

EXHAUST GAS EMISSIONS

EMISSIONS

Across the entire globe, awareness of effects of pollution, to preserve the present natural condition of the Earth and reserves is on the rise. This awareness has initiated through the Chemical industries and automotive industries. Most of the major industrial areas of the world have been experiencing serious motor vehicle pollution problems. The awareness has led to planned actions to reduce these emissions, resulting in formulation of norms for limiting the amount of pollutants from the Vehicles.

During the combustion process of a diesel engine, chemical energy is converted into mechanical energy at high temperatures and under high pressure. A variety of combustion products are formed when diesel fuel is burnt. These are typically carbon monoxide, hydrocarbons, nitrogen oxides and fine particles. Where leaded fuels are used lead is also a major pollutant.

Carbon monoxide is formed at the intermediate combustion stage because of air deficiency, which result in incomplete oxidisation. Carbon monoxide is a tasteless, odorless and colorless gas produced through the incomplete combustion of carbon based fuels. Exposure to elevated levels of CO affect visual perception, work capacity, manual dexterity, learning ability. The health threat from CO is particularly more serious for people suffering from heart diseases.

Hydrocarbons are elements of unburned fuel, which have formed because of a low combustion temperature and a poor fuel to air mixture. They give diesel exhaust its characteristic smell.

Nitrous oxides are formed by a reaction between the N and O in the air at high temperatures. Nox emissions produce a wide variety of health and welfare effects. It can irritate lungs and reduce resistance to respiratory infection (influenza). It can affect ecosystem leading to acid rains.

Particulate matter consists of a core of carbon (<10 μ m) and comes from the fuel and the lubricating oil. Poisonous hydrocarbons condense on the surface of the particles. These are mostly aldehydes with a powerful odor. These are carcinogenic and are harmful to humans. Particulate matter is a general term covering solid particles and liquid droplets in the air. It includes dirt, dust, soot, and smoke. The health impact mainly includes breathing and respiratory symptoms.

Lead, gets deposited on soil and water, reaching humans through food and drinking water. Young children are mainly susceptible for lead pollution. It affects IQ, sensory motor functions, and even blood pressure with small exposures.

MAJOR REGULATORY PROGRAMS WORLDWIDE

Standards for permissible levels of emissions are always based on realistic assessment of costs and benefits, keeping in view the technical and administrative feasibilities. There are three major regulatory programs around the world, the United

States, the European Union and Japan. Each has unique test procedures for different vehicle categories, as well as different emission standards. Other countries have mainly adopted these norms with some combinations and a schedule for implementation to suit their conditions.

KOEL ENGINES STATUS

The first two important points covered in KOEL's environmental Policy are complying with all applicable environmental regulations and to make company products Eco friendly.

KOEL has always made engines suitable for different OEMs to suit their applications and end use. As a result one KOEL engine model gets exposed to a number of different end uses from off-highway use in construction line to stationary use in PG market. Engine emission testing facility is available at ARAI. KOEL has tested all production engines to meet the current applicable emission norms. The testing has to be done for all applications, as each OEMs engine adaptation will vary and will involve intake air restrictions, back pressure on vehicle.

KOEL products are mainly categorised in three sectors. Off-highway / construction equipment's (what we call as Industrial application), Tractor and Power generation. The exhaust emission rules are applicable for engines used for Off Highway / Construction Equipment and engines used for Agricultural Tractors. The details are as follows—

- **Off-Highway/Construction Equipment**

Ministry Of Surface Transport (MOST) have issued Emission norms for Off-Highway/Construction Equipment. Examples of Equipment covered are-- Road Construction Machinery, Mobile Cranes, Wheeled Loaders/Excavators, Fork lift trucks etc. i.e. those equipment which are non-automotive, but can travel on public roads. These Norms were formulated by A.R.A.I., in consultation with engine manufacturers and Association of Earth Moving Equipment Manufacturers. KOEL had also participated in this process. These Norms are published in the Central Motor Vehicle Rules (CMVR)

Engine models covered under these norms (since they are being used for subject applications) are—

RB44, RB44TC, HA494, HA694, 4R1040

All these are tested by A.R.A.I. for the subject Norms and Type Approval certificates are received.

- **Agricultural Tractor Engines**

Exhaust Emission Norms for Agricultural Tractors are formulated by Tractor Manufacturers Association (TMA). These are accepted by MOST, and will be enforced from July 1999.

Following engine models, which we supply to Tractor manufacturers, are covered under these norms--

RV2, RV3, RB33, RB30, 4R1040, 3R1040 (which will be supplied in future.) All these engines are tested by A.R.A.I. and Type Approval certificates are received.

