exceed 20% 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 I.
2) Useful life and warranty period are expressed hours and yrs, whichever comes first.
3) 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.
4) Useful life for constant speed engines with rated speed 3,000 rpm or higher is 5 yrs or 3,000 hrs, whichever comes first.
5) Warranty period for constant speed engines with rated speed 3,000 rmp or higher is 2 yrs or 1,500 hrs, whichever comes first.
6) 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.
7) 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.
8) These standards are phase-out 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.
9) These standards are phased in during the indicated yrs. 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.
10) For Tier 1 engines the standard is for total hydrocarbons.
11) NOx standard for generator sets is 0.67 g/kW-hr.
12) PM standard for generator sets is 0.03 g/kW-hr.

EPA 98 did not establish Tier 3 PM emissions – Tier 2 PM limits carry over.
Also included: averaging, banking and trading (ABT) of emission credits and NTE "Family Emissions limits" (FEL) for emission averaging.
Amended requirements in Sep 07 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. DF's are applicable to all engines.

US FEDERAL (EPA)

Power Rating	Rated engine speed	Useful Life		Recall Testing Period	
		Hrs	Yrs	Hrs	Yrs
< 25 hp (< 19 kW)	all	3,000	5	1,500	2
25-50 hp (19-37 kW)	Constant speed engine ≥ 3,000 rpm	3,000	5	1,500	2
	all others	5,000	7	3,000	5
> 50 hp (> 37 kW)	all	8,000	10	3,000	5

Tier 4 (40 CFR Part 1039)

Application after all the transition and phase-in provisions expire, after MY 2014. Some of these standards also apply for 2014 and earlier MY.

Interim Tier 4 (g/kWh)

Max Engine Power (kW)	PM	NOx	NMHC	NOx + NMHC	CO
< 19	0.40[1]	–	–	7.5	6.6[2]
19 - 56	0.03	–	–	4.7	5.0[3]
56 - 130	0.02	0.40	0.19	–	5.0
130 - 560	0.02	0.40	0.19	–	3.5
> 560 (generator sets)	0.03	0.67	0.19	–	3.5
> 560 (all except generator sets)	0.04	3.50	0.19	–	3.5

1) Optional PM standard EP< 8 kW: hand-startable, air cooled and DI engines: 0.60 g/kWh in 2010, before Tier 2 limits are required.
2) EP < 8 kW: CO: 8.0 g/kWh.
3) EP < 37 kW: CO: 5.5 g/kWh.

Useful Life: No change from Tier 3

Final Tier 4

Tier 4 Emissions Standards – Engines up to 560 kW, g/kWh **(g/bhp-hr)**

Engine Power	Year	CO	NMHC	NMHC + NOx	NOx	PM
kW < 8 (hp < 11)	2008	8.0 (6.0)	–	7.5 (5.6)	–	0.4[1] (0.3)
8 ≤ kW < 19 (11 ≤ hp < 25)	2008	6.6 (4.9)	–	7.5 (5.6)	–	0.4 (0.3)
19 ≤ kW < 37 (25 ≤ hp < 50)	2008	5.5 (4.1)	–		–	0.3 (0.22)
	2013		–		–	0.03 (0.022)
37 ≤ kW < 56 (50 ≤ hp < 75)	2008	5.0 (3.7)	–		–	0.3[2] (0.22)
	2013		–		–	0.03 (0.022)
56 ≤ kW < 130 (75 ≤ hp < 175)	2012-2014[3]	5.0 (3.7)	0.19 (0.14)	–	0.40 (0.30)	0.02 (0.015)
130 ≤ kW < 560 (175 ≤ hp ≤ 750)	2012-2014[4]	3.5 (2.6)	0.19 (0.14)	–	0.40 (0.30)	0.02 (0.015)

1) Hand-startable, air cooled, DI engines may be certified to Tier 2 standards thru 2009 and to an optional PM standard of 0.6 g/kWh starting in 2010.
2) 0.4 g/kWh (Tier 2) if manufacturer complies with the 0.03 g/kWh standard from 2012.
3) 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 31 Dec 14.
4) PM/CO: full compliance from 2011: NOx/HC: 50% engines must comply in 2011-2013.

US FEDERAL (EPA)

Tier 4 Emissions Standards – Engines above 560 kW, g/kWh (g/bhp-hr)

Year	Category	CO	NMHC	NOx	PM
2011	Generator sets > 900 kW	3.5 (2.6)	0.40 (0.30)	0.67 (0.50)	0.10 (0.075)
	All engines except gensets > 900 kW	3.5 (2.6)	0.40 (0.30)	3.5 (2.6)	0.10 (0.075)
2015	Generator sets	3.5 (2.6)	0.19 (0.14)	0.67 (0.50)	0.03 (0.022)
	All engines except gensets	3.5 (2.6)	0.19 (0.14)	3.5 (2.6)	0.04 (0.03)

Tier 4 test cycles (see pages 97-100)

Tier 4 standards have to be met on both NRSC and NRTC cycles
NRTC required from
- 2011 for engines 130-560 kW
- 2012 for engines 56-130 kW
- 2013 for engines < 56 kW

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 109-111)

US FEDERAL (EPA)

Off-Road S.I. engines

Phase I Standards (MY 1997)

(g/kWh)

Class		Engine Displacement	HC + NOx	HC	CO	NOx
I	NH	< 225 cc	16.1	–	519	–
II	NH	≥ 225 cc	13.4	–	519	–
III	H	< 20 cc	–	295	805	5.36
IV	H	≥ 20 cc, < 50 cc	–	241	508	5.36
V	H	> 50 cc	–	161	603	5.36

Phase II Standards

(g/kWh)

Class	HC + NOx	NMHC+NOx (NG engine)	CO	Effective Date
II	16.1	14.8	610	01 Aug 07[1)]
	50	N/A	610	MY 2001
	40	37	610	MY 2001

1) also incl. any Class I eng family produced ≥ 01 Aug 03 before introd. into commerce.

