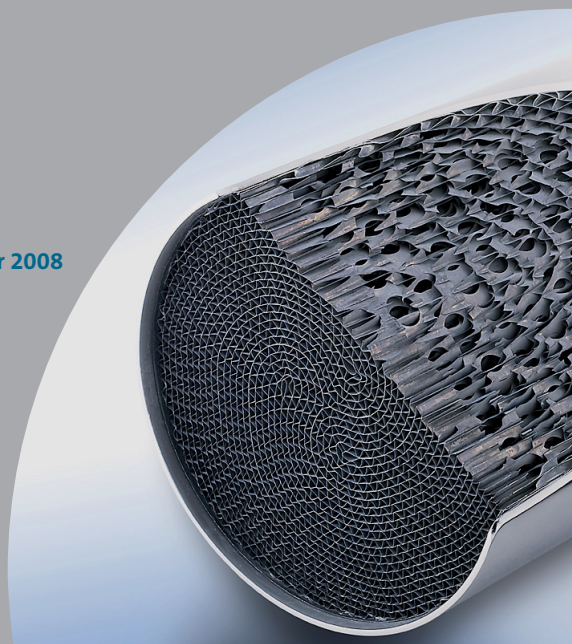


Engines and Systems



# Exhaust Emission Legislation Diesel- and Gas engines

September 2008



## Glossary

### Exhaust emission components

CO	Carbonmonoxide
HC	Hydrocarbons
NO <sub>x</sub>	Nitrogen oxides
NMHC	Non-Methane-Hydrocarbons
PM	Particulate matter
SO <sub>x</sub>	Sulfur oxide
THC	Total Hydrocarbon
VOC	Volatile organic components (equals HC)

### Regulations

BSO	Bodensee Schifffahrtsordnung, Lake Constance Shipping Ordinance
CFR	Code of Federal Register (US regulations)
RheinSchUO	Rhine vessel inspection regulation
TA-Luft	Technische Anleitung zur Reinhaltung der Luft (German clean-air standard for approval authorities)

### Authorities and Organizations

EU	European Union
EC	European Commission
ECE	Economic Commission for Europe (UN economic commission for Europe)
EPA	Environmental Protection Agency (US environmental authority)
CARB	California Air Resources Board
IMO	International Maritime Organization
CCNR	Central Commission for the Navigation on the Rhine
UIC	Union International des Chemins de Fer (International Union of Railways)

### Engine Parameters

MY	Model year
m <sub>n</sub> <sup>3</sup>	standard cubic meter
MW <sub>e</sub>	Megawatt electrical
MW <sub>th</sub>	Megawatt thermal
P <sub>n</sub>	Engine rated power [kW]
n <sub>n</sub>	Engine rated speed [rpm]
V <sub>h,z</sub>	Swept volume per cylinder (cyl. displacement) [liter]

## EU – Inland waterway vessels

The emission limits are valid for propulsion engines of inland waterway vessels in EU watercourses (Nonroad Directive 97/68/EC, amended by 2004/26/EC). The limits and the classification of the engines correspond to stage 2 (Tier 2) of the US-EPA Final Rule for inland marine vessels. However, the time of adoption is two or accordingly three years later.

Category	Cylinder Displac. Power	CO g/kWh	HC + NO <sub>x</sub> g/kWh	PM g/kWh	Date <sup>A</sup>
V 1:1	$V_{h,z} < 0.9 \text{ l}$	5.0	7.5	0.4	2007
	$P_n \geq 37 \text{ kW}$				
V 1:2	$0.9 \text{ l} \leq V_{h,z} < 1.2 \text{ l}$	5.0	7.2	0.3	2007 <sup>B</sup>
V 1:3	$1.2 \text{ l} \leq V_{h,z} < 2.5 \text{ l}$	5.0	7.2	0.2	2007 <sup>B</sup>
V 1:4	$2.5 \text{ l} \leq V_{h,z} < 5.0 \text{ l}$	5.0	7.2	0.2	2009
V 2:1	$5.0 \text{ l} \leq V_{h,z} < 15.0 \text{ l}$	5.0	7.8	0.27	2009
V 2:2	$15.0 \text{ l} \leq V_{h,z} < 20.0 \text{ l}$	5.0	8.7	0.5	2009
	$P_n < 3300 \text{ kW}$				
V 2:3	$15.0 \text{ l} \leq V_{h,z} < 20.0 \text{ l}$	5.0	9.8	0.5	2009
	$P_n \geq 3300 \text{ kW}$				
V 2:4	$20.0 \text{ l} \leq V_{h,z} < 25.0 \text{ l}$	5.0	9.8	0.5	2009
V 2:5	$25.0 \text{ l} \leq V_{h,z} < 30.0 \text{ l}$	5.0	11.0	0.5	2009

<sup>A</sup> Date for placing on the market; Type approvals one year earlier.

<sup>B</sup> Type approval will not be given from 1 July 2005, if the limits are not fulfilled.

**Exempted from the limits** are the following ships:

- Vessels intended for passenger transport carrying no more than 12 people in addition to the crew
- Recreational craft with a length of less than 24 meters (see 94/25/EC)
- Service craft belonging to supervisory authorities
- Fire-service vessels
- Naval vessels
- Fishing vessels on the fishing vessels register of the Community
- Sea-going vessels, including sea-going tugs and pusher craft operating or based on tidal waters or temporarily on inland waterways, provided that they carry a valid navigation or safety certificate.

For the national implementation of the directive, the exceptions have not been fully adopted by all member states.

- The limits also apply to marine auxiliary engines above 560 kW. For other auxiliary engines the limits for nonroad mobile machinery apply.
- Alternatively, the limits of the Rhine Vessel Inspection Regulation may be applied (mutual recognition is agreed).

- Test cycles: ISO 8178-4, E2/E3/D2/C1 (according to engine operation)
- Test condition: air temperature 25°C / water temperature 25°C

## EU – Recreational crafts

The directive 94/25/EC (as amended by 2003/44/EC) includes construction- and design-prescriptions for **recreational crafts from 2.5 to 24 m hull length**. The emission limits are valid for new propulsion engines, which will be installed or are specifically intended for installation on or in recreational crafts and personal watercrafts, as well as for already built in engines, which are installed on or in these crafts and that undergo major engine modifications (Increasing the rated power of the engine by more than 15 % or possible exceeding of the emission limits given in the directive). The directive does not apply for submersibles, air cushion vehicles, hydrofoils, racing boats (intended solely for racing), experimental craft (provided that they are not subsequently placed on the Community market), craft specially intended to be crewed and to carry passengers for commercial purposes and original historical craft and individual replicas (not in mass-production!) designed before 1950.

### Limits (valid since 1 January 2005)

Type	CO [g/kWh]	HC [g/kWh]	NO <sub>x</sub> [g/kWh]	PM g/kWh
Compression Ignition	5.0	$1.5 + 2/P_n^{0.5}$	9.8	1

$P_n$  = Engine rated power in kW

Exhaust emissions are measured according to the harmonised standard ISO 8178-1.

For engines above 130 kW the exhaust emissions can be measured either according to test cycle E3 (IMO) or E5 (water sports) of ISO 8178-4.

## IMO – Seagoing ships

MARPOL (MARine POLLution) is an international convention for prevention of the pollution of the sea from ships. It establishes rules for the protection of the environment valid for international shipping. The text of the convention regulates the basic conditions while the practical relevant issues are handled in the annexes.

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MARPOL has to be followed primarily by ships, which run under the flag of an IMO member country. If a ship runs under another authority but navigates in watercourses of member countries, this ship has to adopt MARPOL too.

### Nitrogen oxides (NO<sub>x</sub>)

Marine diesel engines with a power of more than 130 kW are affected by this regulation depending on the date of their keel laying. Engines in lifeboats or other rescue equipment and vessels that are operated in national waters are exempted.

$n_n$ 1/min	NO <sub>x</sub> [g/kWh]
<b>Stage I, beginning from 1. 1. 2000</b>	
< 130	17.0
130–2000	$45.0 \cdot n_n^{(-0.2)}$
> 2000	9.8
<b>Stage II<sup>A</sup>, beginning from 1. 1. 2011</b>	
< 130	14.4
130–2000	$44.0 \cdot n_n^{(-0.23)}$
> 2000	7.7
<b>Stage III<sup>A</sup>, beginning from 1. 1. 2016<sup>B</sup> in Emission Control Areas (ECAs)</b>	
< 130	3.4
130–2000	$9 \cdot n_n^{(-0.2)}$
> 2000	2.0

<sup>A</sup> The stages II and III have been agreed in the last MEPC 57 meeting and shall be finally adopted in the MEPC 58 in October 2008.

<sup>B</sup> Review of date of entry into force in 2012.

Existing vessels shall be modified so that they fulfil Tier I emission limit values if

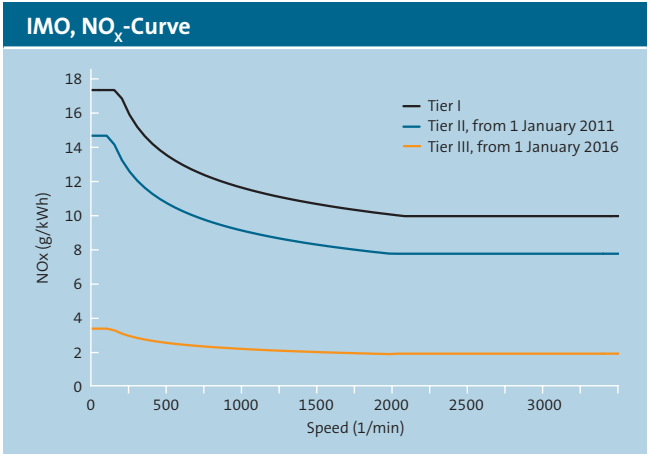
- they have been built between 1990 and 2000,
- they have  $\geq 90$  l displacement per cylinder and
- they have an engine power of  $> 5.000$  kW and
- a retrofit kit at a reasonable price has been approved by the engine manufacturer and certified by the authorities.

Replacement engine or additional engine

- In case of replacement by an identical engine the same requirements apply as for the former one
- In case of replacement by a non-identical engine or installation of an additional engine the standards in force at the time of the installation shall apply.
- Replacement engines only: On or after 1 January 2016 Tier II will be applicable if it can be proven that it is not possible to meet Tier III.

Major engine conversion:

- Engines on ships constructed prior to 1 January 2000 shall meet Tier I
- Engines on ships constructed on or after 1 January 2000 shall meet the standard in place at the time the ship was constructed.



- NO<sub>x</sub> limit dependent on engine rated speed.
- No limits for HC, CO, particulates and soot.
- Test cycle: ISO 8178-4, E2/E3/D2/C1 (according to engine operation).
- Test condition: 25°C air temperature / 25° C water temperature
- Particulate and SO<sub>x</sub> emissions are limited via fuel quality.

### Sulphur oxides (SO<sub>x</sub>)

The SO<sub>x</sub> emission is regulated by the sulphur content in the fuel. The following limits for the sulphur content have been agreed during the 57. MEPC meeting. They shall be adopted during the 58. meeting in October 2008.

Global sulphur limit levels:

- 4.50 % (45.000 ppm) until 2012
- 3.50 % (35.000 ppm) beginning with 2012
- 0.50 % (5.000 ppm) beginning with 2020\*

\*Review of the date of entry into force 2018

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In Emission-Control-Areas (ECAs)

- 1.50 % (15.000 ppm) before 1 March 2010
- 1.00 % (10.000 ppm) beginning from 1 March 2010
- 0.10 % (1.000 ppm) beginning from 2015
- Alternatives (e.g. scrubber) are allowed if they can meet the same reduction rates

### Rhine vessel inspection regulation

The emission limits of combustion engines are established in § 8a of the Rhine Vessel Inspection Regulation (RheinSchUO).

- Only combustion engines which use fuels with a flashpoint above 55°C shall be installed.
- The limits are valid for all engines with a rated power ( $P_n$ ) at or above 37 kW, which are installed in vehicles or machines aboard, unless there are no corresponding directives of the European Union which affect the emission of gaseous pollutants or air pollutant particulates.

#### Stage I (since 2003)

Power $P_n$ kW	Speed $n_n$ rpm	CO g/kWh	HC g/kWh	NO <sub>x</sub> g/kWh	PM g/kWh
37–75	–	6.5	1.3	9.2	0.85
75–130	–	5.0	1.3	9.2	0.70
> 130	500 – 2800	5.0	1.3	$45 \cdot n_n^{(-0.2)}$	0.54
	≥ 2800	5.0	1.3	9.2	0.54

- For engines with a rated power less than 130 kW, the limits correspond to EU Directive 97/68/EC (mobile machinery), stage 1.
- For engines with a rated power of more than 130 kW and a rated speed between 500 and 2800 rpm, the NO<sub>x</sub> limit corresponds to the IMO convention.
- Test cycle: ISO 8178-4, E2/E3/D2/C1 (according to engine operation)
- Test condition: air temperature 25°C /water temperature 25°C

**Stage II (as of the 1 July 2007 [Date of putting in service of the ship])**

Power $P_n$ kW	Speed $n_n$ rpm	CO g/kWh	HC g/kWh	NO <sub>x</sub> g/kWh	PM g/kWh
18–37	–	5.5	1.5	8.0	0.8
37–75	–	5.0	1.3	7.0	0.4
75–130	–	5.0	1.0	6.0	0.3
130–560	–	3.5	1.0	6.0	0.2
> 560	< 343	3.5	1.0	11.0	0.2
	343 – 3150	3.5	1.0	$45 \cdot n_n^{(-0.2)}$	0.2
	$\geq 3150$	3.5	1.0	6.0	0.2

- Test cycles and test conditions as for stage I
- Alternatively, the limits for inland waterway vessel engines of EU Directive 97/68/EC, as amended by Directive 2004/26/EC, may be applied (mutual recognition is agreed).

**Lake Constance shipping ordinance (BSO)**

The compound of the detected carbone monoxide, of the detected hydrocarbons and of the detected nitrogen oxides, as well as the exhaust-gas opacity of diesel engines, may not exceed the following exhaust emission limits for diesel and gasoline engines, which are to be tested according to the prescriptions.

**Stage I (Engines, which have been built before 31 December 1995)**

Power $P_n$ kW	CO		HC		NO <sub>x</sub>	
	A· $P_n^{-m}$ (g/kWh)	m	A· $P_n^{-m}$ (g/kWh)	m	A· $P_n^{-m}$ (g/kWh)	m
< 4	600	0.5	60.0	0.7747	15	0
4–100	600	0.5	39.39	0.4711	15	0
> 100	60	0	10.13	0.1761	15	0

$P_n$  = rated power

The calculated mass-emissions of spark ignited engines of group A or group B, as well as the mass-emissions of diesel engines of group A may not exceed the following values:

- 4500 g/h for carbon monoxide CO
- 290 g/h for hydrocarbons HC
- 1100 g/h for nitrogen oxides NO<sub>x</sub>

Smoke limit for diesel engines: The Bosch-Unit may not exceed 4.0 for naturally aspirated engines and 3.0 for supercharged engines.

