Worldwide Emissions Standards

Heavy Duty and Off-Highway Vehicles

DELPHI

Innovation for the Real World

2015 | 2016

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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

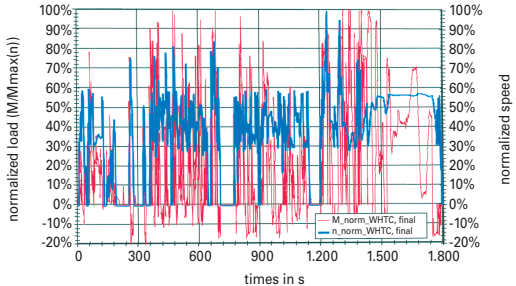
The GTR does not contain emission limit values.

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

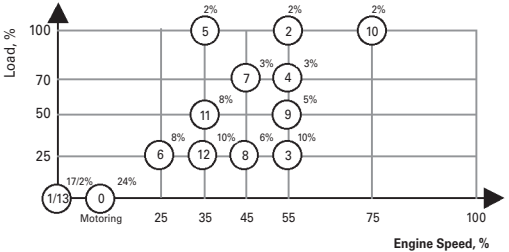
It is a second by second sequence of normalized speed and torque values.



ECE

WHSC - World Heavy Duty Steady-State Cycle
It consists of a number of speed and power modes which cover the typical operating range of HD engines.

Idle mode is separated in 2 modes: mode 1 at the beginning of test cycle
mode 13 at the end of test cycle



Mode	Normalized Speed [%]	Normalized Torque [%]	Mode Length [s] incl. 20 s Ramp
1	0	0	210
2	55	100	50
3	55	25	250
4	55	70	75
5	35	100	50
6	25	25	200
7	45	70	75
8	45	25	150
9	55	50	125
10	75	100	50
11	35	50	200
12	35	25	250
13	0	0	210
Sum			1,895

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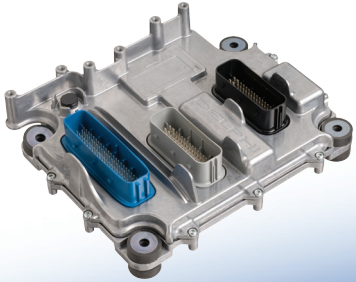
Delphi controllers help HD and MD Diesel engines operate efficiently, reliably and economically. And, Delphi supports CNG applications. All our controllers operate in harsh environments. So commercial and off-highway vehicles meet emissions, fuel economy and performance objectives.



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EUROPEAN UNION

VEHICLE CATEGORIES

Category	Description	Sub-category	Number of Persons	Mass Limit	
M	Transportation of Passengers Min. 4 wheels	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 wheels	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		7,0
	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

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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 16-17). 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

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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

- Diesel engines are tested on ESC, ELR and ETC cycles if required (see pages 14-15)
- Gas engine are tested on ETC cycle

Emissions TA: Oct05 - FR: Oct06	Unit	Euro IV		Euro IV - EEV	
		ESC/ELR Diesel only	ETC Diesel & Gas	ESC/ELR Diesel only	ETC 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 [1]		-	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	-

EURO V - Dir 2005/55/EC + Dir 2005/78/EC amended by Dir 2006/51/EC + Dir 2008/74/EC

For TA and for EEV's, ETC and ESC/ELR tests are applicable (see pages 14-15)

Emissions TA: 01Oct08 - FR: 01Oct09	Unit	Euro V		Euro V - EEV	
		ESC/ELR Diesel Only	ETC Diesel & gas	ESC/ELR Diesel Only	ETC 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 [1]		-	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	-

[1] For natural gas engines only

[2] Not applicable for gas fuelled engines - Euro IV Stage

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Dir 2008/74/EC reflects the change of vehicle scope due to the Euro 5 & 6 regulations for passenger cars and light duty trucks.
It includes test procedures for HD and vehicles with gasoline engines.

N1 Class I category vehicles (reference weight ≤ 1.305 kg) are removed from the scope of the directive. Application date FR 01Sep11.

N1 Class II category vehicles (reference weight > 1.305 kg and ≤ 2.610 kg) are removed from the scope of the directive. Application date FR 01Sep12.

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	-

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EURO VI (Reg EC No: 595/2009 and implementing regulations (EU) No 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	$8{,}0 \times 10^{11}$
WHTC (C.I.)	4.000	160			460	10	10	$6{,}0 \times 10^{11}$
WHTC (P.I.)	4.000		160	500	460	10	10	[3]

C.I. Compression Ignition
P.I. Positive Ignition
WHSC, WHTC (see pages 2-3)

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

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 58)
- Access to vehicle OBD and vehicle repair and maintenance information.
- Off-cycle laboratory testing and vehicle testing of engines at type approval.

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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 yrs
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 yrs
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 yrs

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

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

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.

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Further Requirements

- In-service conformity testing using portable emissions measurement systems (PEMS)
- PEMS must measure CO; THC; NOx (Diesel) Methane (Gas) and CO_2
- The measurement of NH_3 using the laser diode spectrometer (LDS) or the fourier transform infrared (FTIR) measurement principles
- Requirements for crankcase emissions
- Requirements to limit off-cycle emissions (OCE) and in-use emissions
- OBD and in-service conformity
- Measurements of net engine power
- Determination of CO_2 emissions and fuel consumption
- Provisions on CO_2 emissions and fuel consumption for extension of EC type approval for a vehicle type approved with reference mass > 2.380 kg and < 2.610 kg
- EC type approval of replacement pollution control devices as separate technical unit
- Requirements to ensure the correct operation of NOx control measures (including SCR)

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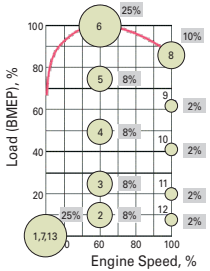
TEST CYCLES EURO I AND II / ECE R49 OR 13 MODE CYCLE

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

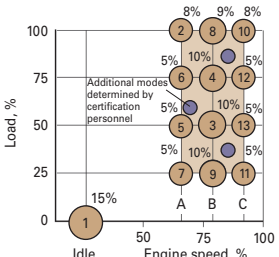
EUROPEAN UNION

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

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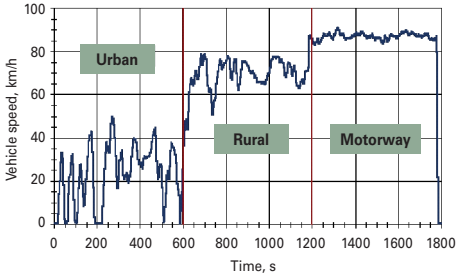
2) European Transient Cycle - ETC

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.

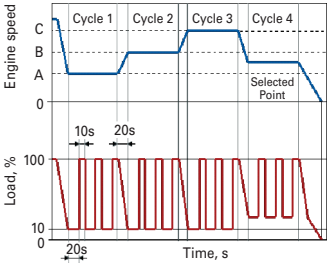


3) European Load Response - ELR

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.



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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>8.500</th><th>14.000</th><th>19.500</th><th>33.000</th></tr>
<tr><td rowspan="2">Federal</td><td></td><td colspan="2">LDT ≤ 8.500</td><td colspan="4">HDV > 8.500</td></tr>
<tr><td></td><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="6">California</td><td></td><td rowspan="5">LDT ≤ 6.000</td><td colspan="5">HDV > 6.000</td></tr>
<tr><td rowspan="2">1994 and earlier</td><td rowspan="2">6.000 < MDV ≤ 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>8.500 < LHDE-S.I. ≤ 14.000</td><td colspan="3">HDDE-Slcd > c14.000</td></tr>
<tr><td rowspan="2">1995+</td><td colspan="2" rowspan="2">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 colspan="3">HDDE-S.I. > ddd14.000</td></tr>
<tr><td>1992+ [1)]</td><td colspan="5">6.000 < MDV ≤ 14.000</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	NMH C	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	-	-	40	-	20 / 15 / 50	-	-
1979-84	1,5	-	10	-	-	25	-	20 / 15 / 50	-	-
1985-87	1,3	-	-	10,7	-	15,5	-	20 / 15 / 50	LHDDE: - / 8 / 110.000 MHDDE: - / 8 / 185.000 HHDDE: - / 8 / 290.000	-
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) [ABT]	0,2 [15]	0,01	15,5	0,5	20 / 15 / 50		
2015	-	0,14 [15]		0,02 [18]	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 sulfur 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

18) Optional. Manfacturers may choose to certify engines to the Californian Optional Low NO Standards of 0,10, 0,05 or 0,02 g/bhp-hr

US FEDERAL (EPA)

Smoke Test Limits

Mode	Accceleration (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	2,00	0,02
2010 and later	0,50	0,02

Supplemental Test (see page 30)

- 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)

SPARK IGNITION HD HIGHWAY - EXHAUST EMISSIONS STANDARDS

Heavy Duty Engines [4]											
Year	GVW	HC [1]	NMHC [2]	NOx	NOx+NMHC [3]	PC	CO	Idle CO	Formaldehyde	Useful Life	Warranty Period
	(lbs)	(g/bhp-hr)						(% exhaust gas flow)		(yrs/miles)	
Prior to control	-	12,7	-	-	6,86	-	155	-	-		-
1970-73	-	275 ppm	-	-	-	-	1,5%	-	-		-
1974-78	-		-	16	-	-	40	-	-		-
1979-84	-	1,5	-	10	-	-	25	-	-		-
1985-86	-	1,9	-	-	10,6	-	37,1	-	-	5/50.000	-
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		-		
	> 14.000	1,9	-	-	6,0	-	37,1		-		
1991-97 [6]	≤ 14.000	1,1 [7]	-	-	5,0	-	14,4		-	8/110.000 [11]	
	> 14.000	1,9 [8]	-	-	5,0	-	37,1		-		
1998-2004 [6]	≤ 14.000	1,1 [7]	-	-	4,0 [9]	-	14,4	0,5	-		5/50.000
	> 14.000	1,9 [8]	-	-		-	37,1		-		
2005-2007 [6]	≤ 14.000	1,1 [7]	-	1,0 [9]	-	-	14,4		-		
	> 14.000	1,9 [8]	-		-	-	37,1		-	10/110.000	
2008+	All	-	0,14	0,20	-	0,01	14,4		-		
Complete Heavy Duty Vehicles [10,14]											
2005-2007	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)

Notes:

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 are 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-carring 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.