Class	Emissions	2001	2002	2003	2004	2005, +
II	HC + NOx	18.0	16.6	15.0	13.6	12.1
	NMHC + NOx	16.7	15.3	14.0	12.7	11.3
	CO	610	610	610	610	610

Class	Emissions	2002	2003	2004	2005	2006	2007
III	HC + NOx	238	175	113	50	50	50
	CO	805	805	805	805	805	805
IV	HC + NOx	196	148	99	50	50	50
	CO	805	805	805	805	805	805
V	HC + NOx	–	–	143	119	96	72
	CO	–	–	603	603	603	603

Phase III Standards

(g/kWh)

Class	MY	HC (g/kWh)	HC+NOx (g/kWh)	NMHC+NOx (g/kWh)	CO	Useful Life (hrs)			Warranty Period
I	2012	–	10.0 [ABT]	–	–	Residential	Extended Life Residential	Commercial	2 yrs
						125	250	500	
II	2011	–	10.0 [ABT]	–	–	250	500	1,000	
II-V	The Phase III exhaust standards are the same as the long-term Phase II								

US FEDERAL (EPA)

Test Procedure: SAE J1088 cycles A, B and C

Cycle A: non handheld engines to operate at an intermediate speed
Similar to ISO 8178-G1
Cycle B: non handheld engines to operate at rated speed
Similar to ISO 8178-G2
Cycle C: Handheld engines
Similar to ISO 8178-G3
except weighting Mode 1: 85% and Mode 2: 15%

Useful Life Categories for Phase 2 Engines

Emissions must be met throughout the engine useful life. Engine manufacturers have to select the most representative category of in-use operating periods in hours for the majority of engines in the engine family.

Class	Category C	Category B	Category A
NH-IA	50	125	300
NH-IB / NH-I	125	250	500
NH-II	250	500	1,000
H-III / H-IV / H-V	50	125	300

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

Non-hand Held engines < 1.0 liter and > 25 Hp: useful life 1,000 hrs

US FEDERAL (EPA)

NON-ROAD S.I. ENGINES ≤ 19kW (Evaporative Emissions Standards)

Engine Category			MY	Fuel Line Permeation		Fuel Tank Permeation (g/m^2/day at 28° c)	Running Loss	Diurnal (g/gal/day)	Useful Life[3] (yrs)	Warranty Period (yrs)
				Nonroad Fuel lines (g/m^2/day)	Cold-Weather Fuel lines[2] (g/m^2/day)					
Small SI Equipment[4]	Nonhand-held	Class I	2012+	15[5][6]	–	15[6,7,8] (ABT)	Design Standard[9]	Optional[10]	5	2
		Class II	2011+	15[5][6]	–	15[6,7,8] (ABT)	Design Standard[9]	Optional[10]	5	2
	Handheld (Classes III, IV, V)		2010	–	–	15[7,8] (ABT)	–	–	5	2
			2012	15[11]	290					
			2013		275					
			2014		260					
			2015		245					
			2016+		225					
Recreational Vehicles			2008+	15	–	1.5 (ABT)	–	–	5	30 months

Notes:

1) Fuel lines used with handheld small S.I. 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.

2) 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.

3) A 2-year useful life period applies for fuel tanks of fuel caps certified to meet permeation emission standards in 2013 and earlier MY for small S.I. and marine SI.

US FEDERAL (EPA)

[4] The small S.I. engine classes are determined by engine displacement:

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

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

[5] Nonhandheld fuel line permeation requirements begin 01 Jan 09.

[6] Small S.I. 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.

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

[8] 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 nonhandheld 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 2-year useful life (40 CFR 90.129(a)). For nonhandheld equipment using engines at or below 80 cc, these requirements apply starting in the 2012 MY.

[9] Running loss requirements apply to nonhandheld Small S.I. engines and equipment that are not used in wintertime equipment.

[10] Nonhandheld 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.

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

[12] The 30-month warranty period applies to all emission-related components of a vehicle/engine (40 CRF 1051.120). However if a manufacturer chooses component certification for fuel tanks/lines/caps under 40 CFR 1060, the warranty period is at least 2 yrs.

US FEDERAL (EPA)

LARGE S.I. ENGINES (harmonized w/CARB thru MY 2009)

40 CFR Part 1048
Includes non-road equipment such as forklift, sweeper, pump and generator. (g/kWh)

Standards	MY	Testing Type	Emission[1] Standards		Alternate em. Stand. for serve duty engines	
			HC + NOx	CO	HC + NOx	CO
Tier 1	2004 - 2006	Duty cycle[2]	4.0	50.0	4.0	130
		Field testing	5.4	50.0	5.4	130
Tier 2	2007	Duty cycle[2]	2.7	4.4	2.7	130
		Field testing	3.8	6.5	3.8	200

Useful life period: 7 yrs or 5,000 operating hrs, severe duty 7 yrs / 1,500 hrs

Blue Sky series emissions standards

MY 2003, when meeting 2004 requirements
MY 2003-2006, when meeting 2007 requirements
In addition:
HC+NOx ≤ 0.08 g/kWh and CO ≤ 4.4 g/kWh (steady-state and transient tests)
HC+NOx ≤ 1.1 g/kWh and CO ≤ 6.6 g/kWh (field test)

1) 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.
2) Tier 1: Steady-State cycle. Tier 2: Steady-State + transient cycles.

Test Procedure

MY 2004-2006: ISO 8178-4 C2, D2
MY 2007: additional requirements: a/ Warm up Segment
b/ Rransient Segment
c/ Steady-State Segment

Other Requirements

Warranty: minimum 1st half of engine's useful life or 3 yrs.
Diagnostic system: from MY 2007
Monitoring area: air-fuel ratio maintained at λ 1 if control system depends on λ = 1
emission control system malfunction
Diurnal emissions: from MY 2007+
Evaporative HC emissions may not exceed 0.2 grams per gallon of fuel tank capacity.

Running Loss

Liquid fuel in the fuel tank may not reach boiling during continuous engine operation in the final installation at an ambiant temperature of 30°C.
Manufacturers required to perform In-Use testing:
- test min of 4 engines in 25% of engine families
- small engine families (< 500 eng) require min of 2 engines tested
- if manufacturer's total production < 2,000 min testing is 2 engines

CALIFORNIA (CARB)

C.I. Engines

New Vehicles CCR, Title 13, Division 3, Chapter 9, Article 4
Similar to US-EPA regulations
Regulation applies to all diesel cycle engines in the given power categories used for agricultural, forestry, constructional and industrial applications.

In-Use Provisions

Core regulations adopted, some secondary modifications pending.
Applies to mobile equipment > 25 hp. Sets fleet average NOx and PM standards.
LARGE FLEETS (> 5,000 hp total hp) required beginning in CY2010 to:

- Meet declining PM standards each year or apply highest level verified diesel emission control system to 20% of its horsepower.
- Meet declining NOx standards each year or repower/replace a certain portion of their fleet with new equipment.