**Stage II (engines, which have been built after 1 January 1996)**

For spark ignition engines, the following limits apply:

Power $P_n$ kW	CO		HC		NO <sub>x</sub>	
	A·P <sub>n</sub> <sup>-m</sup> (g/kWh)		A·P <sub>n</sub> <sup>-m</sup> (g/kWh)		A·P <sub>n</sub> <sup>-m</sup> (g/kWh)	
	A	m	A	m	A	m
< 4	400	0.6505	30	0.6505	10	0.1505
4–100	400	0.6505	30	0.6505	10	0.1505
> 100	20	0	3.375	0.1761	5	0

 $P_n$  = rated power

For gasoline engines, the following limits apply:

Power $P_n$ kW	CO		HC		NO <sub>x</sub>	
	A·P <sub>n</sub> <sup>-m</sup> (g/kWh)		A·P <sub>n</sub> <sup>-m</sup> (g/kWh)		A·P <sub>n</sub> <sup>-m</sup> (g/kWh)	
	A	m	A	m	A	m
< 4	400	0.6505	30	0.6505	10	0.1505
4–100	400	0.6505	30	0.6505	10	0.1505
> 100	20	0	3.375	0.1761	10	0

 $P_n$  = rated power

The calculated mass-emissions of spark ignited engines of group A or group B, as well as the mass-emissions of diesel engines of group A may not exceed the following values:

1500 g/h for carbon monoxide CO

95 g/h for hydrocarbons HC

360 g/h for nitrogen oxides NO<sub>x</sub>

Smoke limit for diesel engines: The Bosch-Unit may not exceed 3.5 for naturally aspirated engines and 2.5 for supercharged engines.

Test cycle: BSO-9-mode-test

Test condition: Air temperature 25°C

## USA –Marine engines

On 6 May 2008 US EPA has published the final rule „40 CFR Parts 9, 85, for marine engines less than 30 liters per cylinder. This rule regulates amongst others the emission limit values for marine engines that are operated in commercial and recreational vessels. The regulation covers propulsion and auxiliary engines.

### Tier 1:

Cat.	Power and displacement	speed $\text{min}^{-1}$	Model year	$\text{NO}_x$ g/kWh	HC- $\text{NO}_x$ g/kWh	PM g/kWh	CO g/kWh
Small	$P_n < 8 \text{ kW}$	–	2000	–	10.5	1.0	8.0
	$8 \text{ kW} \leq P_n < 19 \text{ kW}$	–	2000	–	9.5	0.8	6.6
	$19 \text{ kW} \leq P_n < 37 \text{ kW}$	–	1999	–	9.5	0.8	5.5
C1, C2, C3, Rec.	$P_n \geq 37 \text{ kW}$ und $V_{h,z} \geq 2.5 \text{ l}$	$n_n \geq 2000$	2004	9.8	–	–	–
		$130 \leq n_n < 2000$	2004	$45 \cdot n_n^{-0.2}$	–	–	–
		$n_n < 130$	2004	17.0	–	–	–

### Tier 2:

Cat.*	Cylinder displacement	Power kW	Model year	HC+ $\text{NO}_x$ g/kWh	PM g/kWh	CO g/kWh
Small	–	$P_n < 8$	2005	7.5	0.8	8.0
	–	$8 \leq P_n < 19$	2005	7.5	0.8	6.6
	–	$19 \leq P_n < 37$	2004	7.5	0.6	5.5
C1	$V_{h,z} < 0.9$	$P_n \geq 37$	2005	7.5	0.4	5.0
	$0.9 \text{ l} \leq V_{h,z} < 1.2 \text{ l}$	–	2004	7.2	0.3	5.0
	$1.2 \text{ l} \leq V_{h,z} < 2.5 \text{ l}$	–	2004	7.2	0.2	5.0
	$2.5 \text{ l} \leq V_{h,z} < 5 \text{ l}$	–	2007	7.2	0.2	5.0
C2	$5 \text{ l} \leq V_{h,z} < 15 \text{ l}$	–	2007	7.8	0.27	5.0
	$15 \text{ l} \leq V_{h,z} < 20 \text{ l}$	$P_n < 3300$	2007	8.7	0.5	5.0
	$15 \text{ l} \leq V_{h,z} < 20 \text{ l}$	$P_n \geq 3300$	2007	9.8	0.5	5.0
	$20 \text{ l} \leq V_{h,z} < 25 \text{ l}$	–	2007	9.8	0.5	5.0
	$25 \text{ l} \leq V_{h,z} < 30 \text{ l}$	–	2007	11.0	0.5	5.0
Rec.	$V_{h,z} < 0.9 \text{ l}$	$P_n \geq 37$	2007	7.5	0.4	5.0
	$0.9 \text{ l} \leq V_{h,z} < 1.2 \text{ l}$	$P_n \geq 37$	2006	7.2	0.3	5.0
	$1.2 \text{ l} \leq V_{h,z} < 2.5 \text{ l}$	$P_n \geq 37$	2006	7.2	0.2	5.0
	$2.5 \text{ l} \leq V_{h,z} < 5.0 \text{ l}$	$P_n \geq 37$	2009	7.2	0.2	5.0

\* No Tier-2-Standards for Category 3

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### Tier 3 for C1 marine diesel engines in commercial vessels (standard power density, < 35 kW/l):

Power [kW]	Cylinder displacement [L]	Model year	HC+NO <sub>x</sub> <sup>D</sup> g/kWh	PM g/kWh	CO g/kWh
<19	< 0.9	2009	7.5	0.40	5.0
19–75	< 0.9 <sup>A</sup>	2009	7.5	0.30	5.0
		2014	4.7 <sup>B</sup>	0.30 <sup>B</sup>	5.0
75–3700	<0.9	2012	5.4	0.13	5.0
	0.9 < V <sub>h</sub> < 1.2	2013	5.4	0.12	5.0
	1.2 < V <sub>h</sub> < 2.5	2014	5.6	0.11 <sup>C</sup>	5.0
	2.5 < V <sub>h</sub> < 3.5	2013	5.6	0.11 <sup>C</sup>	5.0
	3.5 < V <sub>h</sub> < 7	2012	5.8	0.11 <sup>C</sup>	5.0

<sup>A</sup> <75 kW engines at or above 0.9 L/cylinder are subject to the corresponding 75–3700 kW standards.

<sup>B</sup> Option: 0.20 g/kWh PM/5.8 g/kWh NO<sub>x</sub>+HC in 2014.

<sup>C</sup> This standard level drops to 0.10 g/kWh in 2018 for <600 kW engines.

<sup>D</sup> Tier 3 NO<sub>x</sub>+HC standards do not apply to 2000–3700 kW engines.

### Tier 3 for C1 marine diesel engines commercial and recreational (high power density, > 35 kW/l):

Power [kW]	Cylinder displacement [L]	Model year	HC+NO <sub>x</sub> g/kWh	PM g/kWh	CO g/kWh
<19	< 0.9	2009	7.5	0.40	5.0
19–75	< 0.9 <sup>A</sup>	2009	7.5	0.30	5.0
		2014	4.7 <sup>B</sup>	0.30 <sup>B</sup>	5.0
75–3700	<0.9	2012	5.8	0.15	5.0
	0.9 < V <sub>h</sub> < 1.2	2013	5.8	0.13	5.0
	1.2 < V <sub>h</sub> < 2.5	2014	5.8	0.12	5.0
	2.5 < V <sub>h</sub> < 3.5	2013	5.8	0.12	5.0
	3.5 < V <sub>h</sub> < 7	2012	5.4	0.12	5.0

<sup>A</sup> <75 kW engines at or above 0.9 L/cylinder are subject to the corresponding 75–3700 kW standards.

<sup>B</sup> Option: 0.20 g/kWh PM/5.8 g/kWh) NO<sub>x</sub>+HC in 2014.

### Tier 3 for C2<sup>A</sup> marine diesel engines:

Power [kW]	Cylinder displacement [L]	Model year	HC+NO <sub>x</sub> <sup>B</sup> g/kWh	PM g/kWh
<3700	7 < V <sub>h</sub> < 15	2013	6.2	0.14
	15 < V <sub>h</sub> < 20	2014	7.0	0.27 <sup>C</sup>
	20 < V <sub>h</sub> < 25	2014	9.8	0.27
	25 < V <sub>h</sub> < 30	2014	11.0	0.27

<sup>A</sup> Option for C2: Tier 3 PM/NO<sub>x</sub>+HC at 0.10 / 5.8 g/bhp-hr (0.14/7.8 g/kW-hr) in 2012, and Tier 4 in 2015.

<sup>B</sup> Tier 3 NO<sub>x</sub>+HC standards do not apply to 2000–3700 kW engines.

<sup>C</sup> For engines below 3300 kW in this group, the PM Tier 3 standard is 0.25g/bhp-hr (0.34 g/kW-hr).

**Tier 4 for C1 und C2 marine diesel engines:**

Power [kW]	Model year	HC g/kWh	NO <sub>x</sub> g/kWh	PM g/kWh
≥ 3700	2014 <sup>C</sup>	0.19	1.8	0.12 <sup>A</sup>
	2016 <sup>B,C</sup>	0.19	1.8	0.06
2000 ≤ P < 3700	2014 <sup>C,D</sup>	0.19	1.8	0.04
1400 ≤ P < 2000	2016 <sup>C</sup>	0.19	1.8	0.04
600 ≤ P < 1400	2017 <sup>B</sup>	0.19	1.8	0.04

<sup>A</sup> This standard is 0.19 g/bhp-hr (0.25 g/kW-hr) for engines with 15–30 liter/cylinder displacement.

<sup>B</sup> Optional compliance start dates can be used within these model years; see discussion below.

<sup>C</sup> Option for C2: Tier 3 PM/NO<sub>x</sub>+HC at 0.10 / 5.8 g/bhp-hr (0.14/7.8 g/kW-hr) in 2012, and Tier 4 in 2015.

<sup>D</sup> The Tier 3 PM standards continue to apply for these engines in model years 2014 and 2015 only.

- Test cycle: ISO 8178-4, E2/E3/D2/C1 (according to engine operation).
- Test condition: air temperature 25°C / water temperature 25°C
- For recreational crafts the test cycle E5, ISO 8178-4 is valid.
- NTE (Not to exceed): In certain sections of the engine performance map, emissions may not exceed 1.2 to 1.5 times the cycle limit. These requirements come into force with 2007 model year.
- ABT (Averaging, Banking and Trading): Emission credits (NO<sub>x</sub>+HC and particulates) can be averaged, banked or traded.
- Voluntary Standards: Engines, which meet clearly lower limits (about 40 % reduced), may use the “Blue Sky Series” label.

**Turkey – Inland waterway vessels**

The emission limit values (Regulation 97/68/AT, amended by 2004/26/AT) for propulsion engines of inland waterway vessels in Turkish watercourses and the categorisation of the engines are identical with the European Directive 97/68/EC and 2004/26/EC respectively and with the Tier 2 US EPA inland waterway regulation. The date of coming into force for all categories is 2010 so one to three years later than regulated in the European Directive.

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Category	Category displacement per cylinder power	CO g/kWh	HC + NO <sub>x</sub> g/kWh	PM g/kWh	Date*
V 1:1	$V_{h,z} < 0.9 \text{ l}$ $P_n \geq 37 \text{ kW}$	5.0	7.5	0.4	2010
V 1:2	$0.9 \text{ l} \leq V_{h,z} < 1.2 \text{ l}$	5.0	7.2	0.3	2010
V 1:3	$1.2 \text{ l} \leq V_{h,z} < 2.5 \text{ l}$	5.0	7.2	0.2	2010
V 1:4	$2.5 \text{ l} \leq V_{h,z} < 5.0 \text{ l}$	5.0	7.2	0.2	2010
V 2:1	$5.0 \text{ l} \leq V_{h,z} < 15.0 \text{ l}$	5.0	7.8	0.27	2010
V 2:2	$15.0 \text{ l} \leq V_{h,z} < 20.0 \text{ l}$ $P_n < 3300 \text{ kW}$	5.0	8.7	0.5	2010
V 2:3	$15.0 \text{ l} \leq V_{h,z} < 20.0 \text{ l}$ $P_n \geq 3300 \text{ kW}$	5.0	9.8	0.5	2010
V 2:4	$20.0 \text{ l} \leq V_{h,z} < 25.0 \text{ l}$	5.0	9.8	0.5	2010
V 2:5	$25.0 \text{ l} \leq V_{h,z} < 30.0 \text{ l}$	5.0	11.0	0.5	2010

\* Date for placing on the market.

### Russia – Marine

Date	Carbon monoxide CO [g/kWh]	Hydrocarbon HC [g/kWh]	NO <sub>x</sub> [g/kWh]
< 1 Jan 2000	6.0	2.4	17.0

Date	Carbon monoxide CO [g/kWh]	Hydrocarbon HC [g/kWh]	n <sub>n</sub> 1/min	NO <sub>x</sub> [g/kWh]
≥ 1 Jan 2000	3.0	1.0	< 130	17.0
			130 – 2000	$45.0 \cdot n_n^{(-0.2)}$
			> 2000	9.8

## Germany – Stationary power plants

The “Technische Anleitung zur Reinhaltung der Luft (TA Luft)” is a common administrative regulation of the German government referring to the “Bundes-Immissionsschutzgesetz” (BImSchG). It contains limit values for emission and imission of pollutants from stationary plants and defines the respective measurement and calculation procedures.

Subject to TA Luft are combustion engine power plants using

- oil residues and landfill gas independent from the rated power
- biogas, natural gas, purification gas with  $MW_{th} > 1$
- other fuels (e.g. diesel fuels) with  $MW_{th} > 1$
- The emission limits refer to dry exhaust gas with 5 % residual oxygen.
- Dust means cumulative dust, including the part of cancer-producing, inheritance-changing and reproduction-toxic substances.

### Diesel engines

$MW_{th}$	Dust $mg/m_n^3$	CO $mg/m_n^3$	$NO_x$ $mg/m_n^3$
< 3	20	300	1000
$\geq 3$	20	300	500

### Gas engines

Gas type	Engine type	$MW_{th}$	CO $mg/m_n^3$	$NO_x$ $mg/m_n^3$
Natural gas	Lean mix engine		300	500
	Others		300	250
Pit gas	Lean mix engine		650	500
	Others		650	250
Biogas / purification gas	Jet ignition	< 3	2000	1000
		$\geq 3$	650	500
	Spark ignition	< 3	1000	500
		$\geq 3$	650	500
Landfill gas	Lean mix engine		650	500
	Others		650	250

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- Limit values applicable to normal operation (i. e. normally at rated power)
- For emergency plants and plants that are operated up to 300 hours per year to cover peak demands (e.g. power generation, gas or water supply) the dust limit is  $80 \text{ mg/m}_n^3$ . The  $\text{NO}_x$ - and CO-limits do not apply.
- The  $\text{NO}_x$ -limit for two-stroke engines is  $800 \text{ mg/m}_n^3$
- The emission of formaldehyde in the exhaust gas must not exceed  $60 \text{ mg/m}_n^3$ . There is no HC-limit.

### Italy

#### Diesel engines

$MW_{th}$	$\text{NO}_x$ $\text{mg/m}_n^3$	CO $\text{mg/m}_n^3$	HC <sup>*</sup> $\text{mg/m}_n^3$	$\text{SO}_2$ $\text{mg/m}_n^3$	Dust $\text{mg/m}_n^3$
< 3	4000	650	600	500	130
≥ 3	2000	650	600	500	130

\* butane-heptane

- Limits comparable to the former German TA Luft (before 2002)
- Pollutant content relating to dry exhaust gas with 5 % residual oxygen
- Local regulatory authorities may demand more stringent limits (in accordance with the technical process/state-of-the-art).

