



ENGINE STANDARDS

Background

Ports around the world depend on the efficiency of the diesel engine to power port operations in each source category – ocean/sea-going vessels, harbor craft, cargo handling equipment, trucks and locomotives. Though diesel engines are the most efficient power sources compared to other internal combustion engines, they are significant contributors to air pollution. Environmental regulations are calling for cleaner engine standards and advanced emission controls to address the negative impact from diesel emissions.

The following fact sheet provides an overview on international engine emission standards. Emission standards are set requirements that limit the amount of pollutants that can be released into the atmosphere. There are emission standards set for both onroad and offroad vehicles and equipment. Generally, emission standards regulate emissions for oxides of nitrogen (NO_x), particulate matter (PM) or soot, carbon monoxide (CO), or volatile hydrocarbons (depends on international engine standard).

European Union Emission Standards

The European Union currently has emission standards set for all road vehicles, locomotives, and 'nonroad mobile machinery.' However, no engine standards apply to ocean/sea-going vehicles and airplanes.

Euro Norm Emissions for Category N2, EDC, (2000 and Up)

Standard	Date	CO (g/kWh)	NO _x (g/kWh)	HC (g/kWh)	Particulates (g/kWh)
Euro 0	1988-1992	12.30	15.8	2.60	None
Euro I	1992-1995	4.90	9.00	1.23	0.40
Euro II	1995-1999	4.00	7.00	1.10	0.15
Euro III	1999-2005	2.10	5.00	0.66	0.10
Euro IV	2005-2008	1.50	3.50	0.46	0.02
Euro V	2008-2012	1.50	2.00	0.46	0.02
Euro VI	Proposed regulations under review.				

Euro Norm Emissions for (Older) ECE R49

Standard	Date	CO (g/kWh)	NO _x (g/kWh)	HC (g/kWh)	Particulates (g/kWh)
Euro 0	1988-1992	11.20	2.40	2.40	None
Euro I	1992-1995	4.50	1.10	1.10	0.36
Euro II	1995-1999	4.00	1.10	1.10	0.15



Heavy-Duty Diesel Truck and Bus Engines

The following table summarizes emission standards and implementation dates for heavy-duty trucks and bus engines.

EU Emission Standards for HD Diesel Engines, g/kWh (smoke in m⁻¹)

Standard	Date	Test	CO	HC	NOx	PM	Smoke
Euro I	1992, > 85 kW		4.5	1.1	8.0	.36	
Euro II	1996		4.0	1.1	7.0	.25	
	1998		4.0	1.1	7.0	.15	
Euro III	1999	ESC & ELR	1.5	0.25	2.0	0.02	0.15
	2000	ESC & ELR	2.1	0.66	5.0	0.10 0.13	0.8
Euro IV	2005		1.5	0.46	3.5	0.02	0.5
Euro V	2008		1.5	0.46	2.0	0.02	0.5

The Euro III standard includes changes in the engine test cycles (2000). Two new test cycles replace the old steady-state engine test cycle ECE R-49. The two test cycles include the European Stationary Cycle (ESC) and the European Transient Cycle (ETC). The European Load Response (ELR) measures smoke opacity.

Nonroad Diesel Engines

Regulations for nonroad diesels were first introduced in 1997 in two stages depending on the engine power output; Stage I – 1999 and Stage II – 2001 to 2004. Nonroad equipment included industrial drilling rigs, compressors, construction wheel loaders, bulldozers, nonroad trucks, highway excavators, forklift trucks, road maintenance equipment, snow plows, ground support equipment I air ports, aerial lifts and mobile cranes. However, ships, locomotives, aircraft, and generating sets were not covered by Stage I and II standards.

In 2004, the European Parliament adopted Stage III and IV emission standards. Stage III emission standards include a phase-in schedule from 2006 to 2013. Stage IV will come into compliance in 2014. Both Stages III and IV include emission standards for locomotives and marine engines. Standards apply only to new vehicles and equipment. Replacement engines to be used in machinery already in use (except for rail car, locomotive and harbor craft propulsion engines) should comply with the limit values that the engine to be replaced had to meet when originally placed on the market.

Stage III/ IV Engine Standards

The following table provides a summary for Stage III and IV engine standards. Stage III standards are divided into two sub-stages: Stage III A and Stage III B. The limits are set for all nonroad diesel engines of indicated power range for use I applications and do not apply to locomotive, rail cars and harbor craft propulsion engines.