MEDIUM FLEETS (2,501-5,000 total hp) must meet the same requirements beginning in CY2013.
SMALL FLEETS must meet the PM requirements beginning in CY2015.
Special provisions exist for newer equip., low-use veh., small bus. credit prog.
Surplus Off-road Opt-in for NOx (SOON) program for air districts to require additional NOx reductions for certain large fleets

SMALL OFF-ROAD S.I. ENGINES ≤ 19KW (SORE)

"Small Off-Road Engine" (SORE) = any engine that produces a gross horsepower (hp) < 25 hp (≤ 19 kW for 2005 and later MY) or is designed (e.g. through fuel feed, valve timing, ...) 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 < 25 hp (≤ 19 kW) and models ≥ 25 hp (> 19 kW), only models < 25 hp (≤ 19 kW) 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 preemption 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 C.I. 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 forintermediate 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.

CALIFORNIA (CARB)

C.I. ENGINES TIER 1-3

(g/kWh)

Max Rated Power	Tier	MY	NOx	HC	NMHC + NOx	CO	PM
kW < 8	1	2000-2004	–	–	10.5	8.0	1.0
	2	2005-2007[1]	–	–	7.5	8.0	0.80
8 ≤ kW < 19	1	2000-2004	–	–	9.5	6.6	0.80
	2	2005-2007[1]	–	–	7.5	6.6	0.80
19 ≤ kW < 37	1	2000-2003	–	–	9.5	5.5	0.80
	2	2004-2007[1]	–	–	7.5	5.5	0.60
37 ≤ kW < 56	1	2000-2003	9.2	–	–	–	–
	2	2004-2007[1]	–	–	7.5	5.0	0.40
	3[2]	2008-2011	–	–	4.7	5.0	– 0.40
56 ≤ kW < 75	1	2000-2003	9.2	–	–	–	–
	2	2004-2007	–	–	7.5	5.0	0.40
	3	2008-2011	–	–	4.7	5.0	0.40

(g/kWh)

Max Rated Power	Tier	MY	NOx	HC	NMHC + NOx	CO	PM
75 ≤ kW < 130	1	2000-2002	9.2	–	–	–	–
	2	2003-2006	–	–	7.5	5.0	0.30
	3	2007-2011	–	–	4.7	5.0	– 0.30
130 ≤ kW < 225	1	1996-2002	9.2	1.3	–	11.4	0.54
	2	2003-2005	–	–	6.6	3.5	0.20
	3	2006-2010	–	–	4.0	3.5	– 0.20
225 ≤ kW < 450	1	1996-2002	9.2	1.3	–	11.4	0.54
	2	2003-2005	–	–	6.4	3.5	0.20
	3	2006-2010	–	–	4.0	3.5	– 0.20
450 ≤ kW < 560	1	1996-2002	9.2	1.3	–	11.4	0.54
	2	2003-2005	–	–	6.4	3.5	0.20
	3	2006-2010	–	–	4.0	3.5	– 0.20
kW > 560	1	2000-2005	9.2	1.3	–	11.4	0.54
	2	2006-2010	–	–	6.4	3.5	0.20

[1] Tier 2 standards for propulsion marine C.I. engines below 37 kW in effect beyond the 2007 end date.

[2] Manufacturers may optionally certifiy engine families to the interim Tier 4 standards in Table 1b for this power category through 2012.

CALIFORNIA (CARB)

C.I. ENGINES TIER 4

(g/kWh)

Max Rated Power	MY	Type	PM	NMHC + NOx	NMHC	NOx	CO
kW < 8[1]	2008 and later	FINAL	0.40[2]	7.5	–	–	8.0
8 ≤ kW < 19[1]							6.6
19 ≤ kW < 37[1]	2008 +- 2012	INTERIM	0.30	7.5	–	–	5.5
	2013 and later	FINAL	0.03	4.7			
37 ≤ kW < 56[3]	2008 +- 2012	INTERIM	0.30	4.7	–	–	5.0
	2013 and later	FINAL	0.03				
56 ≤ kW < 75	2012-2014[4]	PHASE-IN	0.02	–	0.19	0.40	5.0
		PHASE-OUT		4.7	–	–	
		or ALT NOx		–	0.19	3.40[5]	
	2015 and later	FINAL				0.40	
75 ≤ kW < 130	2012-2014[4]	PHASE-IN	0.02	–	0.19	0.40	5.0
		PHASE-OUT		4.0	–	–	
		or ALT NOx		–	0.19	3.45	
	2015 and later	FINAL				0.40	
130 ≤ kW < 560	2011-2013	PHASE-IN	0.02	–	0.19	0.40	3.5
		PHASE-OUT		4.0	–	–	
		or ALT NOx		–	0.19	2.00	
	2014 and later	FINAL				0.40	
130 ≤ GEN[6] < 900	2011-2014	INTERIM	0.10	–	0.40	3.50	3.5
	2015 and later	FINAL	0.03		0.19	0.67	
GEN > 900	2011-2014	INTERIM	0.10	–	0.40	0.67	3.5
	2015 and later	FINAL	0.03		0.19		
ELSE[7] > 560	2011-2014	INTERIM	0.10	–	0.40	3.5	3.5
	2015 and later	FINAL	0.04		0.19		

CALIFORNIA (CARB)

Notes:

1) Propulsion marine C.I. engines below 37 kW are not subject to Tier 4 standards or requirements. All previously adopted requirements remain applicable for these engines.
2) Tier 4 PM standard for hand-start, air cooled, direction injection engines below 8 KW is 0.60 g/kWh but is not required until 2010.
3) Engine families in this power category may alternately meet Tier 3 PM standards from 2008-2011 in exchange for introduction final PM standards in 2012.
4) Manufacturers have the option of complying with the Tier 4 standards over a 2 yr period at 50% per year using banked Tier 2 credits or over 3 yr period at 25% per yr without the use of Tier 2 credits. The 3 yr phase-in period is shown. The 2014 MY cannot extend beyond 31 Dec 14, when the 3 yr phase-in option is used.
5) Manufacturers may comply with the standards during the transitional implementation yrs using either a phase-in / phase-out approach or by using the alternate NOx approach. The 3 yr 25% alternate NOx standard is shown in the table. The 2 yrs 50% phase-in Nox standard would be 2,3 g/kWh.
6) 'GEN' refers to generator engines only.
7) 'ELSE' refers to all mobile machinery excluding generator engines.