#### Gas engines

$\text{NO}_x$ $\text{mg/m}_n^3$	CO $\text{mg/m}_n^3$	HC <sup>*</sup> $\text{mg/m}_n^3$	$\text{SO}_2$ $\text{mg/m}_n^3$	Dust $\text{mg/m}_n^3$
500	650	600	500	130

\* butane-heptane

## UN-ECE Gothenburg Protocol

In the Convention on Long-range Transboundary Air Pollution (CLRTAP), which was adopted in 1979, emission ceilings for the Parties to the Protocol are set and NO<sub>x</sub> limit values for facilities with stationary engines have been defined. The Gothenburg Protocol is intended to abate acidification, eutrophication and ground-level ozone. The Protocol has been adopted in 1999, became effective on 17 May 2005, and sets limit values for specific emission sources. Parties to the Protocol are all EU countries, Eastern Europe states, USA and Canada.

### Limit values (Annex 5, issue 12)

Engine type	Fuel type / Mode of operation	NO <sub>x</sub> mg/m <sub>n</sub> <sup>3</sup>
Spark ignition (gas engines) MW <sub>th</sub> > 1	Lean burn engines	250
	Others	500
Compression ignition (Diesel / Dual fuel) MW <sub>th</sub> > 5	Natural gas (Jet ignition engines)	500
	Heavy fuel oil	600
	Diesel or gas oil	500

- Regenerative gases like biogas, purification gas and landfill gas also have to meet these limits.
- Limit values do not apply to engines running less than 500 hours a year.
- The O<sub>2</sub> reference is 5 %.
- As an alternative, a Party to the Protocol may apply different emission reduction strategies that achieve equivalent overall emission levels for all source categories together.

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### Finland

The emission guideline of the Finish environmental protection agency from October 2003 defines limits on SO<sub>2</sub>-, NO<sub>x</sub>- and particle emissions of **small combustion plants**, which shall be reached by using so called “best available techniques”. A small combustion plant within this regulation means a plant unit, consisting of one or more combustion components (steam boilers, engines, gas turbines) on a single location with MW<sub>th</sub> < 50 and a flue gas evacuation through a common stack. This guideline is **not a law, only a recommendation**, because in Finland local authorities assign the operating licence for plants of this size. The authorities should orientate on the following limits. All limits refer to a 15 % residual oxygen content in the exhaust gas.

#### Limits for new diesel and gas engines

Engine type	NO <sub>x</sub> Primary		NO <sub>x</sub> Secondary		SO <sub>2</sub>		Particulates	
	mg/m <sub>n</sub> <sup>3</sup>	mg/MJ	mg/m <sub>n</sub> <sup>3</sup>	mg/MJ	mg/m <sub>n</sub> <sup>3</sup>	mg/MJ	mg/m <sub>n</sub> <sup>3</sup>	mg/MJ
Oil diesel	< 1400 <sup>A</sup>	< 1600 <sup>A</sup>	< 650 <sup>B</sup>	< 750 <sup>B</sup>	< 500	< 600	< 50	< 60
Gas diesel	< 1400 <sup>A</sup>	< 1600 <sup>A</sup>	< 650 <sup>B</sup>	< 750 <sup>B</sup>				
Spark ign.	< 150	< 175						
Dual fuel	< 150	< 175						

<sup>A</sup> primary methods: engine internal measures (for normal applications)

<sup>B</sup> secondary methods: methods outside the engine (for special application, e.g. urban areas)

#### Limits for already existing diesel and gas engines

Engine type	NO <sub>x</sub>		SO <sub>2</sub>		Particulates	
	mg/m <sub>n</sub> <sup>3</sup>	mg/MJ	mg/m <sub>n</sub> <sup>3</sup>	mg/MJ	mg/m <sub>n</sub> <sup>3</sup>	mg/MJ
Oil diesel	< 2000	< 2300	< 500	< 600	< 60	< 70
Gas diesel	< 1500	< 1750				
Spark ign.	< 160	< 175				
Dual fuel	< 160	< 185				

There are no specific test-cycles. The limits are given for 100 % load as maximum measured values or as values, which can be reached if the reduction of the emissions is based on a “best available technique”.

## France

The French Arrêté 2910 defines emission limits for stationary diesel engines and gas engines.

### Limit values

Operating time h/year	Power MW <sub>th</sub>	NO <sub>x</sub> mg/m <sub>n</sub> <sup>3</sup>			CO mg/m <sub>n</sub> <sup>3</sup>	NMHC mg/m <sub>n</sub> <sup>3</sup>	Dust mg/m <sub>n</sub> <sup>3</sup>
		Nat. gas	Liquid fuel	Dual Fuel			
> 500	20–100	350	1000	1000	650	150	100
	> 100	250	600	750	650	150	100
≤ 500	20–100	875	2500	2500	650	150	100
	> 100	625	1500	1875	650	150	100

- The emission limits refer to dry exhaust gas with 5 % residual oxygen.
- The NO<sub>x</sub> limit for plants operated up to 500 hours per year is multiplied with the coefficient 2.5.
- If the plant is operated as a combined heat and power generation plant, the respective limit value in the table above can be exceeded by 30 mg/m<sub>n</sub><sup>3</sup>.
- The NO<sub>x</sub> limit for plants which have been licensed before 4 December 2000 and which consume liquid fuel amounts 1900 mg/m<sub>n</sub><sup>3</sup> (independent from the power of the plant).
- The NO<sub>x</sub> limit for plants that have been licensed before 4 December 2000 and that consume natural gas can be defined by a person in charge from the responsible regulating authority up to 500 mg/m<sub>n</sub><sup>3</sup> if the operator of the plant can prove by a techno-economic analysis that it is impossible to observe the emission limit in the table above.
- If special fuel is used (e.g. biogas or coke oven gas), the person in charge of the responsible authority can define the maximum limit values separately.
- The limit for VOC in the exhaust gas is 20 mg/m<sub>n</sub><sup>3</sup>, for plants with more than 50 MW<sub>th</sub> per year and a mass flow of organic compounds of more than 0.1 kg/h.

### Limit values for sulphur oxide SO

Fuel type	Natural gas	Fuel oil	Heavy fuel
limit value [mg/m <sub>n</sub> <sup>3</sup> ]	35	300	1500

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### India

The Central Environmental Protection Agency, which is mandated by the Ministry of Environment and Forest, is responsible for the emission limit regulation. The following content refers to diesel engines for power generation.

#### Limit values for engines up to 800 kW rated power

Rated engine power	Implementation	NO <sub>x</sub> g/kWh	HC g/kWh	CO g/kWh	PM g/kWh	Smoke opac.* m <sup>-1</sup>
≤ 19 kW	1 Jul 2005	9.2	1.3	3.5	0.3	0.7
19–50 kW	1 Jan 2004	9.2	1.3	5.0	0.5	0.7
	1 Jul 2004	9.2	1.3	3.5	0.3	0.7
50–176 kW	1 Jan 2004	9.2	1.3	3.5	0.3	0.7
176–800 kW	1 Nov 2004	9.2	1.3	3.5	0.3	0.7

\* Light absorption coefficient measured at full load. All other values are measured according to test-cycle ISO 8178-4 D2, 5-Mode

#### Limit values for engines with more than 800 kW rated power

Date of order	NO <sub>x</sub> ppmV	NMHC mg/m <sub>n</sub> <sup>3</sup>	CO mg/m <sub>n</sub> <sup>3</sup>	PM mg/m <sub>n</sub> <sup>3</sup>
Before 1 July 2003	1100	150	150	75
Between 1 July 2003 and 1 July 2005	970	100	150	75
After 1 July 2005	710	100	150	75

The following two agencies are able to implement type approvals:

- Automotive Research Association of India, Pune
- Vehicle Research and Development Establishment, Ahmednagar

The emission limits refer to dry exhaust gas with 15 % residual oxygen.

## Japan

### Diesel engines

Bore mm	NO <sub>x</sub> ppm (13 % O <sub>2</sub> )	NO <sub>x</sub> mg/m <sub>n</sub> <sup>3</sup> (5 % O <sub>2</sub> )	Particulates mg/m <sub>n</sub> <sup>3</sup> (13 % O <sub>2</sub> )	Particulates mg/m <sub>n</sub> <sup>3</sup> (5 % O <sub>2</sub> )
< 400	950	3900	100*	200
≥ 400	1200	4900	100*	200

\* In certain regions 80 mg/m<sub>n</sub><sup>3</sup> (13 % O<sub>2</sub>)

- Diesel engine plants with fuel consumption > 50 l/h
- Local limits may be lower  
(Example: Tokyo: NO<sub>x</sub> = 470 mg/m<sub>n</sub><sup>3</sup> [5 % O<sub>2</sub>])

### Gas engines

NO <sub>x</sub> ppm (0 % O <sub>2</sub> )	NO <sub>x</sub> mg/m <sub>n</sub> <sup>3</sup> (5 % O <sub>2</sub> )	Particulates mg/m <sub>n</sub> <sup>3</sup> (0 % O <sub>2</sub> )	Particulates mg/m <sub>n</sub> <sup>3</sup> (5 % O <sub>2</sub> )
600	940	50*	38

\* In certain regions 40 mg/m<sub>n</sub><sup>3</sup> (0 % O<sub>2</sub>)

- Local limits may be lower!  
(Example: Tokyo: NO<sub>x</sub> = 310 mg/m<sub>n</sub><sup>3</sup> [5 % O<sub>2</sub>])
- Gas engine plants with fuel consumption > 35 l/hr

## Switzerland

According to the clean air directive (Luftreinhalteverordnung) dated 16 December 1985 (status: 12 July 2005) the following emission limits are valid for stationary combustion engines with kW<sub>th</sub> > 100 per engine:

Fuel type	NO <sub>x</sub> mg/m <sub>n</sub> <sup>3</sup>	CO mg/m <sub>n</sub> <sup>3</sup>	Dust mg/m <sub>n</sub> <sup>3</sup>
Gas fuels*	400	650	50
Other fuels	250	650	50

\* Biogas, purification gas, landfill gas, natural gas

- The pollutant content refers to dry exhaust with 5 % residual oxygen.
- For emergency engines that are operated up to 50 hours per year, the limits above are not valid.
- Specifications for fuels that are used in stationary combustion engines have to be considered.

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### Czech Republic

The current Czech emission regulation for stationary engines has been updated with the order 146/2007 Coll. The new emission limit values in the order came into force on 1 January 2008. The emission regulation sets limits for existing installations, that have been developed and constructed before 17 May 2006 and furthermore new installations whose development and construction has been started after 17 May 2006.

#### Existing installations whose construction has been started before 17 May 2006:

Engine type/ power category	Fuel type	SO mg/m <sub>n</sub> <sup>3</sup>	NO <sub>x</sub> mg/m <sub>n</sub> <sup>3</sup>	SP mg/m <sub>n</sub> <sup>3</sup>	ΣC mg/m <sub>n</sub> <sup>3</sup>	CO mg/m <sub>n</sub> <sup>3</sup>
spark ignition 0.2–1 MW <sub>th</sub>	liquid fuel	<sup>B</sup>	500	130	–	650
	natural gas	<sup>B</sup>	500	–	–	650
	biogas, landfill gas	<sup>B</sup>	1000	130	–	1030
compression ignition 0.2–1 MW <sub>th</sub>	heavy fuel oil, gas oil	<sup>B</sup>	4000	130	–	650
	natural gas, degasifying gas <sup>C</sup>	<sup>B</sup>	4000	130	–	650
spark ignition < 1–5 MW <sub>th</sub>	liquid fuel	<sup>B</sup>	500	130	150 <sup>A</sup>	650
	natural gas	<sup>B</sup>	500	–	150 <sup>A</sup>	650
	biogas, landfill gas	<sup>B</sup>	1000	130	150 <sup>A</sup>	1300
compression ignition > 1–5 MW <sub>th</sub>	heavy fuel oil, gas oil	<sup>B</sup>	4000	130	150 <sup>A</sup>	650
	natural gas, degasifying gas <sup>C</sup>	<sup>B</sup>	4000	130	150 <sup>A</sup>	650
spark ignition > 5 MW <sub>th</sub>	liquid fuel	<sup>B</sup>	500	130	150 <sup>A</sup>	650
	natural gas	<sup>B</sup>	500	–	150 <sup>A</sup>	650
	biogas, landfill gas	<sup>B</sup>	500	130	150 <sup>A</sup>	650
compression ignition > 5 MW <sub>th</sub>	heavy fuel oil, gas oil	<sup>B</sup>	2000	130	150 <sup>A</sup>	650
	natural gas, degasifying <sup>C</sup>	<sup>B</sup>	2000	130	150 <sup>A</sup>	650

<sup>A</sup> Total concentration of all organic substances except methane with a mass flow over 3 kg/h

<sup>B</sup> The sulphur content in fuel shall not exceed the limit values laid down in special legislation and, in diesel fuel shall not exceed 0.05 % by mass

<sup>C</sup> With injection ignition

**New installations whose construction has been started after  
17 May 2006:**

Engine type/ power category	Fuel type	SO mg/m <sub>n</sub> <sup>3</sup>	NO <sub>x</sub> mg/m <sub>n</sub> <sup>3</sup>	SP mg/m <sub>n</sub> <sup>3</sup>	ΣC mg/m <sub>n</sub> <sup>3</sup>	CO mg/m <sub>n</sub> <sup>3</sup>
spark ignition 0.2–1 MW <sub>th</sub>	liquid fuel	<sup>c</sup>	500	130	<sup>B</sup>	650
	natural gas	<sup>c</sup>	500	–	<sup>B</sup>	650
	biogas, landfill gas	<sup>c</sup>	1000	130	<sup>B</sup>	1300
compression ignition 0.2–1 MW <sub>th</sub>	heavy fuel oil	<sup>c</sup>	4000	130	<sup>B</sup>	650
	gas oil	<sup>c</sup>	4000	130	<sup>B</sup>	650
	natural gas, degasifying gas <sup>D</sup>	<sup>c</sup>	4000	130	<sup>B</sup>	650
spark ignition < 1–5 MW <sub>th</sub>	liquid fuel	<sup>c</sup>	500 <sup>A</sup>	130	150 <sup>B</sup>	650
	natural gas	<sup>c</sup>	500 <sup>A</sup>	–	150 <sup>B</sup>	650
	Biogas, landfill gas	<sup>c</sup>	500 <sup>A</sup>	130	150 <sup>B</sup>	1300
compression ignition > 1–5 MW <sub>th</sub>	heavy fuel oil	<sup>c</sup>	600 <sup>A</sup>	130	150 <sup>B</sup>	650
	gas oil	<sup>c</sup>	500 <sup>A</sup>	130	150 <sup>B</sup>	650
	natural gas, degasifying gas <sup>D</sup>	<sup>c</sup>	500 <sup>A</sup>	130	150 <sup>B</sup>	650
spark ignition > 5 MW <sub>th</sub>	liquid fuel	<sup>c</sup>	500 <sup>A</sup>	130	150 <sup>A</sup>	650
	natural gas	<sup>c</sup>	500 <sup>A</sup>	–	150 <sup>A</sup>	650
	biogas, landfill gas	<sup>c</sup>	500 <sup>A</sup>	130	150 <sup>A</sup>	650
compression ignition > 5 MW <sub>th</sub>	heavy fuel oil	<sup>c</sup>	600 <sup>A</sup>	130	150 <sup>A</sup>	650
	gas oil	<sup>c</sup>	500 <sup>A</sup>	130	150 <sup>A</sup>	650
	natural gas, degasifying <sup>D</sup>	<sup>c</sup>	500 <sup>A</sup>	130	150 <sup>A</sup>	650

<sup>A</sup> The emission limits for NO<sub>x</sub> shall apply from 1 January 2008. The emission limits shall not apply to engines operated for less than 500 hours per annum.

<sup>B</sup> Total concentration of all organic substances except methane with a mass flow over 3 kg/h.