CALIFORNIA (CARB)

CARB Standards from 1985-2003 (g/bhp.h)

Year	Total HC or OMHCE [1]	Optional NMHC [1]	CO	NOx		PM	
				Truck	Bus	Truck	Bus
1985	1,3	-	15,5	5,1	5,1	0,60	0,60
1987	1,3	-	15,5	6,0	6,0	0,60	0,60
1991	1,3	1,2	15,5	5,0	5,0	0,25	0,10
1994	1,3	1,2	15,5	5,0	5,0	0,10	0,07
1996	1,3	1,2	15,5	5,0	4,0	0,10	0,05
1996	1,3	1,2	15,5	5,0	0,5-2,5 [2]	0,10	0,05

[1] NMHC gasoline NG and LPG engines
OMHCE: methanol engines

[2] Optional NOx standard between 0,5 and 2,5 by 0,5 g/bhp.h increments

CARB Standards for Engines used in Oct02 and Subsequent (g/bhp.h)

	NOx+NMHC	Optional NOx+NMHC	CO	PM
Option 1	2,4	2,5 (NMHC ≤ 0,5 g/bhp.h)	15,5	0,10
Option 2	N/A	0,3 to 1,8 in 0,3	15,5	0,03 to 0,01

Smoke: Similar to US-EPA smoke test
Acceleration (A): 20%; Lagging (B): 15%; Peak (C): 50% Opacity

Formaldehyde exhaust emissions (NTE)
MY 1993-95: 0,10 g/bhp.h
MY 1996 and subsequent: 0,05 gbhp.h

Standards from 2004 and 2007

Similar to EPA standards (see pages 20-21)

CALIFORNIA (CARB)

Clean Fuel Buses

Fleet operators have to choose between operating:

- a diesel bus fleet → Diesel path
- an alternative-fuel bus fleet → Alternative Fuel Path
- Fleets in South Coast Air Quality Management District must follow altern. path

2007-2009: fleets > 30 must:

a) buy new buses that are 0,2 g/bhph NOx -OR-

b) on 1 to 1 basis, retrofit old buses w/ level 3 PM DECS w/eff. > 40% if available or w/ eff. > 25% -OR-

c) obtain E.O. approval for non-conforming bus purchase

MY	Diesel Path		Alternative Fuel Path	
	NOx+NMHC	PM	NOx+NMHC	PM
2007	0,2	0,01	0,2	0,01
2008	15% of new purchase ZEB's for large fleet (> 200)			
2010			15% of new purchase ZEB's for large fleet (> 200)	

Zero Emissions Buses - ZEB

Additional In-Use Engine Retrofit Requirements

- Installation of certified (approved) NOx/PM reduction equipment
- Places NO_2 requirement constraints on devices in 2007
  Max NO_2 increase: 2007-2008: 30%; 2009+: 20%
- Manufacturers may install uncertified equipment as certific. process progresses
- Requires warranty coverage and in-use compliance testing

Standards for Diesel or Dual-Fuel Urban Bus Engine (g/bhp.h)

MY	NOx	PM	NMHC	Formaldehyde	CO
2004-2006	0,5	0,01	0,05	0,01	5,0
2007+	0,2	0,01	0,05	0,01	5,0

In-use compliance: 90.000 miles Phase-in: (see page 22)

ESC and NTE tests: from MY 2005 - Identical to ESC and NTE HD diesel

NTE: max 1,25 times FTP emission standards - Operation within the NTE control zone

ESC: Emissions equivalent to FTP emissions standards

Emission Useful Life Standards and Emissions Warranty

	CARB	EPA
Useful Life (Yr/mi/hours)		
LHDDE	10/110k	8/110k [2]
MHDDE	10/185k	10/185k
HHDDE	10/435k/22k	10/435k/22k
Emissions Warranty [1]		
All Class	5/100k/3k	5/100k

[1] Longer of listed and mechanical warranty length

[2] 10 yrs for PM and NOx

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 Nov07

- 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 01Jan12, and older trucks must be replaced starting 01Jan15. By 01Jan23 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 serveral (13) categories of vehicles.

Compliance Schedule by Engine MY for Vehicles with GVWR 26.000 lbs or less

Compliance Date as of 01Jan	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	01Jan15
1994-1995	N/A	01Jan16
1996-1999	01Jan12	01Jan20
2000-2004	01Jan13	01Jan21
2005-2006	01Jan14	01Jan22
2007 or newer	01Jan14 if not OEM equipped	01Jan23

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 01Jan	% 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 01Jan	% of Fleet Complying with PM BACT
2012	33%
2013	66%
2014	100%

Compliance Schedule for Log Truck Phase-in Option

Compliance Deadline as of 01Jan	% 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)

Otto-Cycle Medium and Heavy-Duty vehicles (g/bhp.h)

MY	Emission Cat	NMHC+NOx	NMHC	NOx	CO	HCHO	PM
MD > 8.501 - 14.000 lbs GVW							
2004	ULEV	2,4 or 2,5 w/ 0,5 NMHC	-	-	14,4	0,05	-
	SULEV	2,0	-	-	7,2	0,025	-
2005-2007	ULEV	1,0	-	-	14,4	0,05	-
	SULEV	0,5	-	-	7,2	0,025	-
2008, +	ULEV	-	0,14	0,20	14,4	0,01	0,01
	SULEV	-	0,07	0,10	7,2	0,005	0,005
HD > 14.000 lbs GVW							
2004	-	2,4 or 2,5 w/ 0,5 NMHC	-	-	37,1	0,05	-
2005-2007	-	1,0	-	-	37,1	0,05	-
2008, +	-	-	0,14	0,20	14,4	0,01	0,01
Idle CO: if aftertreatment technology is used and not certified OBD max CO: 0,50%							
C.I. MD Optional Standards > 8.601 - 14.000 lbs GVW							
2004 - 2006	ULEV Opt A	2,5 NMHC ≤ 0,5	-	-	14,4	0,050	0,10
	ULEV Opt B	2,4	-	-	14,4	0,050	0,10
2007, +	ULEV	-	0,14	0,2	15,5	0,050	0,01
	SULEV	-	0,07	0,1	7,7	0,025	0,005

Notes:

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) 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, 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), title13 CCR.

3) 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.

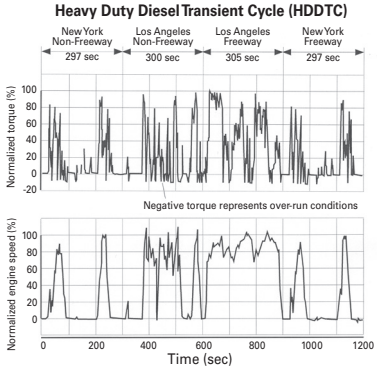
4) This standard only applies to methanol-fueled Otto-cycle engines.

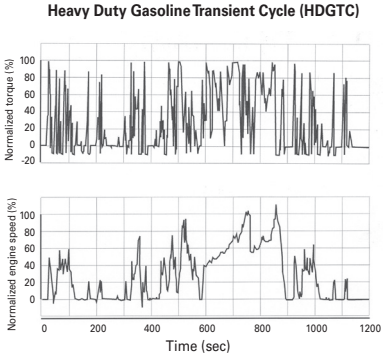
5) A manufacturer may elect to include any or all its MD and HD Otto-cycle engine families in any or all the emissions ABT programs for HDEs, within the restrictions described in section I.15 of these test procedures. For engine families certified to Option 1 or 2 federal standards the FEL must not exceed 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).

6) 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.

7) 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.

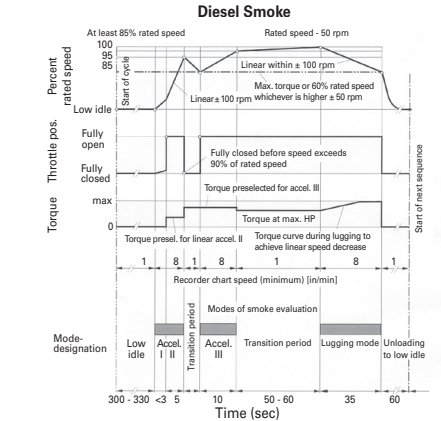
FTP TEST CYCLES





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



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 14)

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 31).