Stage III B standards include PM limit of 0.025 g/kW-hr, which represents about 90% emission reductions compared to Stage II. In order to meet the 90% reduction, emission control technologies will have to be applied such as diesel particulate filters (DPFs). Stage IV introduces stringent NOx standards of 0.4 g/kWh also requiring the use of a NOx emission control technology.



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Stage III A Standards for Nonroad Engines

Category	Net Power	Date	CO	NOx+HC	PM
	kW				
H	$130 \leq P \leq 560$	2006	3.5	4.0	0.2
I	$75 \leq P < 130$	2007	5.0	4.0	0.3
J	$37 \leq P < 75$	2008	5.0	4.7	0.4
K	$19 \leq P < 37$	2007	5.5	7.5	0.6

State III B Standards for Nonroad Engines

Category	Net Power	Date	CO	HC	NOx	PM
	kW					
L	$130 \leq P \leq 560$	2011	3.5	0.19	2.0	0.025
M	$75 \leq P < 130$	2012	5.0	0.19	3.3	0.025
N	$56 \leq P < 75$	2012	5.0	0.19	3.3	0.025
P	$37 \leq P < 56$	2013	5.0	4.7 (NOx+HC)		0.025

Stage IV Standards for Nonroad Engines

Category	Net Power	Date	CO	HC	NOx	PM
	kW					
Q	$130 \leq P \leq 560$	2014	3.5	0.19	0.4	0.025
R	$56 \leq P < 130$	2014	5.0	0.19	0.4	0.025

The Nonroad Transient Cycle (NRTC) test procedure was developed to represent emissions during real conditions in cooperation with the United States Environmental Protection Agency.

Stage III A Standards for Harbor Craft

Category	Displacement	Date	CO	NOx+HC	PM
	Dm3 per cylinder				
V1:1	$D \leq 0.9, P > 37 \text{ kW}$	2007	5.0	7.5	0.40
V1:2	$0.9 < D \leq 1.2$		5.0	7.2	0.30
V1:3	$1.2 < D \leq 2.5$		5.0	7.2	0.20
V1:4	$2.5 < D \leq 5$	2009	5.0	7.2	0.20
V2:1	$5 < D \leq 15$		5.0	7.8	0.27
V2:2	$15 < D \leq 20, P \leq 3300 \text{ kW}$		5.0	8.7	0.50
V2:3	$15 < D \leq 20, P > 3300 \text{ kW}$		5.0	9.8	0.50
V2:4	$20 < D \leq 25$		5.0	9.8	0.50
V2:5	$25 < D \leq 30$	5.0	11.0	0.50	



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Stage III A Standards for Rail Traction Engines

*HC = 0.4 g/kW-hr and NO_x = 7.4 g/kW-hr for engines of P > 2000 kW and D > 5 liters/cylinder

Category	Net Power	Date	CO	HC	HC+NO _x	NO _x	PM
	kW						
RC A	130 < P	2006	3.5	-	4.0	-	0.2
RL A	130 ≤ P ≤ 560	2007	3.5	-	4.0	-	0.2
RH A	P > 560	2009	3.5	0.5*	-	6.0*	0.2

Stage III B Standards for Rail Traction Engines

Category	Net Power	Date	CO	HC	HC+NO _x	NO _x	PM
	kW						
RC B	130 < P	2012	3.5	0.19	-	2.0	0.025
RB	130 < P	2012	3.5	-	4.0	-	0.025

By the end of 2007, Stage III and IV emission standards will undergo technical review. This will determine the feasibility of standards, and recommended relaxing or tightening of the limits, as it may be appropriate.

United States Emission Standards

The United States Environmental Protection Agency set national engine emission standards. In some states such as California, engine standards are set independently for that state. Some of the most strict engine standards in the world are set by the California Air Resources Board.

Heavy-Duty Vehicles and Buses

Heavy-duty diesel vehicles are defined by their gross vehicle weight rating (GVWR). Federal regulations set emission standards for heavy-duty vehicles with a GVWR of 8,500 pounds and higher and California's heavy-duty vehicle emission standards start at 14,000 pounds.

Diesel engines in heavy-duty vehicles are broken down into service classes. These include:

- ▶ Light heavy-duty diesel engines: 8,500 < **LHDDE** < 19,500 (14,000 < **LHDDE** < 19,500 in California, 1995+)
- ▶ Medium heavy-duty diesel engines: 19,500 ≤ **MHDDE** ≤ 33,000
- ▶ Heavy heavy-duty diesel engines (including urban bus): **HHDE** > 33,000

Basic standards are expressed in g/bhp-hr and require emission testing over the transient FTP engine dynamometer.