<sup>C</sup> The sulphur content in fuel shall not exceed the limit values laid down in special legislation and, in diesel fuel shall not exceed 0.05 %.

<sup>D</sup> With injection ignition.

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### World Bank – Guidelines for new thermal power plants

The World Bank Group consists of five organisations. Their main issue is to boost the economic development of the less developed member countries with financial and technical help and consulting.

Within these five organisations, the IFC (International Finance Corporation) has the mission to boost the private economic development with shareholding in companies.

Generally, the limit values shall comply with the specific laws of the country, in which the plant is built. Though, the measured values have to be accepted by the IFC to receive financial and technical help. The values given below apply as a standard which is normally accepted by the IFC.

The limit values are valid for power plants with an electric capacity of **more than 50 MWe**.

All values have to be observed for **95 % of the total operating time**. The rest of 5 % is time where the plant is powered up for example.

Financing received	PM mg/m <sub>n</sub> <sup>3</sup>	SO <sub>2</sub> mg/m <sub>n</sub> <sup>3</sup>	NO <sub>x</sub> mg/m <sub>n</sub> <sup>3</sup> (g/kWh)*
<b>Before 1 July 2000</b>	≤ 50	≤ 2000	< 2300 (17)
<b>After 1 July 2000</b>	≤ 50	≤ 2000	< 2000 (13)

\* Pollutant content referred to dry exhaust gas with 15 % residual oxygen

The limit values correspond to engine driven power plants, which can be either four-stroke or two-stroke engines.

The NO<sub>x</sub> limit for plants which are not covered here is 400 mg/m<sub>n</sub><sup>3</sup>.

## World Bank – General environmental health and safety guideline

On 30 April 2007 the General Environmental Health and Safety Guideline has come into force. This regulation includes amongst others emission limit values for stationary engines.

The emission limits will come into force for stationary engine driven power plant financed by World Bank in a country where no national emission limit values for those installations exist or where limits are available but less strict than those stipulated by World Bank.

The emission limit values are given at 15 % residual oxygen and are valid for stationary engine driven power plants (gas and diesel engines) with 3–50 MWth.

Emission bonuses for NO<sub>x</sub> are granted for power plants with high efficiency (currently no World Bank definition, will be set project related). The emission limit values are to be met for power plants that are operated more than 500 hours per year.

### Gas engines

Operation mode / bore [mm]	PM mg/m <sub>n</sub> <sup>3</sup>	SO <sub>2</sub> mg/m <sub>n</sub> <sup>3</sup>	NO <sub>x</sub> mg/m <sub>n</sub> <sup>3</sup>
spark ignition	–	–	200
Dual Fuel-Mode	–	–	400
compression ignition	–	–	1600

### Diesel engines

Bore [mm]	PM	SO <sub>2</sub>	NO <sub>x</sub>
	mg/m <sub>n</sub> <sup>3</sup>	mg/m <sub>n</sub> <sup>3</sup>	mg/m <sub>n</sub> <sup>3</sup>
< 400	50 or 100 <sup>A</sup>	1.5–3 % S <sup>B</sup>	1460
< 400 and high efficiency			1600
≥ 400 mm			1850

<sup>A</sup> if justified by project specific considerations (e.g. Economic feasibility of using lower ash content fuel, or adding secondary treatment to meet 50, and available environmental capacity of the site)

<sup>B</sup> if justified by project specific considerations (e.g. Economic feasibility of using lower S content fuel, or adding secondary treatment to meet levels of using 1.5 percent sulphur, and available environmental capacity of the site)

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### USA – Stationary diesel engines

US EPA has published on 11 July 2006 a new legislation for stationary diesel engines (40 CFR Parts 60, 85 et al.). It entered into force on 11 September 2006.

The regulation includes emission limit values for all new and updated stationary diesel engines. The intended effect of the standard is to require all new, modified, and reconstructed stationary CI ICE to use the best demonstrated system of continuous emission reduction, considering costs, non-air quality health, and environmental and energy impacts, not just with add-on controls, but also by eliminating or reducing the formation of these pollutants.

**Diesel engines < 10 Liter displacement (effective from model year 2007 with ≤ 3000 hp and effective from model year 2011 with > 3000 hp)**

Maximum engine power [kW]	Model year	NMHC + NO <sub>x</sub>	NMHC	NO <sub>x</sub>	CO	PM
		g/kWh	g/kWh	g/kWh	g/kWh	g/kWh
< 8	2007	7.5			8	0.80
	2008+					0.40
8 ≤ P < 19	2007				6.6	0.80
	2008+					0.40
19 ≤ P < 37	2007	7.5			5.5	0.60
	2008–2012					0.30
	2013+	4.7				0.03
37 ≤ P < 56	2007	7.5			5	0.40
	2008–2012	4.7				0.30 <sup>A</sup>
	2013+					0.03
56 ≤ P < 75	2007	7.5				0.40
	2008–2011	4.7				
	2012, 2013		0.19 <sup>B</sup>	0.4 <sup>B</sup>	5	0.02
	2014+		0.19	0.4		
75 ≤ P < 130	2007	4.0				0.30
	2008–2011					
	2012–2013		0.19 <sup>B</sup>	0.4 <sup>B</sup>	5	0.02
	2014+		0.19	0.4		
130 ≤ P < 560	2007–2010	4.0			3.5	0.20
	2011–2013		0.19 <sup>B</sup>	0.4 <sup>B</sup>		0.02
	2014+		0.19	0.4		
> 560	2007–2010	6.4			3.5	0.20
Except generator sets	2011–2014		0.4	3.5		0.10
	2015+		0.19	3.5		0.04
Generator sets 560 < P ≤ 900	2007–2010	6.4			3.5	0.20
	2011–2014		0.4	3.5		0.10
	2015+		0.19	0.67		0.03
Generator sets P > 900	2007–2010	6.4			3.5	0.20
	2011–2014		0.4	0.67		0.10
	2015+		0.19			0.03

- The emission limit values are valid for non-emergency diesel engines

- <sup>A</sup> A manufacturer has the option of skipping the 0.30 g/KW-hr PM standard for all 37–56 KW (50–75 HP) engines. The 0.03 g/KW-hr standard would then take effect 1 year earlier for all 37–56 KW (50–75 HP) engines, in 2012. The Tier 3 standard (0.40 g/KW-hr) would be in effect until 2012.
- <sup>B</sup> 50 percent of the engines produced have to meet the NO<sub>x</sub> + NMHC standard, and 50 percent have to meet the separate NO<sub>x</sub> and NMHC limits.

### Diesel engines with < 10 Liter displacement (model year before 2007 and model years 2007–2010 with >3000 hp)

Maximum engine power [kW]	Model year	NMHC + NO <sub>x</sub>	NMHC	NO <sub>x</sub>	CO	PM
		g/kWh	g/kWh	g/kWh	g/kWh	g/kWh
< 8	2007–2010	10.5			8.00	1.00
8 ≤ P < 19	2007–2010	9.5			6.60	0.80
19 ≤ P < 37	2007–2010	9.5			5.50	0.80
37 ≤ P < 56	2007–2010			9.20		
56 ≤ P < 75	2007–2010			9.20		
75 ≤ P < 130	2007–2010			9.20		
130 ≤ P < 225	2007–2010		1.30	9.20	11.40	0.54
225 ≤ P < 450	2007–2010		1.30	9.20	11.40	0.54
450 ≤ P ≤ 560	2007–2010		1.30	9.20	11.40	0.54
P > 560	2007–2010		1.30	9.20	11.40	0.54

### Diesel engines with 10–30 Liter displacement (model year beginning with 2007)

Cylinder displacement [L] Power [kW]	THC + NO <sub>x</sub>	CO	PM
	g/kWh	g/kWh	g/kWh
5 ≤ V <sub>H</sub> ≤ 15 all power bands	7.8	5.0	0.27
15 ≤ V <sub>H</sub> ≤ 20 P < 3300 kW	8.7	5.0	0.50
15 ≤ V <sub>H</sub> ≤ 20 P ≥ 3300 kW	9.8	5.0	0.50
20 ≤ V <sub>H</sub> ≤ 25 all power bands	9.8	5.0	0.50
25 ≤ V <sub>H</sub> ≤ 30 all power bands	11.0	5.0	0.50

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### Diesel engines for stationary emergency fire pumps

Maximum engine power [kW]	Model year	NMHC + g/kWh	CO g/kWh	PM g/kWh
<8	2010 and earlier	7.8	6.0	0.75
	2011 +	5.6	–	0.30
8 ≤ P < 19	2010 and earlier	7.1	4.9	0.60
	2011 +	5.6	–	0.30
19 ≤ P < 37	2010 and earlier	7.1	4.1	0.60
	2011 +	5.6	–	0.22
37 ≤ P < 75	2010 and earlier	7.8	3.7	0.60
	2011 +*	3.5	–	0.30
75 ≤ P < 130	2009 and earlier	7.8	3.7	0.60
	2010 +*	3.0	–	0.22
130 ≤ P < 450	2008 and earlier	7.8	2.6	0.40
	2009 +*	3.0	–	0.15
450 ≤ P < 560	2008 and earlier	7.8	2.6	0.40
	2009 +	3.0	–	0.15
P > 560	2007 and earlier	7.8	2.6	0.40
	2008 +	4.8	–	0.15

\* Emergency fire pump engines with a rated speed of greater than 2650 rpm are allowed an additional 3 years to meet these standards.

### Diesel- and gas engines (California)

Date	NO <sub>x</sub>	VOC	CO	Unit
2003	0.50*	1.00	6.00	lbm/MW-hr
	0.23	0.45	2.70	g/kWh
2007**	0.07	0.02	0.10	lbm/MW-hr
	0.03	0.01	0.05	g/kWh

\* For installations with CHP (combined heat and power) this values increases to 0.70

\*\* For CHP installations the heat energy is treated like electric energy

- Partical emissions not higher than for natural gas with sulphur content of 1 grain / 100 scf (= PM < 0,5 mg/kWh)

## USA – Stationary spark ignition internal combustion engines

On 18 January 2008 the US EPA has published a new law for stationary spark ignition engines (40 CFR Parts 60, 63, 85 et al.). It came into force on 18 March 2008.

The regulation covers emission limit values for spark ignition engines that are operated with gasoline, LPG, natural gas, landfill gas and digester gas. Moreover the regulation distinguishes between emergency and non-emergency engines.

**Stationary spark ignition engines ≤19 kW**

Engine class <sup>A</sup>	HC + NO <sub>x</sub> <sup>B</sup>	NMHC + NO <sub>x</sub> <sup>B, C</sup>	CO <sup>B</sup>
	g/kWh	g/kWh	g/kWh
I	16.1	14.8	610
I-A	50	—	—
I-B	40	37	—
II	12.1	11.3	—

<sup>A</sup> Class I-A: Engines with displacement less than 66 cubic centimeters (cc); Class I-B: Engines with displacement greater than or equal to 66 cc and less than 100 cc; Class I: Engines with displacement greater than or equal to 100 cc and less than 225 cc; Class II: Engines with displacement greater than or equal to 225 cc.

<sup>B</sup> Modified and reconstructed engines manufactured prior to 1 July 2008, must meet the standards applicable to engines manufactured after 1 July 2008.

<sup>C</sup> NMHC+NO<sub>x</sub> standards are applicable only to natural gas fueled engines at the option of the manufacturer, in lieu of HC+NO<sub>x</sub> standards.

**Stationary spark ignition engines > 19 kW**
**(Non-emergency SI gasoline engines and rich burn LPG engines)**

Maximum engine power [HP]	Manufacturer date	HC + NO <sub>x</sub> <sup>A, B</sup> [g/kWh]	CO <sup>A, B</sup> [g/kWh]
25 < P < 500 <sup>C</sup>	1 July 2008	2.7	4.4
	1 July 2008 <sup>E</sup> (severe duty)	2.7	130.0
P ≥ 500 <sup>D</sup>	1 July 2007	2.7	4.4
	1 July 2007 <sup>E</sup> (severe duty)	2.7	130.0

<sup>A</sup> Optionally engines may be certified according to the following formula instead of the standards in Table 2 of this preamble:  $(HC+NO_x) CO^{0.784} \leq 8.57$ . The HC+NO<sub>x</sub> and CO emission levels you select to satisfy this formula, rounded to the nearest 0.1 g/KW-hr, become the emission standards that apply for those engines. You may not select an HC+NO<sub>x</sub> emission standard higher than 2.7 g/KW-hr or a CO emission standard higher than 20.6 g/KW-hr.

<sup>B</sup> Provisions in 40 CFR part 1048 allow engines with a maximum engine power at or below 30 KW (40 HP) with a total displacement at or below 1,000 cubic centimeters (cc) to comply with the requirements of 40 CFR part 90.

<sup>C</sup> Modified and reconstructed engines between 25 and 500 HP manufactured prior to 1 July 2008, must meet the standards applicable to engines manufactured after 1 July 2008.

<sup>D</sup> Modified and reconstructed engines greater than or equal to 500 HP manufactured prior to 1 July 2007, must meet the standards applicable to engines manufactured after 1 July 2007.

<sup>E</sup> Severe-duty engines are engines used in, for example, concrete saws, concrete pumps, and similar severe applications where air-cooled engines must be used.

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### Stationary non-emergency SI natural gas engines and lean burn LPG engines 19 < KW < 75 (25 < HP < 100)

Maximum engine power [kW]	Manufacturer date	HC + NO <sub>x</sub> <sup>A,B</sup> [g/kWh]	CO <sup>A,B</sup> [g/kWh]
19 < P < 75 <sup>C</sup>	1 July 2008	3.8	6.5
	1 July 2008 (severe duty)	3.8	200.0

<sup>A</sup> The following formula may be applied to determine alternate emission standards that apply to your engines instead of the standards in paragraph in Table 3 of this preamble:  $(HC+NO_x)CO^{0.791} \leq 16.78$ . HC+NO<sub>x</sub> emission levels may not exceed 3.8 g/kW-hr and CO emission levels may not exceed 31.0 g/kW-hr.

<sup>B</sup> For natural gas fueled engines, it is not required to measure non-methane hydrocarbon emissions or total hydrocarbon emissions for testing to show that the engine meets the emission standards of Table 3 of this preamble; that is, it is assume HC emissions are equal to zero.

<sup>C</sup> Modified and reconstructed engines between 25 and 100 HP manufactured prior to 1 July 2008, must meet the standards applicable to engines manufactured after 1 July 2008.