Criteria for determining NTE Limits[1]

Pollutant	Apply NTE Multiplier of 1.25 when	Apply NTE Multiplier of 1.50 when
NOx	NOx Standard or FEL ≥ 2.5 g/kW-hr	NOx Standard[2] or FEL < 2.5 g/kW-hr
NMHC	NOx Standard or FEL ≥ 2.5 g/kW-hr	NOx Standard[2] or FEL < 2.5 g/kW-hr
NMHC + NOx	NMHC+NOx Standard or FEL ≥ 2.5 g/kW-hr	NMHC+NOx Standard[2] or FEL < 2.5 g/kW-hr
PM	PM Standard or FEL ≥ 0.07 g/kW-hr	PM Standard[2] or FEL[3] < 0.07 g/kW-hr
CO	Always	Never

1) Other provisions described in 2008 and later Test Procedures may affect the calculation of NTE limits.
2) Engines must be certified to these standards without the use of ABT credits.
3) For engines certified to a PM FEL ≤ 0.01 g/kW/hr, the PM NTE limit shall be 0.02 g/kW-hr.

CALIFORNIA (CARB)

Evaporative Emission Requirements

Eng. Displacement	MY	1 day diurnal g HC/day	Fuel Hose ROg/m²/day	Fuel Tank ROg/m²/day	Carbon canister
≤ 80 cc, handheld	2007-2013+			2.0	TP902
> 80 to < 225cc Walk behind Mowers	2006	–	–	–	–
	2007-2008	1,3	–	–	–
	2009-2013+	1,0	–	–	–
> 80 to < 225cc Others	2006	–	15	–	–
	2007-2011	1.20 + 0.056 tank vol (l)		2.5	TP902
	2012-2013+	0.95 + 0.056 tank vol (l)		1.5	
≥ 225cc	2006-2007	–		–	
	2008-2012	1.20 + 0.056 tank vol (l)		2.5	
	2013+	1.20 + 0.056 tank vol (l)		1.5	

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

LARGE OFF-ROAD S.I. ENGINES

Applied to S.I. 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 w/characteristics similar to SORE (< 25 hp): G1

CALIFORNIA (CARB)

LARGE (>19 KW) SPARK IGNITION ENGINE EXHAUST EMISSIONS STANDARDS, HC+NOx / CO g/kWh, (DURABILITY PERIOD)

<table>
<tr><th>Displacement Category</th><th>Test Cycle</th><th>2001</th><th>2002</th><th>2003</th><th>2004</th><th>2005</th><th>2006</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015+</th></tr>
<tr><td>≤ 825 cc</td><td rowspan="2">Steady-state Testing</td><td rowspan="2">–</td><td colspan="9" rowspan="2">12.0 / 549 (1,000 hrs or 2 yrs)</td><td colspan="5">8.0 / 549 (1,000 hrs or 2 yrs)</td></tr>
<tr><td>> 825 cc ≤ 1,0 liter</td><td colspan="4">6.5 / 375 (1,000 hrs or 2 yrs)</td><td>0.8 / 20,6[4] (1,000 hrs or 2 yrs)</td></tr>
<tr><td rowspan="3">> 1,0 liter</td><td>Steady-state Testing</td><td colspan="4">4.0 / 49.6[1]</td><td colspan="3">4.0 / 49.6 (3,500 hrs or 5 yrs)</td><td colspan="2" rowspan="2">2.7 / 4,4[2] (5,000 hrs or 7 yrs)</td><td colspan="5" rowspan="2">0.8 / 20.6 (5,000 hrs or 7 yrs)</td></tr>
<tr><td>Transient Testing</td><td colspan="7">–</td></tr>
<tr><td>Field Testing</td><td colspan="7">–</td><td colspan="5">3.8 / 6.5[3] (5,000 hrs or 7 yrs)</td></tr>
</table>

1) A manufacturer must show that a least 25% of its California engine sales comply with the standards in 2001, 50% in 2002, 75% in 2003.
2) For the 2007-2009 MY manufacturers may alternatively certify their engines according to the following formula: $(HC + NOx) + CO^{0.784} \leq 8.57$.
3) Starting in 2007 manufacturers may apply the following formula to determine alternate emissions standards: $(HC + NOx) + CO^{0.791} \leq 16.78$.
4) For 2011 and subsequent MY large S.I. 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.

CALIFORNIA (CARB)

ABT credits may be generated. No crankcase emissions from MY 2004.

Evaporative Emission Requirements

- HC emis. < 0.2 g/gal
- Non-metallic fuel lines must be made from Cat. 1 materials as defined in SAE J2260

Liquid fuel in tank must not boil when machinery is operated in 30° C ambient

Large S.I. Engine Fleet Average Emission Level Standard: HC+NOx (g/kW-hr)

Fleet Type	01 Jan 09	01 Jan 11	01 Jan 13
Large Forklift	3.2	2.3	1.5
Medium Forklift	3.5	2.7	1.9
Non-Forklift	4.0	3.6	3.4

- Provisions exist for some rental equipment, agricultural equipment, limited use equipment etc.
- Warranty period: shorter of 3 yrs or 2,500 hr OR 3 yrs if no usage meter
- Fleet operator administered in-use compliance program
  - 2001: min 25% sales; 2002 min 50% sales; 2003: min 75% sales
  - MY 2007-2009: alternative certification possible.: $(HC+NOx) \times CO^{0.784} \leq 8.57$
  - From 2007, alternate emission std: (HC+NOx) x CO 0.791 ≤ 16.78

JAPAN

DIESEL POWERED SPECIAL VEHICLES (off-highway)

New Emissions Standards (2014)

Rated Power	NOx		NMHC		CO		PM		Smoke	Implementation dates	
	(g/kWh)										
	Mean	Max	Mean	Max	Mean	Max	Mean	Max	%	New Vehicles	Existing Vehicles
19-37 kW	4.00	5.30	0.70	0.90	5.00	6.50	0.03	0.04	–	01 Oct 16	01 Sep 17
37-56 kW	4.00	5.30	0.70	0.90	5.00	6.50	0.025	0.033	–		
56-75 kW	0.40	0.53	0.19	0.25	5.00	6.50	0.02	0.03	–	01 Oct 15	
75-130 kW	0.40	0.53	0.19	0.25	5.00	6.50	0.02	0.03	–		
130-560 kW	0.40	0.53	0.19	0.25	3.50	4.60	0.02	0.03	–	01 Oct 14	01 Sep 16

Test mode for NOx, NMHC, CO and PM measurement is diesel powered special vehicle 8-mode (see page 89) and NRTC.
Test mode for smoke measurement is diesel powered special vehicle 8-mode and no road acceleration smoke mode.