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
7a Steady-State	219	B	25
7b 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 [1]	2 Diurnal + Hot soak	Running Loss	Refuelling spitback [2]
1998	≤ 14.000	3,0	3,5	0,05	1,0
MY, +	> 14.000	4,0	4,5	0,05	-
2008	≤ 14.000	1,4	1,75	0,05	1,0
MY, +	> 14.000	1,9	2,30	0,05	-

[1] Evaporative emissions limits for NG and LPG fuelled HDDC engines
[2] Methanol - Gas fuelled engines only

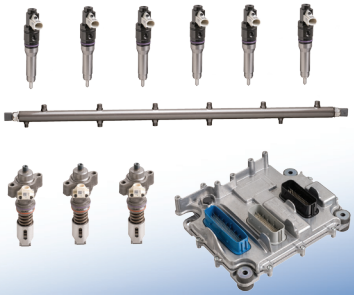
CARB - From 2004 MY, > 8.500 lbs g/test

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%

High pressure. At the head of the class.

Delphi's modular family of F2 HD Diesel common rail systems offers industry-leading 2,700 bar pressure capability and performance. With application flexibility accommodating all engine architectures. And cost-effective upgrades for engines with conventional fuel injection equipment.



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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

		CO		HC		NOx		PM		Smoke [3]
Diesel Engines		**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) 350 (IDI)		-	-	50%
Japan 94 13-Mode test (g/kWh)		9,2		3,8		6,8 (IDI) 7,8 (DI)		0,96		40%
Japan 97 [4] (g/kWh)		7,4	9,2	2,9	3,8	4,5	5,8	0,25	0,49	25%
Gasoline Engines										
Japan 98 13-Mode test (g/kWh)	GVW > 2,5t	51	68	1,8	2,29	4,5	5,9	-	-	-

[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

JAPAN

New Short Term Standards (13-Mode)

Diesel Engines Implementation dates:	2,5t < GVW ≤ 12t	GVW > 12t
New vehicles	from Oct03 to Oct05	from Oct04 to Oct05
Existing and Imported vehicles	from Sep04 to Sep07	from Sep05 to Sep07

CO		HC		NOx		PM		Smoke
(g/kWh)								
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%

[1] TA emissions standard for type assigned vehicle and vehicle with TA equipment

[2] Emissions standard for the vehicles other than defined above

Gasoline Engines Implementation dates:	GVW > 3,5t
New vehicles	from Oct01
Existing and Import vehicles	from Sep03

CO (g/kWh)		HC (g/kWh)		NOx (g/kWh)	
Std [1]	Others [2]	Std [1]	Others [2]	Std [1]	Others [2]
26,0	16,0	0,99	0,58	2,03	1,40

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	1 heat build in 24 hrs
Loss (DBL)	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 Oct05
Existing and Import vehicles	from Sep07

	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 37)

JAPAN

Post New Long Term Emission Standards g/kWh

Trucks and Buses GVW > 3,5t	PM		NOx		NMHC		CO	
	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: 01Oct10
Gasoline: 01Oct09
Imported vehicles and existing domestic vehicles: 11 months later
Test cycle: JE05 Diesel Sulfur 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

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

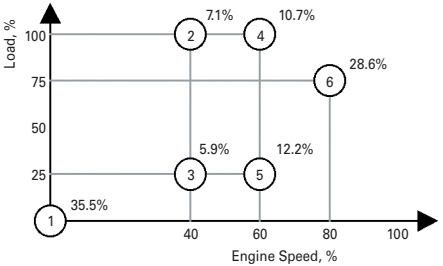
Test mode: Heavy Vehicle Test Mode

JAPAN

TEST CYCLES

6-Mode Cycle (until 2005)

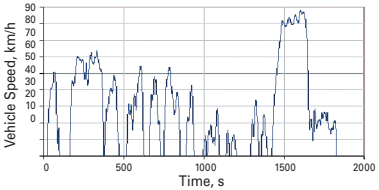
The engine is tested over 6 different speed and load conditions.
The modes are run in sequence and the duration of each mode is 3 main.
Measurements are expressed in ppm (volumetric concentration).



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



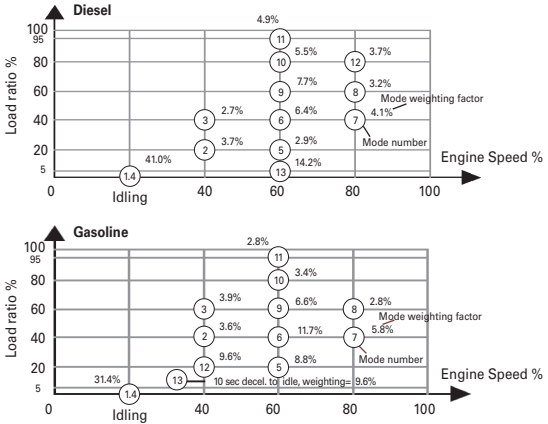
JAPAN

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

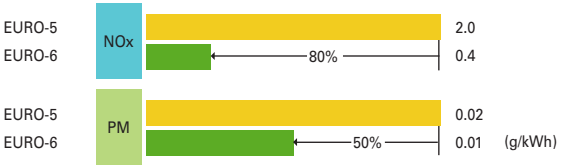


SOUTH KOREA

Euro VI (HD/MD) Start from Jan15

Test mode	CO	HC	NOx	PM	NH_3	Nr of Nano Particle
	[g/kWh]				ppm	[#/kWh]
WHSC	1,5	0,13	0,4	0,01	10	$8x10^{11}$
WHTC	4	0,16	0,46	0,01	10	$6x10^{11}$

New Features	EU	Korea
Introduce Euro VI	New vehicle 01Jan13	New vehicle 01Jan14
Added number of nano particle	Produced vehicle 01Jan14	Produced vehicle 01Jan15
Added NH_3		



PR of CHINA

- Applicable standards GB 17691-2005 (equivalent to EU standards)
- CN4 will be implemented nationwide 1st January 2015 (FR 1.1.2015)
- 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.

(g/kWh)

WHTC Limits										
	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 positive ignition engines [2] Only for C.I. engines

BEIJING AREA

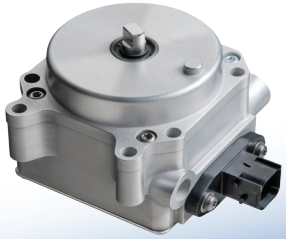
- Beijing 5 stage was implemented June 1, 2015
- Applicable Regulations DB 11/964-2013 and DB 11/965-2013
- DB 11/964-2013 is about limits and measurement methods of engines (bench mode methods).
- DB 11/965-2013 is about limits and measurement methods of HD vehicles usings PEMS equipment.

OTHER AREAS OF THE WORLD

Argentina	Vehicles with max mass > 3.856 kg - ECE 49 Euro V: 2014 (new models); 2016 (all models)			
Australia	ADR 80/03 Euro V \ (Diesel)		from 01Jan10 for new model vehicles from 01Jan11 for all produced vehicles	
	US 07 or Japanese 05 considered as alternative Euro VI proposed introduction 01Jan16 for new vehicles			
Brazil	Proconve P-7, equiv Euro V (Diesel engines only): from 01Jan12			
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	01.2012	HD vehicles	Metropolitan area	NOx: EU III or US 1998 PM: EU IV or US 2007
	09.2012	Busses	Metropolitan area	EU IV or US 2004 NMHC
	09.2013	Urban busses	-	+NOx/ US 2007 PM
	10.2014	New models exc. urban busses	Metropolitan area	EU V
	09.2015	Urban busses	-	EU V
	10.2015	All models	-	US 2004 / US 2007 PM
India	From 2010	BS III (Euro III) BS IV (Euro IV)		Nationwide 15 Metropolitan areas
Israel	European standards applicable: EU V (01Oct08) EU VI introduction proposed 2014			
Malaysia	HD Diesel engines: Euro II			
Mexico	Diesel	2003 2008	US 1998 or Euro III US 2004 or Euro IV	
	Gasoline	No emission standards adopted		
	Regulation	NOM 044 is under revision: expected outcome: EPA 2010 level / Euro VI applicable in 2018		
New Zealand	Gasoline LPG & CNG new model (01Jan10) ADR 80/3, Euro IV, Japan 05 or US 2004			
	Diesel new model (01Jan11) ADR 80/3 and ADR 30/01 Euro V, Japan 05 or US 2007			
Peru	From 2012		Euro III	
Russia	From 01.2013 Euro IV, Euro V to be introduced 01.2016			
Singapore	Euro V for new vehicles as of 01Jan14. 'Early turnover' scheme to subsidize the replacement of older vehicles is in place			
South Africa	Euro II / US 98 / Japan 98 / ADR 80/00 applicable since 2010			
Switzerland	EU standards adopted			
Thailand	From 2012		Diesel HDV Euro IV (TIS 2315-2551)	
Turkey	Diesel Euro V		from 01Jan15 Euro VI	

Smart control for EGR, turbo and exhaust flap.