Model Year 1987 – 2003

The following table summarizes federal (EPA) and California (CARB) emission standards for HDDVs.



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EPA Emission Standards for HDDV Engines, g/bhp-hr

Year	HC	CO	NOx	PM
Heavy Duty Diesel Truck Engines				
1988	1.3	15.5	10.7	0.60
1990	1.3	15.5	6.0	0.60
1991	1.3	15.5	5.0	0.25
1994	1.3	15.5	5.0	0.10
1998	1.3	15.5	4.0	0.10
Urban Bus Engines				
1991	1.3	15.5	5.0	0.25
1993	1.3	15.5	5.0	0.10
1994	1.3	15.5	5.0	0.07
1996	1.3	15.5	5.0	0.05
1998	1.3	15.5	4.0	0.05

California Emission Standard for HDDV Engines, g/bhp-hr

Year	NMHC	THC	CO	NOx	PM
Heavy-Duty Diesel Truck Engines					
1987	-	1.3	15.5	6.0	0.60
1991	1.2	1.3	15.5	5.0	0.25
1994	1.2	1.3	15.5	5.0	0.10
Urban Bus Engines					
1991	1.2	1.3	15.5	5.0	0.10
1994	1.2	1.3	15.5	5.0	0.07
1996	1.2	1.3	15.5	4.0	0.05

The HDDV emission standards include a useful life and warranty period.

- ▶ LHDDE – 8 years/110,000 miles
- ▶ MHDDE – 8 years/185,000 miles
- ▶ HHDDE – 8 years/290,000 miles



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Model Year 2004 and Later

In October 1997, EPA adopted new emission standards for model year 2004 and later for heavy-duty diesel truck and bus engines.

EPA Emission Standards for MY 2004 and Later HDDV Diesel Engines, g/bhp-hr

Option	NMHC + NOx	NMHC
1	2.4	n/a
2	2.5	0.5

Under this ruling, all emission standards other than NMHC and NOx applying to 1998 and later model year heavy-duty engines would continue at their 1998 levels.

Useful life requirements were significantly extended compared to earlier rulings.

- ▶ LHDDE – 110,000 miles/10 years
- ▶ MHDDE – 185,000 miles/10 years
- ▶ HHDDE – 435,000 miles/10 years

The federal 2004 standards for highway trucks are coordinated with California standards.

Model Year 2007 and Later

Emission standards were set for heavy-duty trucks model year 2007 and newer in December 2000. California Air Resources Board adopted very similar standards in October 2001. The rule included two important approaches to further emission reductions; stricter emission standards and diesel fuel regulations.

Emission Standards

The emission standards for HDDVs model year 2007 and newer included:

- ▶ PM 0.01 g/bhp-hr
- ▶ NOx 0.20 g/bhp-hr
- ▶ NMHC 0.14 g/bhp-hr

In 2007, the PM emission standard will take full effect. Standards for NOx and NMHC will be phased in between 2007 to 2010.

Crankcase Emissions

As a part of the 2007 regulation for HDDVs, crankcase emissions will be eliminated. Through the use of emission control technologies, crankcase emissions will be routed back to the engine intake or to the exhaust upstream as a means of recycling the emissions back through the crank shaft.



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Cleaner Fuels

As of July 2006, all on-highway diesel fuel required a lower sulfur content of 15 parts per million (ppm) from the 500 ppm on-highway diesel fuel. Retail stations and wholesale purchasers were required to meet this standard by selling the 15 ppm ultra low sulfur diesel fuel (ULSD) by September 2006. ULSD is a “technology enabler” for sulfur-intolerant exhaust emission control technologies, such as diesel particulate filters and NO_x catalyst, technologies that are necessary to meet 2007 emission standards.

Nonroad Equipment

Similar to the onroad regulations for cleaner engines and the use of ultra low sulfur diesel fuel, the US EPA introduced the Clean Air Nonroad Diesel Rule in May 2004. This comprehensive rule requires that emissions be reduced by integrating engine and fuel controls as an approach to achieve the greatest emission reductions. New nonroad engines are required to have emission control technologies similar to on-road HDDVs. This regulation will help reduce exhaust emissions by more than 90 percent.

EPA’s Clean Air Nonroad Diesel Rule applies to diesel engines in most construction, agricultural, industrial, and airport equipment. The standards will take effect for new engines in 2008 and will be completely phased in by 2014.