JAPAN

GASOLINE AND LPG POWERED SPECIAL VEHICLES

New Emission Standards

Rated Power	NOx		NMHC		CO		Implementation dates	
	(g/kWh)							
	Mean	Max	Mean	Max	Mean	Max	New Vehicles	Existing Vehicles
19-560 kW	0.6	0.8	0.6	0.8	20.0	26.6	01 Oct 13	01 Sep 15

SPECIAL VEHICLES FOR SMALL VOLUME PRODUCTION

19-37 kW	Tier 2, Stage IIIA	07 Oct 01	
	Tier 4	01 Oct 13	01 Sep 15
37-56 kW	Tier 3, Stage IIIA	08 Oct 01	
	Tier 4, Stage IIIB	01 Oct 13	01 Nov 14
56-75 kW	Tier 3, Stage IIIA	08 Oct 01	
	Interim Tier 4, Stage IIIB	01 Oct 12	01 Apr 14

– Tier2 and Tier3 represent the standard defined in the CFR Title 40 Chapter1 Part 89.
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.

JAPAN

TEST CYCLES – DIESEL POWERED SPECIAL VEHICLE 8-MODE

Mode	Operations conditions		Min. operation time (min.)	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		10	0.15

- Rated speed is defined as max. engine speed
- Intermediate speed is defined as follows
  - If a speed at max torque is between 60-75% of the rated speed, the speed is defined as the intermediate speed.
  - If a speed at max torque is less than 60% of the rated speed, the 60% of the rated speed is defined as intermediate speed.
  - If a speed at max torque is greater than 75% of the rated speed, the 75% of the rated speed is defined as intermediate speed.

GASOLINE LPG POWERED SPECIAL VEHICLE 7-MODE

Mode	Operations conditions		Min. operation time (min.)	Weighting factor
	Engine Speed (rpm)	Engine Load (%)		
1	Rated speed	25	5	0.06
2	Intermediate speed	10	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

PR OF CHINA

GB 20891-2014 regulates the limits and measurement methods for exhaust pollutants from diesel engines (China Stages III and IV). It is based on the European 2004/26/EC regulation.

- 1 Dec 2014 – all the engines in the process of TA should meet requirement of China Stage III.
- 1 Oct 2015 – all the engines in production and on sale meet requirement of China Stage III.
- 1 Apr 2016 – all the non-road mobile machinery in production, imported and on sale should be installed with engines that meet requirement of China Stage III.

At the date of publication of this book, there is no fixed date for the introduction of China Stage IV limits.

GB 20891-2014 differs from 2004/26/EC as follows

- Net power <19 kW Variable speed engines are tested using ISO 8178 G2 6 mode cycle (see page 98)
- China Stage III corresponds to Euro Stage IIIA
- China Stage IV corresponds to Euro Stage IIIB
- The regulation extends the engine control requirement to P < 19 kW and P > 560 kW

For Stage III, manufacturers have the option to choose NRTC (see page 100) to test variable speed diesel engines with power < 560 kW. For Stage IV, NRTC is used to test variable speed diesel engines with power < 560 kW. The NRTC includes cold-start and hot-start tests. The weights of cold-start and hot-start test results are 10% and 90%, respectively.

Stage III				Stage IV					
Net Po	CO	HC+NOx	PM	Net Po	CO	HC	NOx	HC+NOx	PM
(kW)	(g/kW)			(kW)	(g/kW)				
P > 560	3.5	6.4	0.20	P > 560	3.5	0.40	3.5/0.67[1)]	–	0.10
130 ≤ P > 560	3.5	4.0	0.20	130 ≤ P > 560	3.5	0.19	2.0	–	0.025
75 ≤ P < 130	5.0	4.0	0.30	75 ≤ P < 130	5.0	0.19	3.3	–	0.025
37 ≤ P < 75	5.0	4.7	0.40	56 ≤ P < 75	5.0	0.19	3.3	–	0.025
P < 37	5.5	7.5	0.60	37 ≤ P < 56	5.0	–	–	4.7	0.025
				P < 37	5.5	–	–	7.5	0.60

Durability requirements

Max Power (P), kW	Speed (rpm)	Useful Life (h)	Allowed Minimum Test Time (h)
P ≥ 37	Any speed	8,000	2,000
19 ≤ P < 37	Non-constant speed	5,000	1,250
	Constant speed < 3,000		
	Constant speed > 3,000		
P < 19	Any speed	3,000	750

1) Applicable to mobile power unit with Pmax > 900 kW

SOUTH KOREA

Emissions Limits for Construction Machinery Engines

Implementation Date	Reference Standard	Engine Power	CO	NOx	HC	PM	Test Cycle
		kW	g/kWh				
01 Jan 04[a]	–	19-37	5.5	9.5		0.8	KC1-8[c]
		37-75	5.5	9.2	1.3	0.6	
		75-130	5.0	9.2	1.3	0.6	
		130-225	5.0	9.2	1.3	0.54	
		225-560	5.0	9.2	1.3	0.54	
01 Jan 05[a]	US Tiers 2	19-37	5.5	7.5		0.6	KC1-8
		37-75	5.0	7.5		0.4	
		75-130	5.0	6.6		0.3	
		130-225	3.5	6.6		0.2	
		225-560	3.5	6.4		0.2	
01 Jan 09[a] 01 Jul 13[b]	US Tiers 3	19-37	5.5	7.5		0.6	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	
01 Jan 15[a][b]	US Tiers 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	
		37-75	5.0	4.7		0.03	
		75-130	5.0	0.19	0.4	0.025	
		130-560	3.5	0.19	0.4	0.025	

[a] For construction machinery.
[b] For agricultural machinery.
[c] The clean Air Conservation Act Enforcement Rules which includes limit values, is currently only available in Korean.

INDIA

Diesel Agricultural Tractors Trem II, III and IIIA

Emissions measured over NRSC [ISO 8178 C1] test cycle (see page 97)

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 (m^{-1})
Trem II	–	01 Jun 03	9.00	–	–	15.00	1.00	3.25
Trem III	–	01 Oct 2005	5.50	–	–	9.50	0.80	3.25
Trem III A	kW < 8	01 Apr 2010	5.50	–	–	8.50	0.80	3.25
	8 ≤ kW < 19		5.50	–	–	8.50	0.80	
	19 ≤ kW < 37		5.50	–	–	7.50	0.60	
	37 ≤ kW < 56	01 Apr 2011	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.