- **Engines for Diesel Gensets**

We also supply engines for Diesel Gensets. As of now, Govt. have not stipulated Norms for Exhaust emissions from D.G. sets, except for large capacity sets (above two MW). For smaller sets, a draft proposal for such norms is forwarded by IDEMA (Indian Diesel Engines Manufacturers Association) to Central Pollution Control Board (CPCB). This proposal was initiated by KOEL, as a member of IDEMA.

CPCB, however have issued Guidelines for control of D.G. sets noise (applicable for sets above 5 kVA). Genset OEMs have to take necessary actions, like providing suitable enclosure for the set. We, as engine manufacturer, give necessary guidance to Genset manufacturers.

TECHNOLOGY

The engines have to undergo major design change, particularly for the combustion improvement to meet the exhaust emission norms. This means change in port layouts, nozzle position, fuel injection timing and Fuel quality. Unlike European markets, Indian fuels are of much lower grade, and with a lot of variation in quality to enable one engine model to qualify for the emission levels. The quality of components, which result in internal friction in working also, has a great impact on the emission levels. Present day engines are manufactured not only with closer dimensional tolerances, but also with matching components, whereby the effective dimensional variation is reduced to one third. Super finishing operations are applied to almost all components, from cam profiles to VR Toes. Such manufacturing improvements, along with good quality fuel, higher injection pressure, zero sac nozzles, high compression ratio and retarded injection timing coupled with low engine friction enable satisfying stringent emission norms like *EURO-1* and *EURO off-stage 1*.

To satisfy *EURO-2* and *EURO off-stage-2* turbocharging the engine seems to be the solution. *EURO-3* and beyond are not yet firmed up. To achieve the stringent standards the technology of fuel injection equipment is under development in India.

TESTING PROCEDURE AND STANDARD

For engines intended for off-road applications, emissions measurements are based on the *ISO 8178-C1 eight-mode* test cycle based on the cycle in *ECE Regulation 96*. The engine is run at different loads, speeds and the emissions are measured, and corrected with weight factors in each mode.

Constant speed generating set engines are tested according to *ISO 8178 D2 test cycle*. The test comprises of a series of five steps, each gauged at a specific load which must be maintained for a given period. In addition, every measured value is given weighting prior to the final total of emissions being determined.

EXHAUST GAS EMISSION LIMITS

Exhaust limits and implementation dates are set by national laws and regulations based on defined test cycles and procedures. KOEL is working on new products not only to meet present Indian national laws, but also to meet relevant international laws like EURO or US TIER norms. This has become important in view of competition threat coming

from western engine manufacturers and growing export of Indian equipment manufacturers to Europe and US.

Typical norms of our interest are

- *CMVR (Central Motor Vehicle Rules)* norms are used in India for both on and off road diesel vehicles.
- *EURO1* and *EURO 2* norms are applicable for on-road vehicles in European countries. These are not applicable for KOEL products.
- *Euro off-stage 1(COM1)* and *Euro off-stage 2(COM2)* norms applicable in the countries of *European Union* for Off-road vehicles. These form a good Benchmark for comparing KOEL products.
- *US TIER1, TIER2* and *TIER3* norms are relevant to America for on and off-road diesel engine. A number of Indian tractor manufacturers are seeking export of their tractors to US. Many leading tractor manufacturers today shown interest in our indigenously developed and 4R1040 models this have qualified for US Tier1 norms.

KOEL ENGINES PERFORMANCE

Table 1 gives the KOEL Engines emission test details along with remarks on how do they compare with relevant applicable norms.

Engine	Rating	Emission limits, g/kW.h				Remark
		CO	HC	NOx	PM	
4R1040NA	76hp@2200 rpm	4.19	1.04	8.92	0.78	Meeting Euro off-stage1 & CMVR emission limits
	77hp@2300 rpm	3.86	0.99	6.76	0.70	Meeting Euro off-stage1, Euro off-stage2 except PM and CMVR emission limits, however EURO1 needs slight improvement required in Particulate
	56hp @ 1500 rpm	2.36	1.15	11.23	-	Power Generation, D2 cycle
						Suitable for US Tier1 std., 8 mode cycle
						Suitable for EURO1 std., 13 mode cycle
4R1040 T	100hp @ 2200 rpm	1.36	0.72	6.81	0.55	Meeting Euro off-stage1, Euro off-stage2 except PM, CMVR and EURO1 limits
4R1040TG	90hp @ 1500 rpm	0.94	0.71	9.66	--	For Power generation
3R1040	56hp @ 2250 rpm	4.40	0.80	11.1	-	Meeting CMVR norms
	50hp @ 2000 rpm	3.80	0.80	10.9	-	Meeting CMVR norms
	42hp @ 1500 rpm	1.64	0.86	10.44	-	Power Generation, D2 cycle
						Suitable for US Tier1
RV3	33.2hp @ 2000 rpm	4.04	3.36	10.20	-	Meeting CMVR norms
RB33	46hp @ 2000 rpm	3.73	2.54	8.20	-	Meeting CMVR norms
RB44 NA	69hp @ 2200 rpm	7.92	1.24	7.38	-	Meeting CMVR norms
RB44T	90hp @ 2200 rpm	3.74	1.65	7.54	-	Meeting CMVR norms
HA494NA	63hp @ 2500 rpm	4.56	1.32	10.64	-	Meeting CMVR norms
HA694NA	111.5hp @ 2500 rpm	11.31	1.58	15.87	-	Meeting CMVR norms