Nonroad Emission Standards, g/hp-hr

Rated Power	First Year that Standards Apply	PM	NO _x
hp < 25	2008	0.30	-
25 ≤ hp < 75	2013	0.02	3.5*
75 ≤ hp < 175	2012 – 2013	0.01	0.30
175 ≤ hp < 750	2011 – 2013	0.01	0.30
hp ≥ 750	2011 – 2014, 2015	0.075, 0.02/0.03**	2.6/0.50

* 3.5 g/hp-hr standard includes both NO_x and nonmethane hydrocarbons.

** The 0.02 g/hp-hr standard applies to gensets; the 0.03 g/hp-hr standard applies to other engines.

2011 to 2014 – 0.50 applies to gensets over 1200 hp.

2015 – 0.50 applies to all gensets.

Nonroad Diesel Fuel Rule

In 2007, all nonroad equipment will be required to use lower sulfur diesel fuel with a maximum sulfur content of 500 ppm. By 2010, all nonroad equipment will be required to use on-highway ULSD with a sulfur content of 15 ppm. This limit also applies to locomotive and marine applications (though not very large marine engines that depend on residual fuel).



Locomotive and Marine Engines

In March 2007, the EPA proposed more stringent exhaust emission standards for locomotives and marine diesel engines. The new emission standards would significantly reduce harmful emissions of PM and NOx. Under this program, three approaches would be put in place.

1. Tighten emission standards for existing locomotives when they are remanufactured. These standards would take effect as soon as certified remanufacture systems are available (as early as 2008), but no later than 2010 (2013 for Tier 2 locomotives).
2. Set near-term engine-out emission standards, referred to as Tier 3 standards, for newly-built locomotives and marine diesel engines. These standards would reflect the application of emission control technologies to reduce PM and NOx exhaust emissions and would start a phase-in by 2009.
3. Set longer-term standards, referred to as Tier 4 standards, for newly-built locomotives and marine diesel engines that reflect the application of high-efficiency aftertreatment technology. These standards would apply to marine engines in 2014 and locomotives by 2015. By 2012, ULSD will be available for US locomotives and marine engines, which would be a “technology enabler” for some emission control technologies such as diesel particulate filters (DPFs).

In addition to these standards, EPA is proposing provisions to eliminate unnecessary idling.

Locomotive Engines

The regulations would apply to all line-haul, passenger, and switch locomotives that operate extensively within the United States, including newly manufactured locomotives and remanufactured locomotives that were originally manufactured after 1972. There is a primary exception that new remanufacturing standards would not apply to existing fleets of locomotives owned by very small railroads.

Marine Engines

The regulations would apply to newly-built marine diesel engines with displacements less than 30 liters per cylinder installed on vessels flagged or registered in the United States. The marine diesel engines are divided into three categories.

- ▶ Category 1 – engines above 50 horsepower (hp) and up to 5 liters per cylinder displacement.
- ▶ Category 2 – engines 5 to 30 liters per cylinder.
- ▶ Category 3 – engines 30 per cylinder.

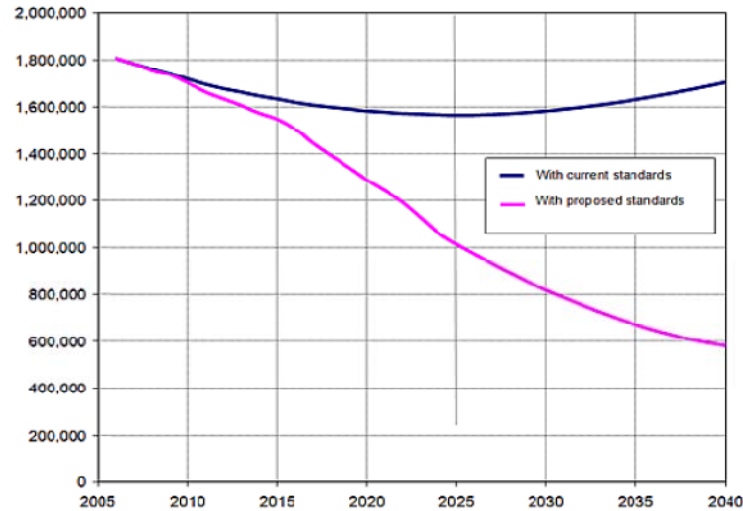
The following figures provide projected emission reductions for NOx and PM under the new emission standards for locomotive and marine diesel engines.¹

¹ NOx and PM figures from EPA fact sheet on *Locomotive and Marine Diesel Engines Proposed Rule*, March 2007



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Projected NOx Emissions (tons per year 'with' and 'without' Proposed New Controls)



Projected PM Emissions (tons per year 'with' and 'without' Proposed New Controls)