Delphi's smart remote actuators control emissions and engine performance devices. To help MD and HD Diesel engine manufacturers meet the toughest standards for particulate and NOx emissions. While helping achieve optimum engine performance. Now that's smart!



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Innovation for the Real World

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	7,0	0,1
Row C (EEV)	7,0	0,1

OBD Stage I (Euro IV) (Diesel engines only)
TA: from 01Oct05 FR: from 01Oct06

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 01Oct08 FR: from 01Oct09

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 09Nov06 FR from 01Oct07

1) In case of engine systems requiring a reagent, NH_3 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 (See page 10) => 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 No 595/2009 and (EU) No 582/2011)

Implementation dates: NEW types	Implementation dates: ALL types	OBD Limits (mg/kWh)				
		PI. Engines	C.I. Engines incl. dual-fuel engines	All Engines		
		CO	PM	NOx	IUPR [2]	Reagent quality & consumption monitoring
31DEC12 (phase-in period)	31DEC13		Performance monitoring [1]	1.500	Phase-in [3]	Phase-in [3]
01SEP14	01SEP15	7.500	-	1.500	Phase-in [3]	Phase-in [3]
31DEC15 (general requir.)	31DEC16	7.500	25	1.200	General [4]	General [4]

[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 appl

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 montoring 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 montoring 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 Option 2 - Frequent Regeneration	- 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 - 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 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 montoring 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) Misfire 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 (+ 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 2)

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

Strategy for reducing Heavy Duty Vehicles fuel consumption and CO_2 emissions (issued by the Commission 21.05.2014).

The Commission, in cooperation with industry stakeholders, has been developing a simulation tool, VECTO, to determine whole vehicle HDV CO_2 emissions, i.e. including emissions due to vehicle's motor, transmission, aerodynamics, rolling resistance, and auxiliaries. VECTO is intended to be a methodology geared to estimate whole vehicle, including trailer, HDV CO_2 emissions. VECTO will initially be operational for at least 3 HDV categories, representing more than 50% of HDV CO_2 emissions.

Legislative actions (proposals to be made in 2015)

- adaptation of the relevant type approval legislation
- new legislation on the reporting of HDV CO_2 emissions as calculated by VECTO by member states to the Commission

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

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.

CO_2 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%
	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 Gasol.	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 01Jul14 for new certificated vehicles.
Implementation date from 01Jul15 for in production vehicles
C-WVTC cycle is used for the fuel consumption (FC) test which is based on the WVTC and adjust the acceleration and deceleration.

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

Gross Combination Weight (GCW) [kg]	FC Limits [l/100km]
GCW ≤ 18.000	33,0
18.000 < GCW ≤ 27.000	36,0
27.000 < GCW ≤ 35.000	38,0
35.000 < GCW ≤ 40.000	40,0
40.000 < GCW ≤ 43.000	42,0
43.000 < GCW ≤ 46.000	45,0
43.000 < GCW ≤ 49.000	47,0
49.000 < GCW	48,0

FC Limits for HD Diesel Vehicles, GB 30510-2014

Gross Vehicle Weight (GVW) [kg]	FC Limits [l/100km]	
	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/100km]	
	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

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EU REFERENCE TEST FUELS

Diesel (B7) Reference Fuel in Regulation (EC) 582/2011

Parameter	Unit	Limits
Cetane nr	-	52-56
Density at 15°C	kg/m^3	833-837
Distillation T50	°C	≥ 245
Distillation T95	°C	345-350
Distillation Final Boiling Point FBP	°C	≤ 360
Flash point	°C	≥ 55
Cold Filter Plug-in Point CFPP	°C	≤ -5
Viscosity at 40°C	mm^2/s	2,3-3,3
Polycyclic aromatic hydrocarbons	% m/m	2,0-4,0
Sulfur	mg/kg	≤ 10
Copper Corrosion	Rating	≤ Class 1
Conradson carbon residue (10% DR)	% m/m	≤ 0,2
Ash content	% m/m	≤ 0,01
Water content	% m/m	≤ 0,02
Neutralisation (strong acid) nr	mg KOH/g	≤ 0,10
Oxidation stability [1] at 110°C	Hours	≥ 20,0
FAME [2]	% vol	6,0-7,0

[1] Even though oxidation stability is controlled, it is likely that shelf life will be limited. Advice shall be sought from the supplier as to storage conditions and life.

[2] Quality of FAME (Fatty Acid Methyl Ester) blendstock to meet specification of EN 14214

Ethanol for Dedicated Compression Ignition Engines (ED95) [1] in Regulation (EC) 582/2011

Parameter	Unit	Limits
Alcohol, mass	% m/m	≥ 92,4
Other alcohol than ethanol	% m/m	≤ 2,0
Density at 15°C	kg/m^3	793-815
Flashpoint	°C	≥ 10
Acidity (as acetic acid)	% m/m	≤ 0,0025
Appearance	Bright and clear	
Dry residue at 100°C	mg/kg	≤ 15
Water content	% m/m	≤ 6,5
Aldehydes (acetaldehyde)	% m/m	≤ 0,0050
Sulfur	mg/kg	≤ 10,0
Esters (as ethylacetat)	% m/m	≤ 0,1

[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 The regulation contains also specifications for Natural Gas (NG), Biomethane and Liquified Petrolium Gas (LPG).

EU REFERENCE TEST FUELS

NRMM EU Diesel Reference Fuel (CEC RF-75-T-96)

Parameter	Unit	Stage I/II		Test Method	Stage IIIA		Test Method	Stage IIIB and IV		Test Method
		Min	Max		Min	Max		Min	Max	
Cetane Number	-	45,0	50,0	EN-ISO 5165	52	54	EN-ISO 5165	-	54,0	EN-ISO 5165
Density at 15°C	kg/m³	835	845	ISO 3675/ASTM D4052	833	837	EN-ISO 3656	833	865	EN-ISO 3675
Distillation T95	°C	-	370	EN-ISO 3405	345	350	EN-ISO 3405	345	350	EN-ISO 3405
Viscosity at 40°C	mm²/s	2,5	3,5	EN-ISO 3104	2,5	3,5	EN-ISO 3104	2,3	3,3	EN-ISO 3104
Sulfur content	% mass	0,1	0,2	ISO 8754, EN 24260	-	300 mg/kg [1)]	ASTM D5453	-	10 mg/kg	ASTM D5453

NRMM EU Gasoline Reference Fuel (CEC RF-75-T-96)

Parameter	Unit	Stage I/II		Test Method
		Min	Max	
RON	-	95	-	EN 25164
MON	-	85	-	EN 25163
Density at 15°C	kg/m³	748	762	ISO 3675
RVP	kPa	56,0	60,0	EN 12
Sulfur	ppm	-	100	EN-ISO 14596
Initial Boiling Point	°C	24	40	EN-ISO 3405
Distillation at 100°C	% vol	49,0	57,0	EN-ISO 3405
Distillation at 150°C	% vol	81,0	87,0	EN-ISO 3405
Final Boiling Point	°C	190	215	EN-ISO 3405

[1)] The actual Sulfur content shall be reported

The fuel for 2-stroke engines is a blend of lubricant oil and petrol

US REFERENCE TEST FUELS

DIESEL

	CALIFORNIA	UNITED STATES														
Year of Implementation	Jun06	Dec10							Apr11							
Spec Name	13 CCR2281-2282	ASTM D 975-10c							ASTM D 975-11							
Grade	CARB [1, 2, 3, 4]	No.1-DS15	No.1-DS500	No.1-DS5000	No.2-DS15	No.2-DS500	No.2-DS5000	NO.4-D	No.1-DS15	No.1-DS500	No.1-DS5000	No.2-DS15	No.2-DS500	No.2-DS5000	NO.4-D	
Additional Comment	Smal Refiners															
Source	CARB [1, 2, 3, 4]	ASTM														
Property																Test Method
Cetane Number,min	40 [5]	40.						30.	40.						30.	ASTM D 613 [6], ASTM D 4737
Cetane Index, min																
Sulfur, ppm, max	15	15(8)	500	5000	15	500	5000	20000	15(8)	500	5000	15	500	5000	20000	ASTM D 129 [6], ASTM D 1552, ASTM D 4294, ASTM D5453
Polyaromatics, wt%, max	4															
Total aromatics, vol%, max	20	35 [7]			35 [7]				35 [7]			35 [7]				
Viscosity @ 40°C, cSt, min	2	1,3			1,9 [9]		1,9	5,5	1,3			1,9 [9]		1,9	5,5	ASTM D 445
Viscosity @ 40°C, cSt, max	4,1	2,4			4,1			24	2,4			4,1			24	ASTM D 445
Distillation																
T10, °C, min	204															
T10, °C, max	254															
T50, °C, min	243															
T50, °C, max	293															

Notes:

1) Requires API Gravity between 33 - 39 per ASTM D 287.
2) Established by CARB regulation (13 CCR 2281-2282; 6/4/97).
3) ASTM D 975 incorporated.
4) Requires Nitrogen content < than 90 ppm per ASTM D 4629.
5) While CARB does not require higher cetane levels than ASTM, it does require emissions testing to certify the fuel (13 CCR 2282). The fuels are tested against a reference fuel with a min cetane of 48 for large refiner, 47 for small refiners; therefore, actual cetane levels to gain certification will likely be similar to, or more than that of the CARB reference fuel.
6) Referee test method
7) Either the specification for min cetane index or that for max total aromatics must be met.
8) Other limits may apply to selected areas.
9) When a cloud point less than -12°C is specified, it is permitted and normal blending practice to combine Grades No.1-D & No.2-D to meet the low temp requirements. In that case, the min flash point shall be 38°C, the min viscosity at 40°C shall be 1,77 cSt, the min 90% recovered temp shall be waived.