### Stationary SI engines ≥ 100 HP (except gasoline and rich burn LPG), stationary SI landfill/digester gas engines and stationary emergency engines > 25 HP

Engine type and fuel	Max. engine power [HP]	Manu- factur date	NO <sub>x</sub> <sup>*</sup> g/HP-hr (ppmvd at 15 % O <sub>2</sub> )	CO <sup>*</sup> g/HP-hr (ppmvd at 15 % O <sub>2</sub> )	VOC <sup>*</sup> g/HP-hr (ppmvd at 15 % O <sub>2</sub> )
Non-emergency SI natural gas and non-emergency SI lean burn LPG	100 ≤ P < 500	1.7.2008	2.0 (160)	4.0 (540)	1.0 (86)
		1.1.2011	1.0 (82)	2.0 (270)	0.7 (60)
Non-emergency SI lean burn natural gas and LPG	500 ≤ P < 1350	1.1.2008	2.0 (160)	4.0 (540)	1.0 (86)
		1.7.2010	1.0 (82)	2.0 (270)	0.7 (60)
Non-emergency SI natural gas and non-emergency SI lean burn LPG (except lean burn 500 ≤ HP < 1350)	P ≥ 500	1.7.2007	2.0 (160)	4.0 (540)	1.0 (86)
		1.7.2010	1.0 (82)	2.0 (270)	0.7 (60)
Landfill and digester gas (except lean burn 500 ≤ HP < 1350)	P < 500	1.7.2008	3.0 (220)	5.0 (610)	1.0 (80)
		1.1.2011	2.0 (150)	5.0 (610)	1.0 (80)
	P ≥ 500	1.7.2007	3.0 (220)	5.0 (610)	1.0 (80)
		1.7.2010	2.0 (150)	5.0 (610)	1.0 (80)
Landfill and digester gas lean burn	500 ≤ P < 1350	1.7.2008	3.0 (220)	5.0 (610)	1.0 (80)
		1.1.2011	2.0 (150)	5.0 (610)	1.0 (80)
Emergency	25 < P < 130	1.1.2009	10.0** (-)	387 (-)	- (-)
	P ≥ 130		2.0 (160)	4.0 (540)	1.0 (86)

- \* Owners and operators of stationary non-certified SI engines may choose to comply with the emission standards in units of either g/HP-hr or ppmvd at 15 percent O<sub>2</sub>.
- \*\* The emission standards applicable to emergency engines between 25 HP and 130 HP are in terms of NO<sub>x</sub>+HC.

## Belgium

The Belgian law Gestez Vlarem 2 regulates the emission limit values of permanently installed stationary (gas and diesel) engines running less than 360 or more operating hours per year. The law distinguishes furthermore in engines that have been installed before 31 December 2007 and after 1 January 2008. The emission limit values are given in mg/m<sub>n</sub><sup>3</sup> and related to 5 % residual oxygen.

### Stationary gas engines installed before 31 December 2007 and operated 360 or more operating hours per year:

Categorie Gas engine	Engine power [MW <sub>th</sub> ]	NO <sub>x</sub> mg/m <sub>n</sub> <sup>3</sup>	CO mg/m <sub>n</sub> <sup>3</sup>	Organic substances
first licence for operation granted before 1 Jan 1993	–	–	2600	–
first licence for operation granted on or after 1 Jan 1993 and before 1 Jan 2000	–	2600 • η/30	1300	–
first licence for operation granted on or after 1 Jan 2000 and before 1 Jan 2005	–	500 • η/30	650	–
first licence for operation granted on or after 1 Jan 2005	1	500 • η/30	650	150
	> 1	500	650	150

### Stationary gas engines installed after 1 January 2008 and operated 360 or more operating hours per year:

Categorie Gas engine	Engine power [MW <sub>th</sub> ]	NO <sub>x</sub> mg/m <sub>n</sub> <sup>3</sup>	CO mg/m <sub>n</sub> <sup>3</sup>	Organic substances
first licence for operation granted before 1 Jan 2000	–	1300 * η/30 *	1300	–
first licence for operation granted on or after 1 Jan 2000 and before 1 Jan 2005	–	500 • η/30	650	150
first licence for operation granted on or after 1 Jan 2005	1	500 • η/30	650	150
	> 1	500	650	150

- \* As a departure from this emission limit value, for gas motors for which the first licence for operation was granted before 1 January 1993 to 31 December 2018 no NO<sub>x</sub> emission limit value is applicable.

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**Stationary diesel engines installed before 31 December 2007 and operated 360 or more operating hours per year:**

Category Diesel engine	Engine power [MW <sub>th</sub> ]	Dust	SO <sub>2</sub> with gas oil*	SO <sub>2</sub> with heating oil*	NO <sub>x</sub>	CO	Organic substances
		mg/m <sup>3</sup>	%	%	mg/m <sup>3</sup>	mg/m <sup>3</sup>	mg/m <sup>3</sup>
first licence for operation granted before 1 Jan 1993	≥ 0.3	–	0.2	1.00	–	2600	–
first licence for operation granted on or after 1 Jan 1993 and before 1 Jan 2000	≥ 0.3	200	0.2	1.00	4000	1000	–
first licence for operation granted on or after 1 Jan 2000 and before 1 Jan 2005	0.3–3	50	0.2		4000	650	–
	≥ 3	50	0.2		2000	650	–
first licence for operation granted on or after 1 Jan 2005	0.3–3	50	0.2		1000	650	150
	≥ 3	50	0.2		500	650	150

\* maximum S-level in fuel (in mass %)

**Stationary diesel engines installed after 1 January 2008 and operated 360 or more operating hours per year:**

Category Diesel engine	Engine power [MW <sub>th</sub> ]	Dust	SO <sub>2</sub> with gas oil*	SO <sub>2</sub> with heating oil*	NO <sub>x</sub>	CO	Organic substances
		mg/m <sup>3</sup>	%	%	mg/m <sup>3</sup>	mg/m <sup>3</sup>	mg/m <sup>3</sup>
first licence for operation granted before 1 Jan 1993	≥ 0.3	300	0.1	0.60	5000	1500	–
first licence for operation granted on or after 1 Jan 1993 and before 1 Jan 2000	≥ 0.3	200	0.1	0.60	4000	1000	–
first licence for operation granted on or after 1 Jan 2000 and before 1 Jan 2005	0.3–3	50	0.1		4000	650	–
	≥ 3	50	0.1		500	650	150
first licence for operation granted on or after 1 Jan 2005	0.3–3	50	0.1		1000	650	150
	≥ 3	50	0.1		500	650	150

\* maximum S-level in fuel (in mass %)

**Stationary gas engines installed before 31 December 2007 and operated less than 360 operating hours per year:**

Category Gas engine	NO <sub>x</sub> mg/m <sup>3</sup>	CO mg/m <sup>3</sup>
first licence for operation granted before 1 January 2000	–	2600
first licence for operation granted on or after 1 January 2000	$500 \cdot \eta/30$	650

**Stationary gas engines installed after 1 January 2008 and operated less than 360 operating hours per year:**

Category Gas engine	NO <sub>x</sub> mg/m <sub>n</sub> <sup>3</sup>	CO mg/m <sub>n</sub> <sup>3</sup>	Organis substances
first licence for operation granted before 1 January 2000	1300 · η/30 *	1300	–
first licence for operation granted on or after 1 January 2000	500 · η/30	650	150

\* For gas motors for which the first licence for operation was granted before 1 January 1993 the above mentioned emission limit value for NO<sub>x</sub> is replaced by 10.000 mg/m<sub>n</sub><sup>3</sup>.

**Stationary diesel engines installed before 31 December 2007 and operated less than 360 operating hours per year:**

Category Diesel engine	Engine Power [MW <sub>th</sub> ]	Dust	SO <sub>2</sub> with gas oil*	SO <sub>2</sub> with heating oil*	NO <sub>x</sub>	CO
		mg/m <sub>n</sub> <sup>3</sup>	%	%	mg/m <sub>n</sub> <sup>3</sup>	mg/m <sub>n</sub> <sup>3</sup>
first licence for operation granted before 1 Jan 2000	≥ 0.3	300	0.2	1.00	–	1500
first licence for operation granted on or after 1 Jan 2000	0.3–3	50	0.2		4000	650
	≥ 3	50	0.2		2000	–

\* maximum S-level in fuel (in mass %)

**Stationary diesel engines installed after 1 January 2008 and operated less than 360 operating hours per year:**

Category Diesel engine	Engine Power [MW <sub>th</sub> ]	Dust	SO <sub>2</sub> with gas oil*	SO <sub>2</sub> with heating oil*	NO <sub>x</sub>	CO
		mg/m <sub>n</sub> <sup>3</sup>	%	%	mg/m <sub>n</sub> <sup>3</sup>	mg/m <sub>n</sub> <sup>3</sup>
first licence for operation granted before 1 Jan 2000	≥ 0.3	300	0.1	0.60	–	1500
first licence for operation granted on or after 1 Jan 2000	0.3–3	50	0.1		4000	650
	≥ 3	50	0.1		2000	–

\* maximum S-level in fuel (in mass %)

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### Portugal

In the regulation “Portaria 1058/94 de 2 de Dezembro” the emission limit values for NO<sub>x</sub> coming from cogeneration plants are regulated. The values are based on 15 % O<sub>2</sub>.

Power category [MW]	NO <sub>x</sub> mg/m <sub>n</sub> <sup>3</sup>
<10	1500
10–50	450–1500 in dependancy of the power
>50	450

In the regulation “Portaria 286/93 de 12 de Marco” the emission limit values for other industrial fixed installations (incl. engines) are generally specified. The values are based on 8 % O<sub>2</sub>.

Emittent	Limit value mg/m <sub>n</sub> <sup>3</sup>
PM	300
SO <sub>2</sub>	2700
H <sub>2</sub> S	50
NO <sub>x</sub> (given as NO <sub>2</sub> )	1500
CO	1000
Organic compounds (with C)	50
Anorganic compounds (with Fluor)	50
Heavy metals	8

### Russia – Industrial engines

Date	Carbon monoxide CO [g/kWh]	Hydrocarbon HC [g/kWh]	NO <sub>x</sub> [g/kWh]
< 1 Jan 2000	6.0	2.4	16.0
≥ 1 Jan 2000	3.0	1.0	10.0

## EU – Nonroad-Directive

97/68/EC (as amended by 2004/26/EC)

### Diesel engines

Power $P_n$ kW	NO <sub>x</sub> g/kWh	HC g/kWh	CO g/kWh	Particulates g/kWh	Date*
	NO <sub>x</sub> + NMHC				
<b>Stage I</b>					
<b>37 ≤ P<sub>n</sub> &lt; 75</b>	9.2	1.3	6.5	0.85	Apr 99
<b>75 ≤ P<sub>n</sub> &lt; 130</b>	9.2	1.3	5.0	0.70	1999
<b>130 ≤ P<sub>n</sub> ≤ 560</b>	9.2	1.3	5.0	0.54	1999
<b>Stage II</b>					
<b>18 ≤ P<sub>n</sub> &lt; 37</b>	8.0	1.5	5.5	0.8	2001
<b>37 ≤ P<sub>n</sub> &lt; 75</b>	7.0	1.3	5.0	0.4	2004
<b>75 ≤ P<sub>n</sub> &lt; 130</b>	6.0	1.0	5.0	0.3	2003
<b>130 ≤ P<sub>n</sub> ≤ 560</b>	6.0	1.0	3.5	0.2	2002
<b>Stage III A</b>					
<b>19 ≤ P<sub>n</sub> &lt; 37</b>	7.5		5.5	0.6	2007
<b>37 ≤ P<sub>n</sub> &lt; 75</b>	4.7		5.0	0.4	2008
<b>75 ≤ P<sub>n</sub> &lt; 130</b>	4.0		5.0	0.3	2007
<b>130 ≤ P<sub>n</sub> ≤ 560</b>	4.0		3.5	0.2	2006
<b>Stage III B</b>					
<b>37 ≤ P<sub>n</sub> &lt; 56</b>	4.7		5.0	0.025	2013
<b>56 ≤ P<sub>n</sub> &lt; 75</b>	3.3	0.19	5.0	0.025	2012
<b>75 ≤ P<sub>n</sub> &lt; 130</b>	3.3	0.19	5.0	0.025	2012
<b>130 ≤ P<sub>n</sub> ≤ 560</b>	2.0	0.19	3.5	0.025	2011
<b>Stage IV</b>					
<b>56 ≤ P<sub>n</sub> &lt; 130</b>	0.4	0.19	5.0	0.025	Oct 2014
<b>130 ≤ P<sub>n</sub> ≤ 560</b>	0.4	0.19	3.5	0.025	2014

\* Date for placing the engine on the market, type approval one year earlier

- Engines above 560 kW are not regulated.
- Stationary test cycle: ISO 8178-4, C1/D2 (according to engine operation)
- Transient test cycle: NRTC (mandatory for stage IIIB)
- Test condition: Air temperature 25°C
- NTE (Not to Exceed): Starting with stage IIIB limits in the performance map will be applied (maximum 100 % above cycle limit).
- For constant speed engines (e.g. mobile gensets) the limits of stage II will be applied as of 2007, the limits of stage IIIA as of 2011.
- For agricultural tractors Directive 2000/25/EC (as amended by 2005/13/EC) is valid. The emission limits are equivalent to those in Directive 97/68/EC.
- As of stage IIIA compliance with the limits must be demonstrated over the useful lifetime of the engine.

## 34 NONROAD MOBILE MACHINERY

A technical review of the directive is currently carried out by the EU Commission. Emission limits and introduction dates of stages IIIB and IV will not be rediscussed. However new power classes <37kW and > 560kW may be introduced and exemptions and additional requirements (PEMS) are under consideration.

### USA – EPA Nonroad Regulation

(40 CFR 89, 40 CFR 1039 and 40 CFR 1068)

#### Diesel engines

Power $P_n$ kW	NO <sub>x</sub> g/kWh	HC* g/kWh	CO g/kWh	Particulates g/kWh	Date as of MY
	NO <sub>x</sub> + NMHC				
<b>Tier 1</b>					
$P_n < 8$	10.5		8.0	1.0	2000
$8 \leq P_n < 19$	9.5		6.6	0.8	2000
$19 \leq P_n < 37$	9.5		5.5	0.8	1999
$37 \leq P_n < 75$	9.2	–	–	–	1998
$75 \leq P_n < 130$	9.2	–	–	–	1997
$130 \leq P_n < 560$	9.2	1.3	11.4	0.54	1996
$P_n > 560$	9.2	1.3	11.4	0.54	2000
<b>Tier 2</b>					
$P_n < 8$	7.5		8.0	0.8	2005
$8 \leq P_n < 19$	7.5		6.6	0.8	2005
$19 \leq P_n < 37$	7.5		5.5	0.6	2004
$37 \leq P_n < 75$	7.5		5.0	0.4	2004
$75 \leq P_n < 130$	6.6		5.0	0.3	2003
$130 \leq P_n < 225$	6.6		3.5	0.2	2003
$225 \leq P_n < 450$	6.4		3.5	0.2	2001
$450 \leq P_n \leq 560$	6.4		3.5	0.2	2002
$P_n > 560$	6.4		3.5	0.2	2006
<b>Tier 3</b>					
$P_n < 8$	no further reduction				
$8 \leq P_n < 19$	no further reduction				
$19 \leq P_n < 37$	no further reduction				
$37 \leq P_n < 75$	4.7		5.0	0.4	2008
$75 \leq P_n < 130$	4.0		5.0	0.3	2007
$130 \leq P_n \leq 560$	4.0		3.5	0.2	2006
$P_n > 560$	no further reduction				
<b>Tier 4 interim</b>					
$19 \leq P_n < 37$	7.5		5.5	0.30	2008
$37 \leq P_n < 56$	4.7		5.0	0.30	2008
$56 \leq P_n < 130$	3.4	0.19	5.0	0.02	2012
$130 \leq P_n \leq 560$	2.0	0.19	3.5	0.02	2011
$P_n > 560$	3.5	0.4	3.5	0.10	2011
<b>Tier 4 interim - Genset</b>					
$P_n > 900$	0.67	0.4	3.5	0.1	2011

Power $P_n$ kW	NO <sub>x</sub> g/kWh	HC g/kWh	CO g/kWh	Particulates g/kWh	Date as of MY
	NO <sub>x</sub> + NMHC				
<b>Tier 4</b>					
$P_n < 8$	7.5		8.0	0.4*	2008
$8 \leq P_n < 19$	7.5		6.6	0.4	2008
$19 \leq P_n < 37$	4.7		5.5	0.03	2013
$37 \leq P_n < 56$	4.7		5.0	0.03	2013
$56 \leq P_n < 130$	0.4	0.19	5.0	0.02	2015**
$130 \leq P_n < 560$	0.4	0.19	3.5	0.02	2014***
$P_n > 560$	3.5	0.19	3.5	0.04	2015
<b>Tier 4 - Genset</b>					
$P_n > 560$	0.67	0.19	3.5	0.04	2015

- <sup>A</sup> hand-startable, air cooled direct injection engines may be certified to Tier 2 standards through 2009 and to an optional PM standard of 0.6 g/kWh starting in 2010
- <sup>B</sup> PM/CO: full compliance from 2012; NO<sub>x</sub>/HC: Option 1 (if banked Tier 2 credits used) – 50 % engines must comply in 2012–2013; Option 2 (if no Tier 2 credits claimed) – 25 % engines must comply in 2012–2014, with full compliance from 31 December 2014
- <sup>C</sup> PM/CO: full compliance from 2011; NO<sub>x</sub>/HC: 50 % engines must comply in 2011–2013

- Optional for Tier 3 / 4: 37–56 kW, PM = 0.3 g/kWh as of 2008; 56–560 kW Phase in / Phase out
- Additionally to particulate measurement, a transient smoke test is required. As of Tier 4 this is only necessary if particulate emissions exceed 0.07 g/kWh. Engines which are operated at constant speed are generally excluded.
- Stationary test cycle: ISO 8178-4, C1/D2/E3. As of Tier 4 the appropriate Ramped Mode Cycle (see chapter 6) may be used alternatively.
- Transient test cycle: NRTC; all engines as of Tier 4, except engines above 560 kW and constant speed engines of any power category.
- Test condition: Air temperature 25°C  
As of Tier 4: Air temperature 20°C–30°C,  
Ambient pressure 0.8–1.03 bar
- Compliance with the emission limits has to be guaranteed over the useful lifetime of the engine.
- ABT (Averaging, Banking and Trading): Emission credits (CO, NO<sub>x</sub>+HC and particulates) can be averaged, banked or traded
- NTE (Not to Exceed): As of Tier 4, the emissions may not exceed 1.25 to 1.5 times the cycle limit.
- The regulations of Tier 4 allow open crankcase ventilation if these emissions are measured and added to the exhaust emissions.