INDIA

Diesel Construction Equipment Vehicle (CEV) Bharat Stage II and III

Emissions measured over NRSC (see page 97)
- 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 (m^{-1})
BS-II	kW < 8	01 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	01 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	01 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	0.80	
	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	

Deterioration factors (DF):

Determine by engine test
or by application of fixed DF's

CO	HC	NOx	PM
1.1	1.05	1.05	1.1

Emissions Durability Period

Category (Power Band)	Useful life (hrs) (Emission Durability Period)
< 19 kW	3.000
19 < kW ≤ 37 (constant speed)	3.000
19 < kW ≤ 37 (variable speed)	5.000
> 37 kW	8.000

INDIA

Diesel Agricultural Tractor, Construction Equipment Vehicle and Combine Harvester

Notification G.S.R. 201 (E) dated 05 Mar 18.

Bharat Stage (CEV / TREM) IV

Emissions measured over NRSC & NRTC (see page 97 & 100).

Category (kW)	Applicable with effect from	CO (g/kWh)	HC (g/kWh)	NOx (g/kWh)	PM (g/kWh)
37 ≤ kW < 56	01 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 Band)	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 DF's.

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

INDIA

Bharat Stage (CEV / TREM) V

Emissions measured over:
- NRSC & NRTC for engines ≥ 19 kW to < 560 kW (see page 97 & 100).
- NRSC only for engines <19 kW and those ≥ 560 kW (see page 97).

Category (kW)	Applicable with effect from	CO (g/kWh)	HC (g/kWh)	NOx (g/kWh)	PM (g/kWh)	PM (#/kWh)
P < 8	01.04.2024	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	$1x10^{12}$
37 ≤ P < 56		5.0	4.7 (HC + NOx)		0.015	$1x10^{12}$
56 ≤ P < 130		5.0	0.19	0.4	0.015	$1x10^{12}$
130 ≤ P < 560		3.5	0.19	0.4	0.015	$1x10^{12}$
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

Brazil

PROCONVE MAR-I Limitation on CO, HC, NOx and PM. Introduction:

Construction machinery	≥ 37 kW	01 Jan 15
	All	01 Jan 17
Farm machinery	≥ 75 kW	01 Jan 17
	All	01 Jan 19

Power kW	CO	HC+NOx (g/kWh)	PM
130 ≤ P ≤ 560	3.5	4.0	0.2
75 ≤ P < 130	5.0	4.0	0.3
37 ≤ P < 75	5.0	4.7	0.4
19 ≤ P < 37	5.5	7.3	0.6

Canada

The Canadian emission standards are aligned with the US EPA Tier 4 standards for non-road engines. They are applicable since Jan12

Russia

European emissions standards adopted for mobile non-road engines. Standard targeted from 2014 & 2015 introduction have not been officially confirmed / published.

Date	Standard	EU Equivalent
2000	GOST R41 96-99	Stage I
2014.01[1]	GOST R41 96-2011[2]	Stage III
2017.02.15[1]	TR-TS 031-2012[3]	Stage IIIA for engines below 37 kW; Stage IIIB above 37 kW

[1] Dates not officially confirmed.
[2] Standard not officially published.

Singapore

Imports of new and rebuilt non-road diesel engines must meet EU Stage II, US Tier II or Japan Tier I off-road engine emission standards since 01 Jul 2012.

Switzerland

New engines for off-road vehicles and machinery must meet current EU standards. Particulate Filters are mandatory for Diesel equipment used for Underground (SUVA) construction. Requirements extended 01 Sept 2002 to General (BUWAL) construction engines operated on large sites.

Turkey

Diesel Nonroad engines Faz I, II, IIIA, IIIB and IV.

Standard harmonised with EU regulations but with different implementation dates.

Stage	Power (P), kW	Date4)
Stage I (Faz I)	37 ≤ P ≤ 560	2003.04
Stage II (Faz II)	18 ≤ P ≤ 560	2007.01
Stage IIA (Faz IIIA)	19 ≤ P ≤ 560	2011.01
Stage IIIB (Faz IIIB)	130 ≤ P ≤ 560	2011.01 (optional)
	56 ≤ P ≤ 130	2012.01 (optional)
	37 ≤ P ≤ 56	2018.10
Stage IV (Faz IV)	130 ≤ P ≤ 560	2019.01
	56 ≤ P ≤ 130	2019.10

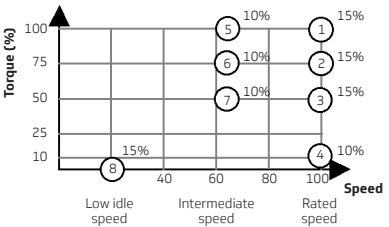
[3] EAEU standard for Agricultural and Forestry tractors.
[4] Market placement.

TEST CYCLES

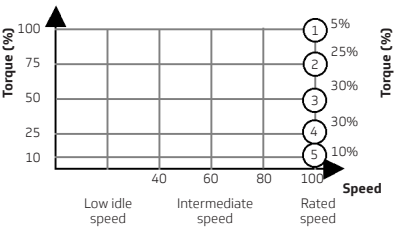
NRSC Test (Non-Road Steady-State Cycle)

With 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 speed or 60% of rated speed if this is higher or 75% if this is lower.

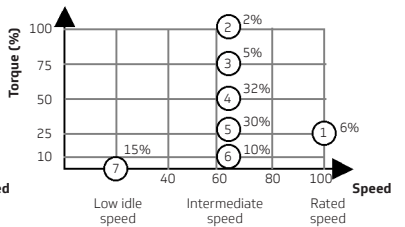
C.I. engines ISO 8178-C1 intermittent



C.I. engines ISO 8178-D2 constant speed

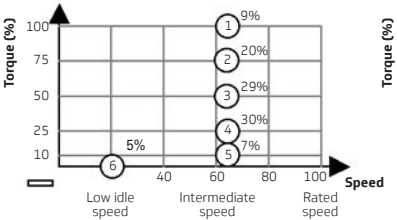


ISO 8178-C2 S.I. engines > 20 kw

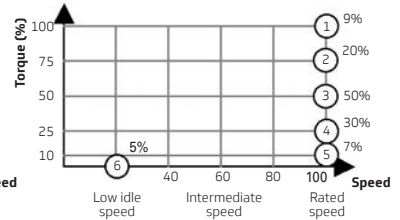


TEST CYCLES

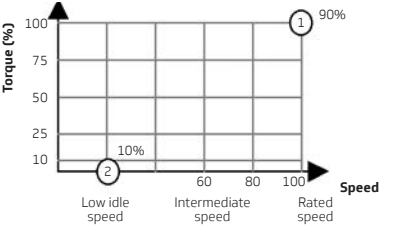
ISO 8178-G1
Non handheld intermediate speed applications



ISO 8178-G2
Non handheld rated speed applications



ISO 8178-G3
Handheld rated speed applications



For stage 1, 0,85 and 0,15 respectively

Intermediate speed is the maximum torque speed if it occurs between 60% and 75% of rated speed
or 60% of the rated speed if this is higher
or 75% of the rated speed if this is lower.