US REFERENCE TEST FUELS

DIESEL – contd.

	CALIFORNIA	UNITED STATES														
Year of Implementation	Jun06	Dec10						Apr11								
Spec Name	13 CCR2281-2282	ASTM D 975-10c						ASTM D 975-11								
Grade	CARB [1, 2, 3, 4]	No.1-DS15	No.1-DS500	No.1-DS5000	No.2-DS15	No.2-DS500	No.2-DS5000	NO.4-D	No.1-DS15	No.1-DS500	No.1-DS5000	No.2-DS15	No.2-DS500	No.2-DS5000	NO.4-D	
Additional Comment	Smal Refiners															
Source	CARB [1, 2, 3, 4]	ASTM														
Property																Test Method
T90, °C, min	288				282[9]	282						282[9]	282			
T90, °C, max	321	288			338				288			338				
FBP °C, max	349															
Flashpoint, °C, min	52	38			52[9]	52		55	38			52[9]	52		55	ASTM D 93
Carbon Residue 10% wt%, max		0,32=5							0,15			0,35				
Water and Sediment, vol%, max		0,05						0,5	0,05						0,5	ASTM D 2709, ASTM D 1796
Ash, wt%, max		0,01						0,1	0,01						0,1	ASTM D 482
Lubricity, HFRR wear scar diam @ 60°C, micron, max		520							520							
Copper corrosion, 3hrs @ 50°C, merit (class), max		No,3							No,3							
Conductivity @ ambient temp. pS/m, min		25[10, 11]							25[10, 11]							
Dye Content, g/100 l, max			[12]	[13]		[12]	[13]			[12]	[13]		[12]	[13]		
FAME Content, vol%, max		5[14]							5[14]							
Other	[1]															

Notes:

10) The conductivity specification becomes effective 12Nov08.

11) The electrical conductivity of the diesel fuel is measured at the time and temperature of the fuel at delivery. The 25 pS/m min conductivity requirement applies at all instances of high velocity transfer (7 m/s) but sometimes lower velocities (see 8,2 of ASTM D975 for detailed requirements) into mobile transport (for example, tanker trucks, rail cars and barges).

12) If low sulfur No.1-D S500 or low sulfur No.2-D S500 are sold for tax exempt purposes then, at or beyond terminal storage tanks, they are required by 26 CFR Part 48 to contain the dye Solvent Red 164 at a concentration spectrally equal to 3,9 lbs. per thousand barrels of the solid dye standard Solvent Red 26, or the tax must be collected.

13) Grades No.1-D S5000, No.2-D S5000 & No.4-D are required by 40 CFR Part 80 to contain a sufficient amount of the dye Solvent Red 164 so its presence is visually apparent. At or beyond terminal storage tanks, they are required by 26 CFR Part 48 to contain the dye Solvent Red 164 at a concentration spectrally equivalent to 3,9 lbs. per thousand barrels of the solid dye standard Solvent Red 26.

14) Biodiesel blendstock must meet ASTM D6751.

US REFERENCE TEST FUELS

US GASOLINE

Parameter / Unit	EPA	CARB Phase 3
MON/RON	-	82/87
(MON + RON) / 2, min	93	91 [1) 2)]
RVP (kPA) @ 37,8 °C	55,2-63,4	47.574-49.642
FBP (°C)	415	198.889
T10 (°C)	120-135	54.444-62.556
T50 (°C)	200-230	96.111-101.667
T90 (°C)	300-325	154.444-160
Lead (g/l) Max	0,013	0,0026 [3)]
Sulfur (ppm) Max	1.000 [1)]	8 min - 11 max
Benzen (% vol) Max	-	0,6 min - 0,8-1 max
Aromatics (% vol) Max	35	19,5 min - 22,5 max
Olefins (% vol) Max	10	4,0 min - 6,0 max

1) A minium Octane sensitivity requirement of 7,5 is included.

2) The octane rating of the gasoline used must be no higher than 1,0 Retail octane number above the lowest octane rating that meets the fuel grade the manufacturer will recommend to the utilimate purchaser for the relevant production vehicles.

3) Originally specified as max 0,01 g/gal.

JAPAN REFERENCE TEST FUELS

AUTOMOTIVE FUEL QUALITY REGULATIONS

Type of Fuel	Fuel Property	Limit	JIS
Gasoline	Lead	Not detected	K2255-4,5
	Sulfur	Max. 0,001 (mass %)	
	Benzene	Max. 1 (vol %)	
	MTBE	Max. 7 (vol %)	
	Oxygen	Max. 1,3 (mass %)	K2536-2,4,6
Diesel	Sulfur	Max. 0,001 (mass %)	
	Cetane Index	Min. 45	K2280
	Distillation at 90%	Max. 360 (deg C)	K2254

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COMPRESSION IGNITION ENGINES - EURO STAGE I AND STAGE II Dir 97/68/EC, amended by Dir 2002/88/EC
ECE GTR 11 'Engine emissions from agricultural and forestry and from non-road mobile machinery' published 12Nov09
The GTR 11 is applicable to the determination of gaseous and particulate mass exhaust emissions from C.I. engines of ≥ 19 kW and ≤ 560 kW to be used in non-road mobile machinery and tractors.

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	01Jul98	01Jan99
B	75-130	5,0	1,3	9,2	0,70	01Jul98 [1]	01Jan99 [2]
C	37-75	6,5	1,3	9,2	0,85	01Jul98 [1]	01Apr99 [2]
Stage II [4]							
E	130-560	3,5	1,0	6,0	0,2	01Jan01	01Jul02
F	75-130	5,0	1,0	6,0	0,3	01Jan02	01Jul03
G	37-75	5,0	1,3	7,0	0,4	01Jan03	01Jan04
D	18-37	5,5	1,5	8,0	008	01Jan01 [3]	01Jan02 [3]

Test cycle: NRSC (see page 96)
ISO 8178-C1 for C.I. engines operated under intermittent speed
ISO 8178-D2 for C.I. engines operated under constant speed

[1] 01Jan01 for agricultural and forestry tractors
[2] 01Jul01 for agricultural and forestry tractors
[3] 1 year later for agricultural applications and forestry tractors
[4] For constant speed engines, implementation date: 01Jan07

Test cycles: - Variable speed engines: 9-mode test cycle (see page 98) or ramped modal cycle
- Constant speed engines: 5-mode test cycle (see page 98) or ramped modal cycle
Engines with periodic regenerating aftertreatment systems need to be tested 3 times on RMC, 2 times without regeneration and 1 time with the regeneration process occurring at least once.

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 (01Apr10)
Test cycle (see pages 96-99)

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 (kW)	CO (g/kWh)	HC (g/kWh)	NOx (g/kWh)	PM (g/kWh)	TA	NR
Stage III A [1]							
H	130 ≤ P < 560	3,5	NOx + HC: 4,0		0,2	30Jun05	31Dec05
I	75 ≤ P < 130	5,0	NOx + HC: 4,0		0,3	31Dec05	31Dec06
J	37 ≤ P < 75	5,0	NOx + HC: 4,7		0,4	31Dec06	31Dec07
K	19 ≤ P < 37	5,5	NOx + HC: 7,5		0,6	31Dec05	31Dec06
Stage III B							
L	130 ≤ P < 560	3,5	0,19	2,0	0,025	31Dec09	31Dec10
M	75 ≤ P < 130	5,0	0,19	3,3	0,025	31Dec10	31Dec11
N	56 ≤ P < 75	5,0	0,19	3,3	0,025	31Dec10	31Dec11
P	37 ≤ P < 56	5,0	NOx + HC: 4,7		0,025	31Dec11	31Dec12
Stage IV							
Q	130 ≤ P < 560	3,5	0,19	0,4	0,025	31Dec12	31Dec13
R	56 ≤ P < 130	5,0	0,19	0,4	0,025	30Sep13	30Sep14

[1] Other than constant speed engines

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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 66

Implementation Dates

Stage	Cat.	Engine Power EP (kw)	TA	NR
Stage I	C	130 ≤ P < 560	01Jul98	01Jul01
	B	75 ≤ P < 130	01Jan01	01Jul01
Stage II	D	18 ≤ P < 37	01Jan01	01Jan02
	G	37 ≤ P < 75	01Jan03	01Jan04
	F	75 ≤ P < 130	01Jan02	01Jul03
	E	130 ≤ P < 560	01Jan01	01Jul02
Stage III A	H, I & K	75 ≤ P < 560 19 ≤ P < 37	31Dec05	H: 31Dec05 I, K: 31Dec06
	J	37 ≤ P < 75	31Dec06	31Dec07
Stage III B	L	130 ≤ P < 560	31Dec09	31Dec10
	M & N	56 ≤ P < 130	31Dec10	31Dec11
	P	37 ≤ P < 56	31Dec11	31Dec12
Stage IV	Q	130 ≤ P < 560	31Dec12	31Dec13
	R	56 ≤ P < 130	31Dec13	30Sep14

Deterioration Factors (DF) and Emission Durability Period (EDP)

- Additive DF's are applied for each pollutant for C.I. engines not using any aftertreatment device.
- Multiplicative DF's are applied for each pollutant for C.I. engines using an aftertreatment device.