**India**

On 21 September 2006 the emission limit values for diesel engine driven mobile machinery in India have been published and came into force. The Indian law defines a construction machine as equipment driven by a diesel engine as propulsion engine (constant or variable speed) that provides power for both movement of vehicle and intended operations. The equipment can be rubber tyred (including pneumatic tyred), rubber padded or steel drum wheel mounted. The equipment can be developed for the on- and the nonroad-sector.

Power $P_n$ kW	NO <sub>x</sub> g/kWh	HC g/kWh	CO g/kWh	PM g/kWh	Date
	HC + NO <sub>x</sub> [g/kWh]				
<b>Bharat Stage II (CEV)</b>					
$P_n < 8$	9.20	1.30	8.00	1.00	Oct 2008
$8 \leq P_n < 19$	9.20	1.30	6.60	0.85	Oct 2008
$19 \leq P_n < 37$	9.20	1.30	6.50	0.85	Oct 2007
$37 \leq P_n < 75$	9.20	1.30	6.50	0.85	Oct 2007
$75 \leq P_n < 130$	9.20	1.30	5.00	0.70	Oct 2007
$130 \leq P_n < 560$	9.20	1.30	5.00	0.54	Oct 2007
<b>Bharat Stage III (CEV)</b>					
$P_n < 8$	7.50		8.00	0.80	Apr 2011
$8 \leq P_n < 19$	7.50		6.60	0.80	Apr 2011
$19 \leq P_n < 37$	7.50		5.50	0.60	Apr 2011
$37 \leq P_n < 75$	4.70		5.00	0.40	Apr 2011
$75 \leq P_n < 130$	4.00		5.00	0.30	Apr 2011
$130 \leq P_n < 560$	4.00		3.50	0.20	Apr 2011

- Test cycle: ISO 8178 part 4 C1-8 and
- ISO 8178 part 4 D2-5
- The test shall be on engine dynamometer.
- The test procedure for measurement of gross power (without fan) shall be as per Part IV of MoSRT/CMVR/TAP-115/116 Issue No. 3.
- The test procedure for measurement of emission of visible and gaseous pollutants and Particulate Matter shall be as per MoSRT/CMVR/TAP-115/116 Part X (sub part B).
- The emission of visible pollutants shall not exceed the limit values given in sub-rule (3) of rule 115A when tested on engine dynamometer at eighty per cent load at six speeds as per sub-rule (3) of rule 115A.

- To meet the Bharat Stage III (CEV) standards with effect from 1 April 2011 engine manufacturer may opt for an engine test as mentioned in the table below for evaluating deterioration factors as per Annex V of Part X, sub part B of MoSRTTH/CMVR/TAP-115/116 issue No. 3.
- There shall be no relaxation of norms for COP (Conformity of production) purposes.
- COP selection procedure shall be as per MoSRTTH/CMVR/TAP-115/116 Part VI.
- COP-frequency:
  - a) for equipment with annual production up to 200: once in two years per engine family.
  - b) for equipment with annual production exceeding 200: once in every year per engine family

Power band [kW]	Durability Emission resistance
< 19	3000
19 < P < 37 (constant speed)	3000
19 < P < 37 (variable speed)	5000
> 37	8000

**Deterioration factors**

CO	HC	NO <sub>x</sub>	PM
1.10	1.05	1.05	1.1

**Emission limit values for agricultural tractors**

	NO <sub>x</sub> g/kWh	HC g/kWh	CO g/kWh	PM g/kWh	Date
	HC + NO <sub>x</sub> [g/kWh]				
Bharat (Trem) Stage I	18.0	3.5	14.0	–	Oct 99
Bharat (Trem) Stage II	15.0		9.0	1.0	Jun 03
Bharat (Trem) Stage III	9.5		5.5	0.80	Oct 05

- Test cycle: ISO 8178 C1-8

## 38 NONROAD MOBILE MACHINERY

### Japan

Emission limit values stipulated by the Ministry of Environment (MOE) for “Special Motor Vehicles” and “Nonroad Motor vehicles”:

Power $P_n$ kW	NO <sub>x</sub> g/kWh	CO g/kWh	HC g/kWh	PM g/kWh	Smoke %	Date	Date for imported machines and vehicles
<b>Stage I</b>							
$19 \leq P_n < 37$	8.0	5.0	1.5	0.80	40	Oct. 03	–
$37 \leq P_n < 56$	7.0	5.0	1.3	0.40	40	Oct. 03	–
$56 \leq P_n < 75$	7.0	5.0	1.3	0.30	40	Oct. 03	–
$75 \leq P_n < 130$	6.0	5.0	1.0	0.30	40	Oct. 03	–
$130 \leq P_n < 560$	6.0	3.5	1.0	0.20	40	Oct. 03	–
<b>Stage II</b>							
$19 \leq P_n < 37$	6.0	5.0	1.0	0.40	40	Oct. 07	31. Aug. 08
$37 \leq P_n < 56$	4.0	5.0	0.7	0.30	35	Oct. 08	31. Aug. 09
$56 \leq P_n < 75$	4.0	5.0	0.7	0.25	30	Oct. 08	31. Aug. 2010
$75 \leq P_n < 130$	3.6	5.0	0.4	0.20	25	Oct. 07	31. Aug. 08
$130 \leq P_n < 560$	3.6	3.5	0.4	0.17	25	Oct. 06	31. Aug. 08

- Test cycle: ISO 8178-4,C1
- Smoke measurement according to JCMAS T-004.
- Definition „Special Motor Vehicles“: self propelled nonroad vehicles and mobile machinery that have registration plate for usage in traffic
- Definition „Nonroad Motor Vehicles“: self propelled nonroad vehicles and mobile machinery that have no registration plate for usage in traffic

Emission limits of the Ministry of Construction (MOC) for construction machines:

Power $P_n$ kW	CO g/kWh	NO <sub>x</sub> g/kWh	HC g/kWh	PM g/kWh	Smoke %
<b>Stufe II</b>					
$8 \leq P_n < 19$	5.0	NO <sub>x</sub> +HC: 7.5		0.80	40
$19 \leq P_n < 37$	5.0	1.0	6.0	0.40	40
$37 \leq P_n < 56$	5.0	0.70	4.0	0.30	35
$56 \leq P_n < 75$	5.0	0.70	4.0	0.25	30
$75 \leq P_n < 130$	5.0	0.40	3.6	0.20	25
$130 \leq P_n < 560$	3.5	0.40	3.6	0.17	25

- Test cycle: ISO 8178-4,C1
- The emission limit values for engines with 19-560 kW are identical with the limits stipulated by the Ministry of Transport (MOT) according to stage I. But they came into force one year earlier.

## Turkey

The Turkish Ministry of Industry and Trade is responsible for the emission legislation of non-road mobile machinery in Turkey. The Ministry has adopted the emission limit values of the European non-road Directive 97/68/EC. Differing are solely the dates of coming into force of stages I – IIIA. The dates of coming into force for stage IIIB and stage IV are identical to those in the European legislation.

Power P <sub>n</sub> [kW]	NO <sub>x</sub> g/kWh	HC g/kWh	CO g/kWh	PM g/kWh	Date*
	NO <sub>x</sub> + NMHC				
<b>Stage I (Faz I)</b>					
37 ≤ P <sub>n</sub> < 75	9.2	1.3	6.5	0.85	5 Apr 2003
75 ≤ P <sub>n</sub> < 130	9.2	1.3	5.0	0.70	5 Apr 2003
130 ≤ P <sub>n</sub> ≤ 560	9.2	1.3	5.0	0.54	5 Apr 2003
<b>Stage II (Faz II)</b>					
18 ≤ P <sub>n</sub> < 37	8.0	1.5	5.5	0.8	2007
37 ≤ P <sub>n</sub> < 75	7.0	1.3	5.0	0.4	2007
75 ≤ P <sub>n</sub> < 130	6.0	1.0	5.0	0.3	2007
130 ≤ P <sub>n</sub> ≤ 560	6.0	1.0	3.5	0.2	2007
<b>Stage III A (Faz IIIA)</b>					
19 ≤ P <sub>n</sub> < 37	7.5		5.5	0.6	2010
37 ≤ P <sub>n</sub> < 75	4.7		5.0	0.4	2010
75 ≤ P <sub>n</sub> < 130	4.0		5.0	0.3	2010
130 ≤ P <sub>n</sub> ≤ 560	4.0		3.5	0.2	2010
<b>Stage III B (Faz IIIB)</b>					
37 ≤ P <sub>n</sub> < 56	4.7		5.0	0.025	2013
56 ≤ P <sub>n</sub> < 75	3.3	0.19	5.0	0.025	2012
75 ≤ P <sub>n</sub> < 130	3.3	0.19	5.0	0.025	2012
130 ≤ P <sub>n</sub> ≤ 560	2.0	0.19	3.5	0.025	2011
<b>Stage IV (Faz IV)</b>					
56 ≤ P <sub>n</sub> < 130	0.4	0.19	5.0	0.025	Oct 2014
130 ≤ P <sub>n</sub> ≤ 560	0.4	0.19	3.5	0.025	2014

\* Date for placing on the market.

- Engines >560 kW are not regulated
- Test cycle: ISO 8178-4, C1/D2

## Russia – mobile machinery and small tractors

The limits became effective at 1 July 2001.

Power	Carbon monoxide CO [g/kWh]	Carbon monoxide HC [g/kWh]	NO <sub>x</sub> [g/kWh]
all power bands	11.0	6.0	18.0

## EU – Rail

The directive 97/68/EC (as amended by 2004/26/EC) applies for compression ignition engines installed on railway vehicles with a rated power of more than 130 kW for propulsion engines, and at least 19 kW for engines running at constant speed. For engines that are operated at constant speed the limits apply as of 31 December 2006.

### Locomotive propulsion engines

Stage	Power $P_n$ Cylinder displ.	NO <sub>x</sub> g/kWh	HC g/kWh	CO g/kWh	PM g/kWh	Date*
IIIA	$130 \leq P_n < 560$ kW	4.0		3.5	0.2	2007
	$560 \leq P_n < 2000$ kW	6.0	0.5	3.5	0.2	2009
	$P_n > 2000$ kW $V_{h,z} > 5$ l	7.4	0.4	3.5	0.2	2009
IIIB	$P_n > 130$ kW	4.0		3.5	0.025	2012

### Railcar propulsion engines

Stage	Power $P_n$	NO <sub>x</sub> g/kWh	HC g/kWh	CO g/kWh	PM g/kWh	Date*
IIIA	$P_n > 130$ kW	4.0		3.5	0.2	2006
IIIB	$P_n > 130$ kW	2.0	0.19	3.5	0.025	2012

\* Date for placing on the market of engines, type approval one year earlier.

- No stage I and II
- Test cycle: ISO 8178-4, C1 (railcars) respectively F
- Test condition: air temperature 25°C
- As of stage IIIB there are limits in the performance map (NTE).
- Compliance with the limits must be demonstrated over the useful lifetime of the engine.

## UIC – International Union of Railways

UIC code 624V establishes emission limits for railway propulsion engines, which are mandatory for all UIC members. The UIC stage III corresponds to the stage IIIA of the EU – Nonroad-Directive 97/68/EC (see above).

Stage	Power $P_n$ Speed $n_n$	NO <sub>x</sub> g/kWh	HC g/kWh	CO g/kWh	PM g/kWh	Date
UIC II	$P_n > 560$ kW	6.0	0.6	2.5	0.25	1 Jan 2003
	$P_n > 560$ kW $n_n > 1000$ rpm	9.5	0.8	3.0	0.25	1 Jan 2003
	$P_n > 560$ kW $n_n \leq 1000$ rpm	9.9	0.8	3.0	0.25	1 Jan 2003

- UIC II: test cycle ISO 8178-4, F
- The UIC stage III corresponds to the stage IIIA of the EU – Nonroad-Directive 97/68/EC (see above).
- UIC III: test cycle ISO 8178-4, F (C1 for railcars, corresponding to EU – Nonroad-Directive 97/68/EC)
- Test fuel corresponding to ISO 8178-5
- Test condition: air temperature 25°C
- Exempted are engines with a rated power of less than 100 kW as well as engines installed in special locomotives (e.g. refinery- or mining-locomotives).

## USA

On 6 May 2008 the US EPA has published the final rule „40 CFR Parts 9, 85, et al. Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression-Ignition Engines Less Than 30 Liters per Cylinder”. This law regulates the emission limit values for all rail diesel engines.

### Line-haul Locomotives

Engine category	Take effect in year	PM [g/bhp-hr]	NO <sub>x</sub> [g/bhp-hr]	HC [g/bhp-hr]
Remanufactured Tier 0 without separate loop intake air cooling	2008, as available 2010 required	0.22	8.0	1.00
Remanufactured Tier 0 with separate loop intake air cooling	2008, as available 2010 required	0.22	7.4	0.55
Remanufactured Tier 1	2008, as available 2010 required	0.22	7.4	0.55
Remanufactured Tier 2	2008, as available 2013 required	0.10	5.5	0.30
New Tier 3	2012	0.10	5.5	0.30
New Tier 4	2015	0.03	1.3	0.14

### Switch-haul locomotives

Engine category	Take effect in year	PM [g/bhp-hr]	NO <sub>x</sub> [g/bhp-hr]	HC [g/bhp-hr]
Remanufactured Tier 0	2008, as available 2010 required	0.26	11.8	2.10
Remanufactured Tier 1	2008, as available 2010 required	0.26	11.0	1.20
Remanufactured Tier 2	2008, as available 2013 required	0.13	8.1	0.60
Tier 3	2011	0.10	5.0	0.60
Tier 4	2015	0.03	1.3	0.14

- Test specification: US EPA Part 1065: Test Procedures

## Turkey

The rule 97/68/AT (2004/26/AT) is valid for rail vehicles propelled with diesel engines with 130 kW (propulsion engine).