Steady-State Ramped Modal Testing

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

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 max torque at the commanded engine speed.
c) Advance from one mode to the next within a 20 sec 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 max test torque.
b) Advance from one mode to the next within a 20 sec 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.

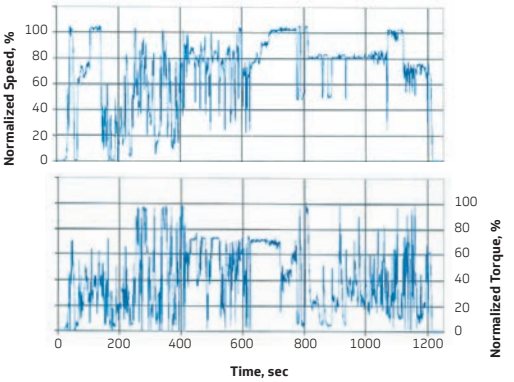
TEST CYCLES

NRTC Test (Non-Road Transient Cycle)

Emissions Test Run

- Engine preparation, Pre-test measurements and Calibration
- NRTC
- Generation engine map (max torque curve)
  Generate reference test cycle
- Run one or more practice cycle as necessary
  to check engine/test cell/emission systems
- Natural or forced cool down
- Ready all systems for sampling (analyser 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.



2018 | 2019

Diagnosable components and engine management systems.

On-Board Diagnostics (OBD) monitor the integrity of emission-related components and engine control functions, as part of state of the art engine management strategies.

Delphi Technologies offers globally certified solutions for OBD at the component and/or system level, as well as emission controls in our software portfolio.

FUELS

This section contains only selected reference test fuel definitions for EU, US, Japan and India markets.

EU REFERENCE TEST FUELS

DIESEL FOR HEAVY DUTY ROAD VEHICLES

Diesel fuel for compression-ignition (CI) engines

Parameter	Unit	Euro I/II/III 88/77/EEC Annex IV		Euro IV/V 2005/55 EC Annex IV		Euro VI EU 582/2011 Annex IX		Test Method
		Min	Max	Min	Max	Min	Max	
Cetane Number	–	49	53	52	54	52	56	EN ISO 5165
Density at 15°C	kg/m³	835	845	833	837	833	837	EN ISO 3675
Distillation 50%	°C	245	–	245	–	245	–	EN ISO 3405
Distillation 95% (90% for Euro I/II/III)	°C	320	340	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 20856 / 20884
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	6	2	4	EN 12916
Copper Corrosion Rating		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	% m/m	–	0.05	–	0.05	–	0.02	EN ISO 12937
Neutralisation (strong acid) nr	mg KOH/g	–	0.20	–	0.02	–	0.10	ASTM D974
Oxidation stability (for middle distillate fuels)	Mass		2.5 mg/100ml		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	EN ISO 12156
FAME content	% vol					6	7	EN 14078

If the manufacturer permits to operate 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

EU REFERENCE TEST FUELS

NATURAL GAS FOR HEAVY DUTY ROAD VEHICLES

Natural Gas / Biomethane

Parameter	Unit	Euro IV, V and VI – 2005/55 EC Annex IV, EU 582/2011 Annex IX			
		Basis	Min	Max	Test Method
Reference fuel G_R					
Methane	%mole	87	84	89	
Ethane	%mole	13	11	15	
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	
Balance	%mole	–	–	1	ISO 6974
N_2	%mole	7.5	6.5	8.5	
Sulphur content	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	mg/m³	–	–	10	ISO 6326-5

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.

EU REFERENCE TEST FUELS

ETHANOL FOR HEAVY DUTY ROAD VEHICLES and NON ROAD MOBILE MACHINERY

Ethanol for diesel engines / dedicated compression-ignition engines (ED95)[1)]

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		
		Min	Max	Min	Max	Test Method
Total alcohol	% m/m	92.4	–	92.4	–	EN15721
Other higher saturated mono-alcohols (C_3 - C_5)	% m/m	–	2	–	2	EN15721
Methanol	% m/m			–	0.3	EN15721
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			–	0.005	ISO 1388-4
Neutralisation (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/kg			–	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

[1)] 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 97/86/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		
		Min	Max	Min	Max	Min	Max	Min	Max	Test Method
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	0.1%	0.2%	–	300[1]	–	10[1]	–	10 mg/kg	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		Class1		EN ISO 2160
Conradson carbon residue (10% DR)	% m/m	–	0.2	–	0.3	–	0.2	–	0.2	EN ISO 10370
Ash content	% m/m	–	0.01	–	0.01	–	0.01	–	0.01	EN ISO 6245
Water content	% m/m	–	0.05	–	0.05	–	0.02	–	0.02	EN ISO 12937
Neutralisation (strong acid) nr	mg KOH/g	0.2	–	–	0.02	–	0.02	–	0.1	ASTM D974
Oxidation stability (for middle distillate fuels)[2]	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

[1] The actual sulphur content shall be recorded.

[2] 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
		Min	Max	
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

Parameter	Unit	Stage V – EU 2017/654 Annex IX			
		Basis	Min	Max	Test Method
Reference fuel G_R					
Methane	%mole	87	84	89	
Ethane	%mole	13	11	15	
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	
Balance	%mole	–	–	1	ISO 6974
N_2	%mole	7.5	6.5	8.5	
Sulphur content	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	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	mg/m³	–	–	10	ISO 6326-5
Wobbe Index (net)	mg/m³	48.2	47.2	49.2	

EU 2017/654 Annex IX section 3.2.2 permits an alternative reference NG fuel supplied from a pipeline with 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.

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

Parameter	Unit	Ultra low sulphur		Low sulphur		High sulphur		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 sulphur, ultra low sulphur	mg/kg	7	15					See 40 CFR 80.580
Total sulphur, low and high sulphur	mg/kg			300	500	800	2.500	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

Fuels with sulphur 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 7-15 ppm sulphur content. The transition from 2000 ppm specification to the 7-15 ppm specification took place 2006-2010 (see Certification Diesel Fuel).