DF's are determined by manufacturers in accordance with a specific test procedure which must be representative of use and have duration of at least 1/4 EDP.

EDP for C.I. Engines Stages III A, III B, and IV

Category	EDP (hrs)
≤ 37 kW (constant speed engines)	3.000
≤ 37 kW (not constant speed engines)	5.000
> 37 kW	8.000

Implementation Dates

Category	TA	NR
H	31Dec09	31Dec10
I	31Dec09	31Dec10
J	31Dec10	31Dec11
K	31Dec09	31Dec10

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NB: For engines of categories H to R, the NR dates can be postponed for 2 yrs for engines with production dates prior to the said date.

Opacity for Exhaust Gases Dir 77/537/EEC as amended by Dir 97/54/EC

Application: tractors equipped with wheels or endless tracks, having at least 2 axles and with 6 km/h < max design speed ≤ 40 km/h

2 tests are required:

1) Test at steady speed

6 measurements shall be made at engine speeds spaced out uniformly between that corresponding to max power and the higher of the following two engine speeds: 55% of the engine speed corresponding to the maximum power and 1.000 rpm

The engine shall be running under 80% of the maximum load. The light absorption coefficient of the exhaust gases shall be measured with an opacimeter. For each measuring point, the smoke measured should not exceed the limit values (SL) specified in the directive, which are a function of the air flow rate. The value selected will be measured (SM) nearest the relevant limit value.

2) Test under free acceleration

With warm engine from the idle to maximum speed giving an average (XM) of 4 consecutive non-dispersed values.

The free acceleration smoke limit is the lower of the two values calculated below XL1= (SL/SM) * XM and XL2 = XM + 0,5

Amendment Dir 2010/22/EU to Dir 2005/25/EC

Engine marking

Stage I	A	[1] new
Stage II	B	
Stage III A	C [1]	
Stage III B	D [1]	
Stage IV	E [1]	

Amendment 2011/87/EU to Dir 2000/25/EC and Dir 2005/13/EC

- Stage III B and IV implementation is delayed by 3 yrs for tractors of categories T2, C2 and T4.1
  Until that date stage III A is applicable.
  - T2 wheeled tractor w/ min track width < 1.150 mm, unladen mass > 600 kg and ground clearance ≤ 600 mm
  - C2 track laying tractor equivalent to T2
  - T4.1 high clearance tractor (vineyard tractor)

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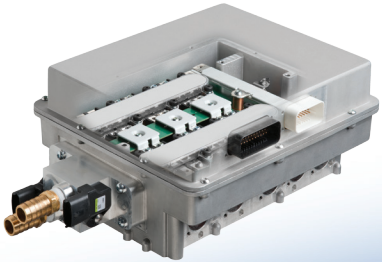

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SPARK IGNITION ENGINES

Dir 2002/88/EC amending Dir 97/68/EC by extending its scope to small S.I. engines (≤ 19kW).

Classification

Main Class S: small engines with a net power ≤ 19 kW			
SH		SN	
Engines for handheld machinery		Engines for non handheld machinery	
Category	Displacement (cc)	Category	Displacement (cc)
SH: 1	< 20	SN: 1	< 66
SH: 2	20 ≤ D < 50	SN: 2	66 ≤ D < 100
SH: 3	≥ 50	SN: 3	100 ≤ D < 225
		SN: 4	≥ 225

Test Cycles (see pages 96-99) ISO 8178-4 to be applied

Cycle D	engines with constant speed and intermittent load
Cycle G1	non-handheld intermediate speed machinery
Cycle G2	non-handheld rated speed machinery
Cycle G3	handheld machinery

Emissions Limits

Engine Class	Stage I				Stage II		
	CO	HC	NOx	TA	CO	HC+NOx	TA
	(g/kWh)				(g/kWh)		
SH: 1	805	295	5,36	11Aug04	805	50	01Aug07
SH: 2	805	241	5,36	11Aug04	805	50	01Aug07
SH: 3	603	161	5,36	11Aug04	603	72	01Aug08
SN: 1	519	HC + NOx = 50		11Aug04	610	50	01Aug04
SN: 2	519	HC + NOx = 40		11Aug04	610	40	01Aug04
SN: 3	519	HC + NOx = 16,1		11Aug04	610	16,1	01Aug07
SN: 4	519	HC + NOx = 13,4		11Aug04	610	12,1	01Aug06

Max limit NOx (Stage II) for all engines: 10g/kWh

Stages III and IV: see page 66 (C.I. engines Stage III/IV)

Emission Durability Period and Deterioration Factor

EDP (in hours) - category shall be the category which most closely approaches the expected useful lives of the equipment into which the engines will be installed.

DF's - manufacturers can get an assigned DF or calculate a DF, for each regulated pollutant for all stage 2 engine families. These DF's will be used for TA and COP testing.

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Engine Class	1	2	3	Engine Class	1	2	3
SH: 1	50	125	300	SN: 1	50	125	300
SH: 2	50	125	300	SN: 2	125	250	500
SH: 3	50	125	300	SN: 3	125	250	500
				SN: 4	250	500	1.000

NRMM Dir 97/68/EC

Amendments implemented in Dir 2010/26/EU, 2011/88/EU and 2012/46/EU

- Top handle machine tree service chainsaw and hand-held hedge trimmer using engine classes SH:2 and SH:3 are exempted in Stage II until 31Jul13.
- Test cycles: Stage I and II, III A NRSC only (engines 19-560 kW constant and variable speed operation; Stage III B, IV NRSC and NRTC (engines 19-560kW variable speed operation).
- NRTC cold cycle adapted and test sequence defined (see page 99).
- Adapted emissions calculation method for NTCTA tests.
- The emission limits for Stages III B and IV are applicable for TA (see page 70).
- The density of 15°C of the reference fuel is amended to 833-865 kg/m^3.
- The flexibility scheme got adopted.
- The correct operation of NOx control systems is to be ensured. If a reagent is used the level quality and dosing are monitored; the ammonia emissions cannot exceed a mean of 25 ppm during the applicable emission cycle.

EU STAGE V NRMM EMISSIONS PROPOSAL - Compression Ignition Engines

Engines other than: S.I. Engines < 56 kW / IWV / Rail				Limit values proposed					
(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	-		
	8-19 kW			6,6	7,5	0,4	-		
	19-37 kW				4,7				
	37-56 kW			5,0	4,7		0,015	1X10^{12}	1,1
Engines	56-130 kW				0,4				
	130-560 kW								
PI. Engines	> 560 kW	Variable		3,5	3,5	0,19	0,045	-	
		Constant	Other than Gen-Sets					-	6,0
			Gen-Sets		0,67		0,035	-	

- Limits for smaller engines (< 19 kW), and larger engines (> 560 kW) are now included
- For 19-560 kW there is a lower Particulate Mass limit than Stage IV, and the introduction of a Particle Number limit
- For 19-37 kW the NOx limit is reduced from Stage IV; for 37-560 kW NOx limit remains as for Stage IV
- The NRTC test cycle remains the same as Stage IV

(Note that for engines > 56 kW, S.I. and C.I. engine limits are now the same)

EUROPEAN UNION

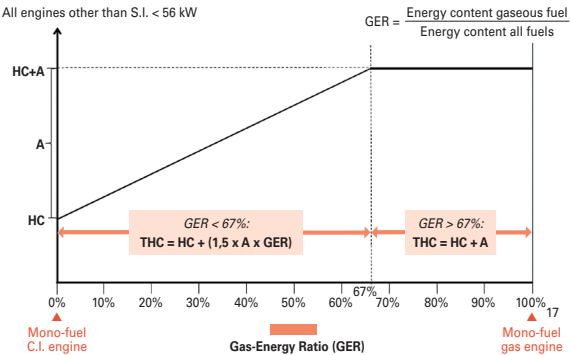
EU STAGE V NRMM EMISSIONS PROPOSAL
SPARK-IGNITED ENGINES

S.I. Engines Emissions in g/kWh		Limit values proposed				
		CO	NOx	HC	PM	PN
S.I.engines 0-19 kW	SH:1 (< 20 cc)	805	50		-	-
	SH:2 (20-50 cc)	805	50		-	-
	SH:3 (> 50 cc)	603	72		-	-
	SN:1 (< 66 cc)	610	10		-	-
	SN:2 (66-100 cc)	610	10		-	-
	SN:3 (100-225 cc)	610	10		-	-
	SN:4 (> 225 cc)	610	8		-	-
S.I. engines 19-56 kW		4,4-20,6ΣΣ 2,7-Σ 0,8			-	- [1]
S.I. engines for snowmobiles		275	-	75	-	-
S.I. engines ATV & SBS		400	8		-	-