The dates of coming into force for the emission stage Faz IIIA are both for locomotives and railcars consistently in 2010. That is 1–4 years after the appropriate dates in the EU legislation. The dates for the emission stage Faz IIIB are identical with the appropriate dates in the EU legislation.

### Propulsion engines for locomotives

Stage	Power $P_n$	NO <sub>x</sub> g/kWh	HC g/kWh	CO g/kWh	PM g/kWh	Date
		NO <sub>x</sub> + HC g/kWh				
Faz IIIA	$130 \leq P_n \leq 560$ kW	4.0		3.5	0.2	2010
	$560 < P_n \leq 2000$ kW	6.0	0.5	3.5	0.2	2010
	$P_n > 2000$ kW $V_{h,z} > 5$ l	7.4	0.4	3.5	0.2	2010
Faz IIIB	$P_n > 130$ kW	4.0		3.5	0.025	2012

### Propulsion engines for railcars

Stage	Power $P_n$	NO <sub>x</sub> g/kWh	HC g/kWh	CO g/kWh	PM g/kWh	Date*
IIIA	$P_n > 130$ kW	4.0		3.5	0.20	2010
IIIB	$P_n > 130$ kW	2.0	0.19	3.5	0.025	2012

\* Date for placing on the market.

- No emission stages I and II

### Russia – Locomotives

Date	Carbon monoxide CO [g/kWh]	Hydrocarbon HC [g/kWh]	NO <sub>x</sub> [g/kWh]
< 1 Jan 2000	6.0	2.4	18.0
≥ 1 Jan 2000	3.0	1.0	12.0

## 44 HEAVY-DUTY VEHICLES

### EU – Heavy-Duty Vehicles

#### Directive 88/77/EEC (as amended by 2005/78/EC)

Applies to heavy-duty vehicles with a gross weight over 3.5 t. Compression ignition and gas engines are treated as propulsion engines within this directive.

#### Limits for **ESC- and ELR-test:**

Stage	CO g/kWh	HC g/kWh	NO <sub>x</sub> g/kWh	PM g/kWh	Smoke m <sup>-1</sup>	Date <sup>B</sup>
<b>Euro III</b>	2.1	0.66	5.0	0.10 0.13 <sup>A</sup>	0.80	1 Oct 2001
<b>Euro IV</b>	1.5	0.46	3.5	0.02	0.50	1 Oct 2006
<b>Euro V</b>	1.5	0.46	2.0	0.02	0.50	1 Oct 2009
<b>EEV<sup>C</sup></b>	1.5	0.25	2.0	0.02	0.15	

<sup>A</sup> For engines with a displacement below 0.75 dm<sup>3</sup> per cylinder and a rated power speed of more than 3000 rpm.

<sup>B</sup> Date for placing on the market, type approval one year earlier.

<sup>C</sup> EEV: Facultative limits for very environment-friendly vehicle

#### Limits **ETC-test:**

Stage	CO g/kWh	NMHC g/kWh	CH <sub>4</sub> <sup>B</sup> g/kWh	NO <sub>x</sub> g/kWh	PM <sup>C</sup> g/kWh	Date <sup>A</sup>
<b>Euro III</b>	5.45	0.78	1.60	5.0	0.16 0.21 <sup>D</sup>	1 Oct 2001
<b>Euro IV</b>	4.00	0.55	1.10	3.5	0.03	1 Oct 2006
<b>Euro V</b>	4.00	0.55	1.10	2.0	0.03	1 Oct 2009
<b>EEV</b>	3.00	0.40	0.65	2.0	0.02	

<sup>A</sup> Date for placing on the market, type approval one year earlier.

<sup>B</sup> Only for natural gas engines.

<sup>C</sup> Not valid for gas-driven engines of stages III, IV and V.

<sup>D</sup> For engines with a displacement of less than 0.75 dm<sup>3</sup> per cylinder and a rated power speed of more than 3000 rpm

In stage Euro III only diesel engines with a particulate filter and/or a DeNO<sub>x</sub> catalytic converter are additionally subjected to the ETC-test. In stages Euro IV and Euro V all engines are additionally subjected to the ETC-test.

Gaseous emissions of gas engines are measured using the ETC-test.

From stage Euro IV all new vehicle types have to be equipped with an “On-Board-Diagnosis-System” (OBD) or an “On-Board-Monitoring-System” (OBM) to control the exhaust emissions during operation.

From stage Euro IV for new vehicles and engines the operational reliability of emission-relevant components has to be guaranteed for the useful lifetime of the vehicle or the engine to get the corresponding type approval.

## USA

The limits apply for heavy-duty vehicles with a gross weight of more than 3,856 t (8500 lbm). The vehicles are separated in the following **sub-categories**:

- Light heavy-duty diesel engines:  
8500 lbm (California: 14500 lbm) < LHDDE < 19500 lbm
- Medium heavy-duty diesel engines:  
19500 lbm ≤ MHDDE ≤ 33000 lbm
- Heavy heavy-duty diesel engines (including urban buses):  
HHDE > 33000 lbm

Compliance of the limits has to be demonstrated over the **useful lifetime** of the engine, respectively **mileage** (depending on which occurs first):

- LHDDE: 110000 miles / 10 years
- MHDDE: 185000 miles / 10 years
- HHDE: 435000 miles / 10 years / 22000 hours

### Limits

Model year MY	NO <sub>x</sub> g/kWh	NMHC g/kWh	NO <sub>x</sub> + NMHC g/kWh	CO g/kWh	PM g/kWh
2004			3.2*	20.8	0.130
2007	0.27	0.19		20.8	0.013

\* optionally 3.4 g/kWh if NMHC < 0.7 g/kWh

- Test standard: US-FTP transient test procedure for heavy-duty diesel engines as of 2007, additionally SET (Supplemental Emission Test). In addition to the particulate measurement, a transient smoke test is required.
- For urban buses, lower particulate limits apply. Fleet-emission should be decreased about 85 % (compared to the emissions in January 2002) until 2007 (on alternative fuels until 2009).
- NO<sub>x</sub>- and NMHC-limits for MY 2007 will be introduced gradually. As of 2007 a minimum of 50 % of all sold vehicles must comply with these limits (for the rest, the limits of model year 2004 apply), as of 2010 all vehicles have to comply with the limits of model year 2007.
- NTE (Not to exceed): In a certain map area (operating range), pre-defined upper emission limits must not be exceeded.
- ABT (Averaging, Banking and Trading): Emission credits (NO<sub>x</sub>+HC and particulates) can be averaged, banked or traded.
- NCP (Non-conformance penalties): Compensation payment is possible if the limits are exceeded.

## 46 HEAVY-DUTY VEHICLES

### Japan

The limits apply to heavy-duty vehicles with a gross weight of more than 3.5 tons (2005) respectively 2.5 tons (2003).

Date** of type test	CO g/kWh	HC g/kWh	NO <sub>x</sub> g/kWh	PM g/kWh
Oct 2003	2.22	0.87	3.38	0.180
Oct 2005	2.22	0.17*	2.00	0.027

\* Non-methane hydrocarbons

\*\* Different dates for different weight classes

- Testing with the Japanese 13-mode test, respectively from 2005 with the Japanese transient test JE05 (Duration: 1800 s, measuring point defined as speed of the vehicle at certain points of time.)
- In addition a smoke limit must be met.

## TEST CYCLES

### ISO 8178

- Part 4 of ISO 8178 deals with the test cycles for different non-road engine applications.
- The test cycles for the measurement and evaluation of gaseous and particulate exhaust emissions in reciprocating internal combustion engines are established, if the power is determined with a dynamometer.
- The tests are carried out under steady state operation.
- Engines for motor vehicles primarily designed for road use are excluded.
- The **engine** has to **warm-up** to the rated power used in the test cycle, according to the recommendations of the manufacturer, to **stabilise** the engine **operating-parameters**.
- The **test conditions** are established in ISO 8178-1 and ISO 8178-2.

#### Classification of the test cycles:

- A Heavy-duty diesels in road vehicles (compare ECE R49)
- B Universal, includes all test modes of cycles A, C, D, F, E1 and E2 without weighting, and can be used as the basis for calculating emissions for these test cycles
- C Vehicles (except on-road vehicles) and industrial equipment
  - C1 Nonroad vehicles and industrial equipment with diesel engines
  - C2 Nonroad vehicles and industrial equipment with spark-ignition engines and rated power above 20 kW
- D Constant speed
  - D1 Gensets, irrigation pumps
  - D2 Units with intermittent load
- E Marine engines
  - E1 Diesel engines for craft less than 24 m, except engines for tug/push boats
  - E2 Heavy-duty, constant-speed engines for marine propulsion, without restriction of vessel length
  - E3 Heavy-duty engines running on the propeller curve for marine main propulsion, without restriction of vessel length,
  - E4 Spark-ignition engines for craft less than 24 m, except engines for tug/push boats
  - E5 Diesel engines for craft less than 24 m, except for tug/push boats

## 48 TEST CYCLES

**F** Rail engines

**G** Engines with a rated power usually less than 20 kW, for utility, lawn and garden equipment

**G1** Non hand-held applications with intermediate speed

**G2** Non hand-held applications with rated speed

**G3** Hand-held applications with rated speed

### Weighting factors (mean pressure referenced to full-load curve)

Test mode B-cycle	Speed	Mean pr. $P_{me}/P_{meP\ max}$	Cycle						
			C1	C2	D1	D2	E1	E2	F
<b>1</b>	Rated speed	1	0.15		0.3	0.05	0.08	0.2	0.15
<b>2</b>		0.75	0.15		0.5	0.25	0.11	0.5	
<b>3</b>		0.5	0.15		0.2	0.3		0.15	
<b>4</b>		0.25		0.06		0.3		0.15	
<b>5</b>		0.1	0.1			0.1			
<b>6</b>	Intermediate speed	1	0.1	0.02					
<b>7</b>		0.75	0.1	0.05			0.19		
<b>8</b>		0.5	0.1	0.32			0.32		0.25
<b>9</b>		0.25		0.3					
<b>10</b>		0.1		0.1					
<b>11</b>	Low idle	0	0.15	0.15			0.3		0.6

### Intermediate speed:

- For engines which are designed to operate over a speed range on a full-load torque curve, the intermediate speed shall be the declared maximum torque speed if it occurs between 60 % and 75 % of rated speed.
- If the declared maximum torque speed is less than 60 % of rated speed, then the intermediate speed shall be 60 % of the rated speed.
- If the declared maximum torque speed is greater than 75 % of the rated speed then the intermediate speed shall be 75 % of rated speed.
- For engines which are not designed to operate over a speed range on the full load torque curve at steady state conditions, the intermediate speed will typically be between 60 % and 70 % of the maximum rated speed.
- For engines to be tested on cycle G1, the intermediate speed shall be 85 % of the maximum rated speed.

**Weighting factors** (for test cycles based on the propeller curve)

Test mode	Speed $n/n_n$	Power $P/P_n$	Cycle	
			E3	E5
1	1.00	1.00	0.20	0.08
2	0.91	0.75	0.50	0.13
3	0.80	0.50	0.15	0.17
4	0.63	0.25	0.15	0.32
5	idle	0.00		0.30

**ECE R49 – Test cycle**

Stationary heavy-duty vehicle test (Euro II) corresponding to ISO 8178, A-cycle

Test mode	Speed $n/n_n$	Mean pressure $p_{me}/p_{me, max}$	Weighting factor
1	Low idle	0.00	0.25/3
2	Intermediate speed	0.10	0.08
3		0.25	0.08
4		0.50	0.08
5		0.75	0.08
6		1.00	0.25
7	Low idle	0.00	0.25/3
8	Rated speed	1.00	0.10
9		0.75	0.02
10		0.50	0.02
11		0.25	0.02
12		0.10	0.02
13	Low idle	0.00	0.25/3

**ECE/EU Smoke measurement**  
(ECE R 24/03 and 97/20/EC respectively)

Measurement of the light-absorption coefficient (opacity) of the exhaust-gas for all vehicles with diesel engines (commercial vehicles up to Euro II)

**1. Testing** at constant speeds under full load

- Measurement of the full-load smoke at six different constant speeds between rated speed and 45 % of the rated speed, or at 1000 rpm.
- For ECE R 24/03: the 7th measuring point at maximum torque.

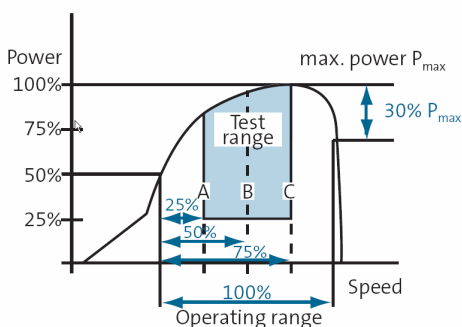
## 50 TEST CYCLES

### 2. Testing at free acceleration

- Measurement of smoke at free acceleration of the engine from idle to maximum speed.
- Limit specified only for engines with turbocharger.

### ESC – European Steady State Cycle

Stationary heavy-duty vehicle test cycle. Operating range, test range and test speeds A, B and C are defined as follows within the full-load curve.



Test range	Speed	Mean pr: $p_{me}/p_{me,max}$	Weighting factor	Test time minutes
1	Low idle	0	0.15	4
2	A	1.00	0.08	2
3	B	0.50	0.10	2
4	B	0.75	0.10	2
5	A	0.50	0.05	2
6	A	0.75	0.05	2
7	A	0.25	0.05	2
8	B	1.00	0.09	2
9	B	0.25	0.10	2
10	C	1.00	0.08	2
11	C	0.25	0.05	2
12	C	0.75	0.05	2
13	C	0.50	0.05	2

$NO_x$  emission is measured at three additional points in the test range. The values measured at these points may exceed the values interpolated from the four neighbouring points by max. 10 %.

## ELR – European Load Response Test

- Transient smoke test for diesel engines of commercial vehicles with a gross weight of more than 3.5 tons.
- Torque-increasing of 10 percent on the maximum torque at each constant testing-speeds A, B and C (compare with ESC-test).
- Additionally, smoke is to be tested at a speed between A and C and another speed that is freely selectable by the tester.
- Measurement is to be repeated three times.
- The exhaust-opacity is measured in  $\text{m}^{-1}$ .
- The opacity which is measured at the free selectable speed may not exceed the value of the neighbouring speeds more than 20 percent and may not exceed the limit value more than 5 percent.

## ETC – European Transient Cycle

- Transient test cycle for diesel engines from commercial vehicles with a gross weight more than 3.5 t (Euro III and IV), consisting of 1800 secondly changing load stages with specification of rotation speed and engine torque.
- The city, country and super-highway/motorway engine loads are simulated.
- Power and exhaust-gas emissions are integrated over the cycle.
- As of Euro III the ETC-test is mandatory only for engines with particulate filter and/or DeNO<sub>x</sub> catalytic converter. As of Euro IV the ETC-test is mandatory for all engines.

## RMC – Ramped Mode Cycle

- Stationary Nonroad test cycle, created by the EPA (for Nonroad-engines, Tier 4).
- The test modes of the ISO test cycles are connected by transition periods of 20 seconds (ramps).
- The whole test sequence has to be performed in a specified time without interruption.