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			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			
Total Aromatic Hydrocarbons	volume %	21.0 - 25.0			ASTM D5769
C6 Aromatics (benzene)	volume %	0.5 - 0.7			
C7 Aromatics (toluene)	volume %	5.2 - 6.4			
C8 Aromatics	volume %	5.2 - 6.4			
C9 Aromatics	volume %	5.2 - 6.4			
C10 + Aromatics	volume %	4.4 - 5.6			
Olefins	mass %	4.0 - 10.0			ASTM D6550.
Ethanol blended	volume %	9.6 - 10.0			
Ethanol confirmatory	volume %	9.4 - 10.2			ASTM D4815 or D5599.
Total Content of Oxygenates Other than Ethanol	volume %	0.1 Maximum			ASTM D4815 or D5599.
Sulphur	mg/kg	8.0 - 11.0			ASTM D2622, D5453 or D7039.
Lead	g/l	0.0026 Maximum			ASTM D3237.
Phosphorus	g/l	0.0013 Maximum			ASTM D3231.
Copper Corrosion		No. 1 Maximum			ASTM D130.
Solvent-Washed Gum Content	mg/100 ml	3.0 Minimum			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	Max. 213	Max. 212	
Hydrocarbon composition: Olefins	volume %	Max. 10	Max. 17.5	ASTM D1319
Hydrocarbon composition: Aromatics	volume %	Max. 35	Max. 30.4	
Hydrocarbon composition: Saturates	volume %	Remainder	Remainder	
Lead	g/l	Max. 0.013	Max. 0.013	ASTM D3237
Phosphorus	g/l	Max. 0.0013	Max. 0.005	ASTM D3231
Total sulphur	mg/kg	Max. 80	Max. 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	K22554,5
	Sulphur	Max. 0,001 (mass %)	
	Benzene	Max. 1 (vol %)	
	MTBE	Max. 7 (vol %)	
	Oxygen[1)]	Max. 1,3 (mass %)	K2536-2,4,6
Diesel	Sulphur	Max. 0,001 (mass %)	
	Cetane Index	Min. 45	K2280
	Distillation at 90%	Max. 360 (deg C)	K2254

[1)] Min 1.3 % and Max 3.7 % for E10 and ETBE22 Fuel.

INDIA REFERENCE TEST FUELS

Diesel fuel For Heavy Duty and Non-Road Mobile Machinery

Parameter	Unit	Heavy-Duty BS III		Heavy-Duty BS IV		EU 582/2011 Annex IX Heavy-Duty BS VI and NRMM BS IV & V		
		Min	Max	Min	Max	Min	Max	Test Method
Cetane Index	–					46	–	EN ISO 4264
Cetane Number	–	52	54	53	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	2.3	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			EN116
Cloud Point	°C					–	-10	EN 23015
Polycyclic Aromatic Hydrocarbons	% m/m	3	6	3	6	2	4	EN 12916
Copper Corrosion Rating 3 hrs @ 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	mg KOH/g					–	0.10	EN ISO 6618
Neutralisation number	mg KOH/g	–	0.02	–	0.02			ASTM D974
Oxidation Stability @ 110°C	Hours					20	–	EN 15751
Oxidation Stability	mg/ml	–	0.025	–	0.025			EN ISO 12205
Lubricity (HFRR Wear Scar @ 60°C)	µm				400	–	400	EN ISO 12156
FAME Content	% vol			Prohibited		6	7	EN 14078

Source: ARAI

INDIA REFERENCE TEST FUELS

Petrol (E5) – BS VI ED95 is same as EU

Parameter	Unit	BS III		BS IV		BS VI		
		Min	Max	Min	Max	Min	Max	Test Method
Research Octane Number RON	–	95	–	95	–	95	–	EN ISO 5164:2005
Motor Octance 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 1320
HC Analysis: Benzene	% v/v	–	1	–	1	–	1	EN 12177
Saturates		Balance		Report		Report		ASTM 1319
Carbon/Hydrogen Ratio		Report		Report		Report		
Carbon/Oxygen Ratio						Report		
Induction Period	Minutes			480	–	480	–	EN ISO 7536
Oxigen Content	% m/m	–	2.3	–	0.1	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/kg	–	5.0	–	5.0	–	5.0	EN 237
Phosphorus Content	mg/kg	–	1.3	–	1.3	–	1.3	ASTM D 3231
Ethanol	% v/v	–		–		4.7	5.3	EN 1601 / EN 13132

Source: ARAI

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	100	99	100	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)					48,2	47,2	49,2				
Reference fuel G_{23}		**Reference fuel G_{20}**			**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}**			**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	mg/m³	–	–	50	–	–	10	–	–	10	ISO 6326-5
Wobbe Index (net)					39.4	38.2	40.6				

Source: ARAI

GLOSSARY

ABT	Average Banking & Trading
CI	Compression Ignition Engine
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 (EU)
FE	Fuel Economy (US)
FEL	Family Emission Limits
FR	First Registration, entry into service
FTP	Federal Test Procedure
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
LDT	Light Duty Truck
LDV	Light Duty Vehicle = passenger car
LEV	Low Emission Vehicle (LEV1, LEV2)
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
NTE	Not To Exceed
OBD	On-board Diagnostic
OMHCE	Organic Material Hydrocarbon Equivalent
OTL	OBD Threshold Limit
PEMS	Portable Emissions Measuring System
PI	Positive Ignition Engine
PM	Particulate Matter
PMP	Particulate Measurement Program
PN	Particulate Number
SCR	Selective Catalytic Reduction
SHED	Sealed House for Evaporation Determination
SORE	Small Off-Road Engine
SULEV	Super Ultra Low Emission Vehicle
TA	Type Approval

THCE	Total Hydrocarbon Equivalent
ULEV	Ultra Low Emission Vehicle (ULEV1, ULEV2)
WWH-OBD	Worldwide Harmonized On-board Diagnostics
ZEV	Zero Emissions Vehicle

TEST CYCLES

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
HDGTC	Heavy Duty Gasoline Transient Cycle
SET	Steady-state Emissions Test
WHSC	Worldwide Heavy Duty Steady-state Cycle
WHTC	Worldwide Heavy Duty Transient Cycle
WHVC	World Harmonised Vehicle Cycle

ADMINISTRATIONS & ASSOCIATIONS

CARB	California Air Resource Board
ECE	Economic Commission for Europe
EPA	US Environmental Protection Agency
EU	European Union
NHTSA	US National Highway Traffic Safety Administration

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