[1] Limit values depending on (NOx + HC) / CO combinations

Irland Waterway Vessels (IWV) and Rail Classes are included in the proposal.
http://ec.europa.eu/enterprise/sectors/automotive/documents/consultations/2012-emisssions-nrmm/index_en.htm)

Gaseous and Dual-Fuel Engines



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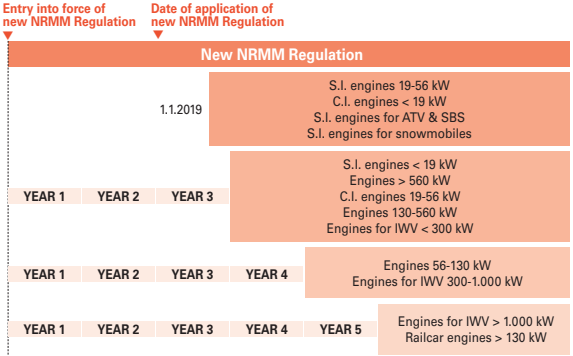
EU STAGE V NRMM EMISSIONS PROPOSAL - Timeplan for Stage V introduction



- The new Stage V legislation will be in the form of an EU Regulation, not a Directive (as it has been set up to Stage IV). This means that it applies to all member states immediately it is adopted, and does not require transposition into the National Law of each Member State (which is time-consuming).
- The new regulation looked to prevent "replacement" engines being built and certified to old emission levels. OEMs can only supply spares to rebuild a broken engine, but it must adopt the identity (serial nr) of the old engine. Industry objected as this will extend the downtime period of the machine following a major engine failure. Additional proposals on the table, including option to allow replacement engines up to a limited time period (e.g. 3, 7 yrs…).
- As of July 2015, the proposed draft regulations are passing in parallel through the European Parliament and the Council of Ministers, with a plan to achieve adoption by the Legislators by end of 2015, and entry into force from 2016. It is possible that amendments could be made at a very late stage.
- For further updates see: http://ec.europa.eu/enterprise/sectors/automotive/environment/non-road-mobile-machinery/index_en.htm and http://www.euromot.org

In-Service Conformity (ISC)

- The proposed Stage V regulation will include a requirement for engine OEMs to test engines installed in machines over their normal operating duty cycle. This will be done by the use of a PEMS.
- The current proposal requires only that the ISC emissions results are monitored and reported - currently there are no specified ISC emissions limits in the proposal.
- The Commission "shall then review the situation and propose final prescriptive requirements for ISC". There is currently no timetable for these requirements.

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 < 750	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/yr) [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			

US FEDERAL (EPA)

Rated Power	Tier	MY	NMHC	NMHC + NOx	NOx	PM	CO	Smoke [1] Life	Useful Period	Warranty
(kW)			(g/kW/hr)						(%)	(hrs/yr) [2]
75 ≤ kW < 130	1	1997-2002	-	-	9,2	-	-	20/15	8.000/10	3.000/5
	2	2003-2006	-	6,6	-	0,30	5,0	/50		
	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	-	6,4	-	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			
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			
560 ≤ kW < 900	1	2000-2005	1,3 [10]	-	9,2	0,54	11,4			
	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]	0,04 [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.

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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 Sep07 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< 8kW: hand-startable, air cooled and DI engines: 0,60g/kWh in 2010, before Tier 2 limits are required

[2] EP < 8kW: CO: 8,0 g/kWh

[3] EP < 37kW: 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	2008	5,5	-	7,5 (5,6)	-	0,3 (0,22)
(25 ≤ hp < 50)	2013	(4,1)	-	4,7 (3,5)	-	0,03 (0,022)
37 ≤ kW < 56	2008	5,0	-	4,7	-	0,3 [2] (0,22)
(50 ≤ hp < 75)	2013	(3,7)	-	(3,5)	-	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)	2011-2014 [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 31Dec14

[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 96-99)
Steady-state test cycle: ISO 8178 Transient test
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: Fuels with sulfur levels no greater than 0,2 wt% (2.000 ppm) were used for certification testing of Tier 1-3 engines. From 2011 all Tier 4 engines are tested using fuels of 7-15 ppm sulfur content. The transition from 2000 ppm specification to the 7-15 ppm specification took place 2006-2010 (see Certification Diesel Fuel).

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	805	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
I	16,1	14,8	610	01Aug07 [1)]
I-A	50	N/A	610	MY 2001
I-B	40	37	610	MY 2001

[1)] also incl. any Class I eng family produced ≥ 01Aug03 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

Class	MY	HC	HC+NOx	NMHC+NOx	CO	Usefil Life (hrs)			Warranty Period
		(g/kWh)							
I	2012	-	10.0 [ABT]	-	-	Residential 125	Extended Life Residential 250	Commercial 500	2 yrs
II	2011	-	8.0 [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 ≤	Class V
2	Class I-A < 66cc	66 ≤ Class I-b < 100 cc	100 ≤ Class I < 225cc	Class II ≤ 225cc	< 20 cc	Class IV	≥ 50 cc
3	Class I < 225 cc		Class II < 225 cc			< 50 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 01Jan09

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 01Jan09 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

1) Alternative according to the following formula: $(HC+NOx) \times (CO)^{0,784} \leq 8,57$
Field testing limits use: $(HC+NOx) \times (CO)^{0,791} \leq 16,78$

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

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:

$HC+NOx \leq 0,08$ g/kWh and $CO \leq 4,4$ g/kWh (steady-state and transient tests)

$HC+NOx \leq 1,1$ g/kWh and $CO \leq 6,6$ g/kWh (field test)

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 $\lambda = 1$
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

[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

(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

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	
560 ≤ 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	3,50	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 colled, 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 31Dec14, 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 diumal 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 < 225 cc Walk behind Mowers	2006	-	-	-	-
	2007-2008	1,3	-	-	-
	2009-2013+	1,0	-	-	-
> 80 to < 225 cc Others	2006	-	15	-	-
	2007-2011	1,20 + 0,056 tank vol (l)	15	2,5	TP902
	2012-2013+	0,95 + 0,056 tank vol (l)	15	1,5	TP902
≥ 225 cc	2006-2007	-	15	-	TP902
	2008-2012	1,20 + 0,056 tank vol (l)	15	2,5	TP902
	2013+	1,20 + 0,056 tank vol (l)	15	1,5	TP902

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 SPARK IGNITION ENGINE EXHAUST EMISSIONS STANDARDS (> 19kW), 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="3">4,0 / 49,6 [1]</td><td colspan="3">4,0 / 49,6
(3.500 hrs or 5 yrs)</td><td colspan="2">2,7 / 4,4 [2]
(5.000 hrs or 7 yrs)</td><td colspan="5">0,8 / 20,6 (5.000 hrs or 7 yrs)</td></tr>
<tr><td>Transient Testing</td><td colspan="7">-</td><td colspan="2">2,7 / 4,4 [2]
(5.000 hrs or 7 yrs)</td><td colspan="5">0,8 / 20,6 (5.000 hrs or 7 yrs)</td></tr>
<tr><td>Field Testing</td><td colspan="7">-</td><td colspan="7">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 def'd 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	01Jan09	01Jan11	01Jan13
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 equip., agricultural equip., limited use equip. 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) x CO0,784 ≤ 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

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	6,00	7,98	1,00	1,33	5,00	6,50	0,40	0,53	40	07OCT01	
	4,00	5,30	0,70	0,90	5,00	6,50	0,03	0,04	25	01OCT13	01SEP15
37-56 kW	4,00	5,32	0,70	0,93	5,00	6,50	0,30	0,40	35	08OCT01	
	4,00	5,32	0,70	0,90	5,00	6,50	0,025	0,033	25	01OCT13	01NOV14
56-75 kW	4,00	5,32	0,70	0,93	5,00	6,50	0,25	0,33	30	08OCT01	
	3,30	4,40	0,19	0,25	5,00	6,50	0,02	0,03	25	01OCT12	01APR14
75-130 kW	3,60	4,79	0,40	0,53	5,00	6,50	0,20	0,27	25	07OCT01	
	3,30	4,40	0,19	0,25	5,00	6,50	0,02	0,03	25	01OCT12	01NOV13
130-560 kW	3,60	4,79	0,40	0,53	3,50	4,55	0,17	0,23	25	06OCT01	
	2,00	2,70	0,19	0,25	3,50	4,60	0,02	0,03	25	01OCT11	01APR13

Test mode for NOx, NMHC, CO and PM measurement is diesel powered special vehicle 8 mode and NRTC (see page 94)

Test mode for smoke measurement is diesel powered special vehicle 8 mode and no road acceleration smoke mode

NMHC is measured from Oct11 instead of HC

NOx (mean) is planned to be reduced to 0.4 (g/kWh) for 130-560 kW vehicles from 2013

NOx (mean) is planned to be reduced to 0.4 (g/kWh) for 56-75 kW and 75-130 kW vehicles from 2014

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	01OCT13	01SEP15

SPECIAL VEHICLES FOR SMALL VOLUME PRODUCTION

19-37 kW	Tier 2, Stage IIIA	07OCT01	
	Tier 4	01OCT13	01SEP15
37-56 kW	Tier 3, Stage IIIA	08OCT01	
	Tier 4, Stage IIIB	01OCT13	01NOV14
56-75 kW	Tier 3, Stage IIIA	08OCT01	
	Interim Tier 4, Stage IIIB	01OCT12	01APR14

- 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

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

- 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.