## **NRTC – Nonroad Transient Cycle**

- Dynamic test for mobile machinery.
- Is valid in the USA (Tier 4) for measurement of particulate and gaseous emission.
- To use for the EU-stages III B and IV for measurement of particulate emission at all engines for mobile machinery except engines with constant speed, rail engines and propulsion engines of inland navigation vessels.
- The manufacturer can use this test also for measurements in EU-stage IIIA and for measurement of gaseous pollutants in EU-stages III B and IV.

## **US – Smoke test (commercial vehicles and nonroad engines)**

- Measurement of the exhaust-gas opacity at transient engine operation on a test stand.
- Starting at idle, the engine is accelerated in two phases with a brief interruption (acceleration-mode).
- The engine is then operated at rated speed and power and subsequently lugged down through increasing of the load until the intermediate speed (Lugging-mode).
- Thereupon, the engine is decelerated to idle speed.
- This cycle is repeated three times. From the values measured during all three runs, the average opacity for acceleration, lugging and the maximum figure (peak) are calculated.

## **US transient test (FTP) for commercial vehicle engines**

- Since 1985, a dynamic testing procedure in the USA is used for engines of commercial vehicles.
- The test cycle lasts 1200 seconds, whereas speed and clutch-torque are defined for each second.
- The city traffic operation modus as well as highway driving should be represented.
- The major operation frequency focus on eight points in the performance map, which are dedicated primarily to the rated speed and speeds above idle.
- The speed at maximum torque, which has a high weighting factor in ECE R49, practically does not exist.

## US stationary test (SET) for commercial vehicle engines

The Supplemental Emission Test (SET) corresponds to the European ESC test and will be mandatory in the US as of MY 2007.

## US locomotive test cycle

As a result of the special operating conditions of locomotives in the USA, EPA has worked out a separate test cycle.

Test mode	Throttle setting	Duration (minutes)	Weighting factor Line-haul cycle	Weighting factor Switch cycle
Warm-up	Notch 8	5 ± 1	0 <sup>A</sup>	0 <sup>A</sup>
Warm-up	Lowest idle	max. 15	0 <sup>A</sup>	0 <sup>A</sup>
1a	Low idle <sup>B</sup>	6	0.190	0.299
1	Normal idle <sup>C</sup>	6	0.190	0.299
2	Dynamic braking	6	0.125	0
3	Notch 1	6	0.065	0.124
4	Notch 2	6	0.065	0.123
5	Notch 3	6	0.052	0.058
6	Notch 4	6	0.044	0.036
7	Notch 5	6	0.038	0.036
8	Notch 6	6	0.039	0.015
9	Notch 7	6	0.030	0.002
10	Notch 8	max. 15	0.162	0.008

<sup>A</sup> no measurement

<sup>B</sup> not applicable if equipped differently

<sup>C</sup> for applications with only one idle speed, the weighting factor is doubled

## Cycle value calculation

The cycle value  $E_x$  (g/kWh) is calculated as follows using the pollutant mass flows  $M_{xi}$  (g/h) that are measured at the cycle points 1 to  $i$  with power  $P_i$  and weighting factor  $W_i$ :

$$E_x = \frac{\sum_{i=1}^i M_{xi} \cdot W_i}{\sum_{i=1}^i P_i \cdot W_i}$$

## Lake Constance Shipping Ordinance (BSO) 9-mode test

- The test is executed on a **power-absorption** roller. Outboard-engines are put in a water tank and the propeller-driveshaft is connected with the power-brake (with removed propeller).
- In the **heating-phase**, the engine is firstly operated 10 minutes with free selectable part load. Then it is operated 20 minutes with full load at 50 (+/-5) percent of the rated rotation speed.
- In the **first step** of the test, the warm engine is operated from **measuring point 1 to measuring point 9**, whereas all required data are measured.
- In the **second step** of the test, the warm engine is operated from measuring point 9 to measuring point 1, whereas all required data are measured.
- Hydrocarbons HC, carbon monoxide CO, carbon dioxide CO<sub>2</sub> and nitrogen oxides NO<sub>x</sub> have to be measured. Furthermore the power and the fuel consumption has to be measured at every operating state.
- At diesel engines the exhaust-gas opacity has to be measured simultaneous or directly after the test.
- Depending on the engine operation, the test is run at the propeller- or the generator-curve (propeller curve  $P - n^{2.5}$ ).

### Propeller curve

Measuring point	Rotation speed min <sup>-1</sup>	Power kW	Weighting factor
1	idle	0	0.30
2	$0.4 \cdot n_n$	$0.1012 \cdot P_{Vn}$	0.10
3	$0.5 \cdot n_n$	$0.1768 \cdot P_{Vn}$	0.10
4	$0.6 \cdot n_n$	$0.2789 \cdot P_{Vn}$	0.10
5	$0.7 \cdot n_n$	$0.4100 \cdot P_{Vn}$	0.20
6	$0.8 \cdot n_n$	$0.5724 \cdot P_{Vn}$	0.05
7	$0.9 \cdot n_n$	$0.7684 \cdot P_{Vn}$	0.05
8*	$n_n$	$P_{Vn}$	0.05
9*	$n_{Pmax}$	$P_{max}$	0.05

\* Measuring points 8 and 9 are combined, if  $P_{Vn}$  differs not more than 5 percent of  $P_{max}$  (weighting factor 0.1)

$n_n$  Rated speed

$P_{Vn}$  Not reducible full-load power at rated speed

$n_{Pmax}$  Speed at maximum power

$P_{max}$  Not reducible maximum power

The exhaust-gas opacity (smoke) has to be measured at full load (rotation speed at full power, thus at point 8 or 9) with the filtering-method.

**Generator curve:**

Operation at the same power levels but all with rated speed.  
Power in point 9 should be 1.1 times  $P_{v\eta}$ .

## FUELS

## EU – Directives 98/70/EC (as amended by 2003/17/EC) and 2005/33/EC

- **Diesel fuels:** Gasoils which belong to KN-Code 27 10 19 41 and which are used for propulsion of vehicles for the purpose of the directives 70/220/EEC and 88/77/EEC.
- The member states ensure, that at the latest on **1 January 2005** diesel fuel with a maximum sulphur content of 10 ppm is placed on the market in their sovereign territory. In all other aspects, the fuel has to comply to the specifications stated below.
- As of **1 January 2009** only diesel fuel may be placed on the market, which complies with the specifications below and has a maximum sulphur content of 10 mg/kg (= 10 ppm).

Attribute <sup>A</sup>	Unit	Minimum <sup>B</sup>	Maximum <sup>B</sup>
<b>Cetane number</b>		51	–
<b>Density at 15°C</b>	kg/m <sup>3</sup>	–	845
<b>Boiling characteristics: 95 % (v/v) re-extracted at</b>	°C	–	360
<b>Polycyclic aromatic hydrocarbons</b>	% m/m	–	11
<b>Sulphur content</b>	ppm	–	50 10 <sup>C</sup>

<sup>A</sup> Test procedure according to EN 590:1999

<sup>B</sup> "Effective Values" according to ISO 4259

<sup>C</sup> As of 1 January 2009 the regulated maximum sulphur content has to be satisfied by every diesel fuel that is placed on the market.

- Furthermore, the Member States shall assure that the gasoils which are placed on the market for use in **mobile machinery** or in **agricultural tractors** have a maximum sulphur content of 2000 mg/kg (= 2000 ppm).
- As of **1 January 2008** the maximum sulphur content of the above mentioned gasoils is 1000 mg/kg (= 1000 ppm).

- As of 1 January 2010 the maximum sulphur content of fuels for **inland navigation vessels** is 1000 mg/kg (= 1000 ppm) as regulated in the directive 2005/33/EC.
- For **seagoing vessels** the directive 2005/33/EC regulates for special areas (so called **SO<sub>x</sub> Emission Control Areas (SECA)**) the following limits for the sulphur content: 1.5 % sulphur content for the North Sea (11 August 2007) and the Baltic Sea and also for passenger ships at regular service between Community Ports (11 August 2006); 0.1 % for all ships at berth in Community Ports (1 January 2010).

### USA 40 CFR

- For mobile machinery the sulphur limit is 500 ppm as of 2007 and 15 ppm as of 2010.
- For trains and ships the sulphur limit is 15 ppm as of 2012.

### IMO – Marine fuels

The IMO is further reducing the sulphur level in marine fuels. For details see chapter “Marine”.

## Conversion formulas

For sulfur free diesel fuel (10 ppm sulfur) corresponding to EN 590 with a density of  $\rho = 830 \text{ kg/m}^3$  (15° C), the following applies approximately:

Conversion of  $\text{g/m}_n^3$  (5 %  $\text{O}_2$ ) to  $\text{g/kWh}$ :

$$EP_i = EA_i \cdot b_{\text{eff}} \cdot \frac{m_N^3}{73\text{g}} \qquad EA_i = EP_i \cdot \frac{73\text{g}}{m_N^3 \cdot b_{\text{eff}}}$$

Conversion with differing residual oxygen content (as per "TA Luft"):

$$EA_i = EX_i \cdot \frac{21-5}{21-X}$$

Conversion of ppm to  $\text{g/kWh}$ :

$$EP_i = EV_{i,d} \cdot \frac{M_i}{M_{\text{Exh,d}}} \cdot \frac{\dot{m}_{\text{Exh,d}}}{P_{\text{eff}}} = EV_{i,w} \cdot \frac{M_i}{M_{\text{Exh,w}}} \cdot \frac{\dot{m}_{\text{Exh,w}}}{P_{\text{eff}}}$$

$EP_i$  Pollutant mass, i, referenced to  $P_{\text{eff}}$  ( $\text{g/kWh}$ )

$EA_i$  Pollutant mass, i, referenced to exhaust volumes based on dry exhaust with 5 % residual oxygen under standardized conditions ( $\text{g/m}_n^3$ )

$EX_i$  Pollutant mass, i, referenced to exhaust volumes based on dry exhaust with X % residual oxygen under standardized conditions ( $\text{g/m}_n^3$ )

$EV_i$  Exhaust emission value of components, i, as volume share (ppm)

$M_i$  Mol mass of the components, i, ( $\text{kg/kmol}$ )

$M_{\text{Exh}}$  Mol mass of the exhaust ( $\text{kg/kmol}$ )

$\dot{m}_{\text{Exh}}$  Exhaust mass flow ( $\text{kg/h}$ )

$P_{\text{eff}}$  Power output (kW)

$b_{\text{eff}}$  Specific fuel consumption ( $\text{g/kWh}$ )

Index d: dry

Index w: wet

Component	Mol mass kg/kmol	Remarks
<b>NO<sub>2</sub></b>	46.006	NO <sub>x</sub> treated as NO <sub>2</sub>
<b>CO</b>	28.0104	
<b>HC</b>	13.876	HC 1
<b>SO<sub>2</sub></b>	64.061	
<b>Exhaust dry</b>	30.21 / 29.84	5 % O <sub>2</sub> / 9.6 % O <sub>2</sub>
<b>Exhaust wet</b>	28.84 / 28.82	5 % O <sub>2</sub> / 9.6 % O <sub>2</sub>

- At 5 % residual oxygen (corresponding to an excess air ratio of 1.3 : 1) and  $b_{eff} = 210$  g/kWh, the following applies approximately:

$$\frac{\dot{m}_{Exh, d}}{P_{eff}} = 3873 \text{ g/kWh} \qquad \frac{\dot{m}_{Exh, w}}{P_{eff}} = 4160 \text{ g/kWh}$$

- 1000 ppm  $NO_x$ , measured wet, corresponds to 2310 mg/ $m_n^3$ , d, 5 % (6.60 g/kWh)
  - 100 ppm HC, measured wet, corresponds to 70 mg/ $m_n^3$ , d, 5 % (0.20 g/kWh)
  - 100 ppm CO, measured dry, corresponds to 125 mg/ $m_n^3$ , d, 5 % (0.36 g/kWh)
- At an excess air ratio of 1.8 : 1 (residual oxygen content corresponding to 9.6 %) and  $b_{eff} = 210$  g/kWh the following applies approximately:

$$\frac{\dot{m}_{Exh, d}}{P_{eff}} = 5400 \text{ g/kWh} \qquad \frac{\dot{m}_{Exh, w}}{P_{eff}} = 5710 \text{ g/kWh}$$

- 1000 ppm  $NO_x$ , measured wet, corresponds to 9.10 g/kWh (3150 mg/ $m_n^3$ , d, 5 %)
- 100 ppm HC, measured wet, corresponds to 0.27 g/kWh (95 mg/ $m_n^3$ , d, 5 %)
- 100 ppm CO, measured dry, corresponds to 0.51 g/kWh (176 mg/mm $m_n^3$ , d, 5 %)

### Units:

Energy	1 J	= 1 Nm	= 1 Ws	= 1 VAs
	1 Wh	= 3.6 kJ		
	1 kWh	= 3.6 MJ		
Power	1 W	= 1 VA	= 1 J/s	= 1 Nm/s
Force	1 N	= 1 kgm/s <sup>2</sup>		
Pressure	1 Pa	= 1 N/m <sup>2</sup>		
	1 bar	= 10 <sup>5</sup> Pa		

### Conversion of non-SI units:

#### Length

Inch	1 in	= 25.4 mm	
Foot	1 ft	= 304.8 mm	= 12 in
Yard	1 yd	= 914.4 mm	= 3 ft
Statute mile	1 mi	= 1609.34 m	= 1760 yd
Nautical mile	1 nm	= 1852 m	

## 60 CONVERSION FORMULAS

### Surface

Square inch            1 sq in            = 645.16 mm<sup>2</sup>

### Volume

Cubic inch            1 cu in            = 0.016387 Liter

Gallon (US)           1 gal (US)        = 3.78541 Liter

Gallon (UK)           1 gal (UK)        = 4.54609 Liter

Liquid barrel (US)   1 liq bbl          = 119.24 Liter

Barrel Petroleum     1 bbl              = 158.99 Liter

### Mass

Grain                  1 gr                = 64.7989 mg

Ounce                 1 oz                = 28.3495 g

Pound mass           1 lbm              = 0.45359 kg    = 16 oz            = 7000 gr

Hundredweight (US) 1 cwt (US)       = 45.3592 kg    = 1 short cwt    = 100 lbm

Hundredweight (UK) 1 cwt (UK)       = 50.8023 kg    = 1 long cwt     = 112 lbm

Ton (US)             1 ton (US)        = 907.185 kg    = 1 short ton     = 2000 lbm

Ton (UK)             1 ton (UK)        = 1016.05 kg    = 1 long ton      = 2240 lbm

### Force

Pound force           1 lbf               = 4.44822 N

### Pressure

Atmosphere           1 atm              = 1.01325 bar

Water column         1 mm WS          = 9.80665 Pa

Mercury column      1 mm Hg          = 133.322 Pa      = 1 Torr

Psi                     1 lbf / in<sup>2</sup>        = 6894.76 Pa pound per square inch

### Energy

Calorie                1 kcal             = 4186.8 J

Foot pound-force     1 ft lbf            = 1.35582 J

British thermal unit 1 Btu              = 1055.06 J

Mineral coal unit    1 kg SKE          = 29.3076 MJ      = 8.141 kWh

Oil equivalent        1 kg OE            = 41.868 MJ        = 11.63 kWh

### Power

Horsepower (metric) 1 PS                = 735.499 W

Horsepower (US)    1 bhp              = 745.70 W        = 550 ft • lbf/s

### Temperature

T (K)                  = t (°C) + 273.15

t (°C)                 = 5/9 • (t(°F) – 32)



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