SOUTH KOREA

Tier 3 starts from Jan 13 - Tier 4 starts from Jan15

Category	Test Mode	Engine Output Range	CO	NMHC	NOx	PM
				(g/kWh)		
Tier 3 (1st Stage)	KC1-8 (NRSC)	19 ≤ kW < 37	5,5	7,5 (NMHC + NOx)		0,6
		37 ≤ kW < 56	5,0	4,7 (NMHC + NOx)		0,4
		56 ≤ kW < 130	5,0	4,0 (NMHC + NOx)		0,3
		130 ≤ kW < 560	3,5	4,0 (NMHC + NOx)		0,2
Tier 3 (2nd Stage)	KC1-8 (NRST)	kW < 8	8,0	7,7 (NMHC + NOx)		0,4
		8 ≤ kW < 19	6,6	7,5 (NMHC + NOx)		0,4
		19 ≤ kW < 37	5,5	4,7 (NMHC + NOx)		0,03
		37 ≤ kW < 56	5,0	4,7 (NMHC + NOx)		0,03
		56 ≤ kW < 130	5,0	0,19	0,40	0,02
		130 ≤ kW < 560	3,5	0,19	0,40	0,02

Tier 4 starts from Jan15

NRSC, NRTC		kW < 8	8,0	7,5 (NMHC + NOx)		0,4
		8 ≤ kW < 19	6,6	7,5 (NMHC + NOx)		0,4
		19 ≤ kW < 37	5,5	4,7 (NMHC + NOx)		0,03
		37 ≤ kW < 56	5,0	4,7 (NMHC + NOx)		0,03
		56 ≤ kW < 130	5,0	0,19	0,40	0,02
		130 ≤ kW < 560	3,5	0,19	0,40	0,02

PR OF CHINA

GB 20891-2014 is released, it regulates the limits and measurement methods for exhaust pollutants from diesel engines (Chine III, IV). It is based on the European 2004/26/EC regulation.
1Dec2014 - all the engines for TA should meet requirement of Stage III
1Oct2015 - all the engines in production and sales meet requirement of Stage III
1Apr2016 - all the non-road mobile machinery in production, import and sales should be installed with the engine that meet requirement of Stage III
GB 20891-2014 defers from 2004/26/EC as follows

- Net power < 19 kW engines operated in non constant speed are tested in ISO 8178 G2 6 mode cycle (see page 97)
- China Stage III corresponds to Euro Stage III, China Stage IV corresponds to Euro Stage IIIb
- The regulation extends the engine control requirement to P < 19 kW and P > 560 kW

Stage III				Stage IV					
Net Power	CO	HC+NOx	PT	Net Power	CO	HC	NOx	HC+NOx	PT
(kW)	(g/kWh)			(kW)	(g/kWh)				
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

[1] Applicable to mobile power unit with Pmax > 900 kW

The method for determining the conformity check is simplified
Some technical parameters of the test reference fuel are different

OTHER AREAS OF THE WORLD

Brazil

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

Construction machinery	≥ 37 kW	01Jan15
	All	01Jan17
Farm machinery	≥ 75 kW	01Jan17
	All	01Jan19

Power	CO	HC+NOx	PM
9 kW	(g/kWh)		
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

India

Agricultural and forestry tractors.
Bharat TREM III: HC+NOx 9,5; CO 5,5; PM 0,8 g/kWh
Bharat Stage IIIA equivalent to EU Stage IIIA engines < 37 kW from Apr10, engines ≥ 37 kW from Apr11
Construction machinery:
Bharat Stage II (CEV) equivalent to EU Stage I from Oct07/Oct08
Bharat Stage III (CEV) equivalent to US Tier 2/3 from Apr11

Russia

Proposed: 01Jan14 EU Stage III (for new vehicles)

Singapore

Newly imported non-road diesel engines must meet EU Stage II. US Tier II or Japan Tier I off-road engine emission standards since 01Jul12

Switzerland

New engines for off-road vehicles and machinery to meet current EU standards. Diesel engines operated on large construct, on sites must be equippped with DPF.

Turkey

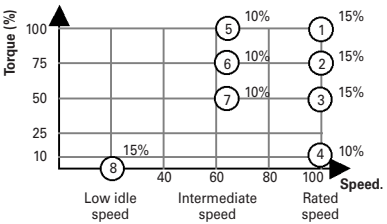
01Jan14 130 ≤ P ≤ 560
01Oct14 56 ≤ P ≤ 130

TEST CYCLES

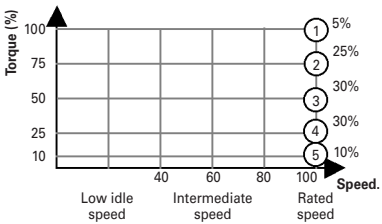
NRSC TEST (Non-Road Steady-State Cycle)

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.

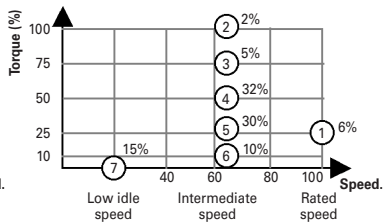
C.I. engines ISO 8178-C1 intermittent



C.I. engines ISO 8178-D2 constant speed

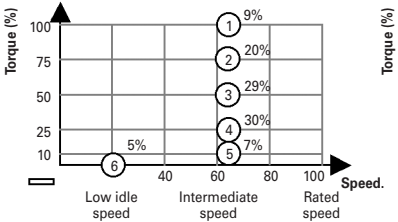


ISO 8178-C2 S.I. engines > 20 kw

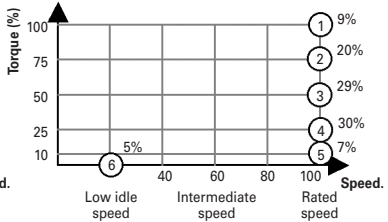


TEST CYCLES

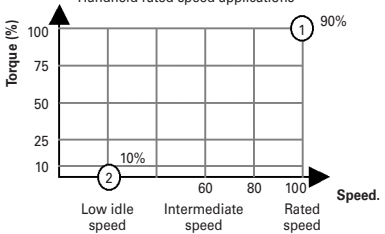
ISO 8178-G1
Non handheld intermediate speed applications



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

TEST CYCLES

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	Torque [a] [b] [%]
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.

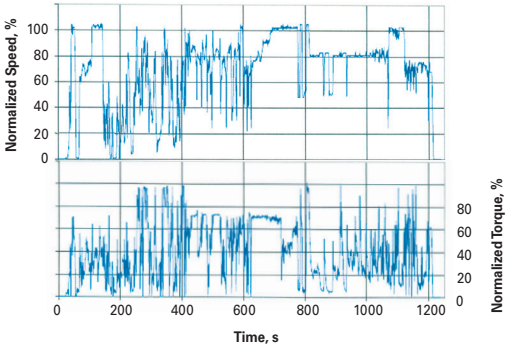
TEST CYCLES

NRTC TEST (Non-Road Transient Cycle)
The NRTC test has been developed by the US EPA in cooperation with the EU authorities. It will be used for both US EPA Tier 4 and EU Stage III and IV regulations.
Emissions Test Run - Following chart outlines the test sequence.

Engine preparation, Pre-test measurements and Calibration
↓
NRTC
↓
Generation engine map (max torque curve)
Generate reference test cycle
↓
Run one or more practise cycle as necessary to check engine/test cell/emissions 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

One or more Practice Cycles may run as necessary to check engine, test cell and emissions systems before the measurement cycle.

The NRTC is run twice (cold start/hot start) with the weighted PM being an
- average of the hot (90%) and cold (10%) cycles for EU Stage III
- average of the hot (95%) and cold (5%) cycles for US Tier 4



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
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
ISC	In-Service Conformity
LDT	Light Duty Truck
LDV	Light Duty Vehicle = passenger car
LEV	Low Emission Vehicle (LEV1, LEV2)
LPG	Liquified Petroleum Gas
MY	Model Year
MTBE	Methyl Tertiary Butyl Ether
NG	Natural Gas
NHV	Net Heating Value of Fuel
NLEV	National Low Emissions Vehicle
NMHC	Non-methane Hydrocarbons
NMOG	Non-methane Organic Gases
OBD	On-board Diagnostic
OMHCE	Organic Material Hydrocarbon Equivalent
ORVR	On-board Refueling Vapour Recovery
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
TLEV	Transitional Low Emission Vehicle
VT SHED	Variable Temperature SHED
ULEV	Ultra Low Emission Vehicle (ULEV1, ULEV2)
WWH-OBD	Worldwide Harmonized On-board Diagnostics
ZEV	Zero Emissions Vehicle

TEST CYCLES

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
WHDC	World Harmonized Driving Cycle
WHSC	Worldwide Heavy Duty Steady-state Cycle
WHTC	Worldwide Heavy Duty Transient Cycle

ADMINISTRATIONS & ASSOCIATIONS

ACEA	European Car Manufacturer Association
ECE	Economic Commission for Europe
EPA	US Environmental Protection Agency
EU	European Union
MVEG	Motor Vehicle Emissions Group (Advisory Committee)

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