OFF-ROAD VEHICLES EMISSION NORMS

CMVR norms for off-road vehicles

Implementation date	Emission limits, g/kW.h			
	CO	HC	NOx	PM
July 1, 1999 – Tractor Existing for construction Machinery	14.0	3.5	18.0	-

CMVR norms for heavy duty engines

Implementation date	Emission limits, g/kW.h			
	CO	HC	NOx	PM
1 April 2000	4.5/4.9*	1.1/1.23*	8.0/9.0*	0.36/0.40*

*Note: These data apply to Type Approval and *Conformity of Production test*

Euro off-stage 1(COM1) Emission limits

Engine power kW	Emission limits, g/kW-h				Implementation	
	CO	HC	NOx	PM	NTA	ANR
37≤kW<75	6.50	1.30	9.20	0.85	1. July 98	1. April 99
75≤kW<130	5.00	1.30	9.20	0.70	1. July 98	1. January 99
130≤kW≤560	5.00	1.30	9.20	0.54	1. July 98	1. January 99

*Notes: NTA – New type approval, ANR – All new registrations, selling and use
The above given standards for stage 1 are engine- out emissions. They have to be met without exhaust gas treatment*

Euro off-stage 2 (COM2) Emission limits

Engine power kW	Emission limits, g/kW-h				Implementation	
	CO	HC	NOx	PM	NTA	ANR
18≤kW<37	5.50	1.50	8.00	0.80	1. Jan 2000	1. Jan 2001
37≤kW<75	5.00	1.30	7.00	0.40	1. Jan 2003	1. Jan 2004
75≤kW≤130	5.00	1.00	6.00	0.30	1. Jan 2002	1. Jan 2003
130≤kW≤560	3.50	1.00	6.00	0.20	1. Jan 2001	1. April 2002

Note: New engines, built before the given NTA dates for Stage 1 and 2, may be sold for a period of 2 years after the given ANR implementation after permission from the certification authorities. Final adoption of the new regulations is expected after the second reading in the European Parliament.

EPA Non-road diesel engine emission standards

Engine power	Tier	Model year	Emission limits, g/kW.h				
			CO	HC	NOx	NMHC+ NOx	PM
19≤kW<37	Tier1	1999	5.50	-	-	9.5	0.80
	Tier2	2004	5.50	-	-	7.5	0.60
37≤kW<75	Tier1	1998	-	-	9.20	-	-
	Tier2	2004	5.00	-	-	7.5	0.40
	Tier3	2008	5.00	-	-	4.7	-*
75≤kW<130	Tier1	1997	-	-	9.20	-	-
	Tier2	2003	5.00	-	-	6.6	0.30
	Tier3	2007	5.00	-	-	4.0	-*

Note: (1)* - PM for Tier3 to be proposed and adopted in the 2001 review

(2) Engines of all sizes must also meet smoke standards of 20/15/50 % opacity at acceleration/lug/peak modes respectively. For measuring opacity

(a) 50 to 100 hp should be tested with 1.5" exhaust pipe

(b) 100 to 200 hp should be tested with 3.0" exhaust pipe

(c) 200 to 300 hp should be tested with 4.0" exhaust pipe

(d) 300 to 500 hp should be tested with 5.0" exhaust pipe

(e) Engine rated over 500 hp should be tested with 6.0" exhaust pipe

Fig 1 compares the some of KOEL engines with US and EURO norms.

POWER GENERATION ENGINE EMISSION NORMS

IDEMA proposal to Central Pollution Control Board (CPCB) for PG Engines

Model	Emission limits, g/kWh at 100% load, D2 cycle			
	CO	HC	NOx	Smoke
NA Engine	< 14	<3.5	< 18	< 3.5 Bosch
Turbocharged Engine				< 2.5 Bosch

Fig 2 compares the some of KOEL engines with the norms

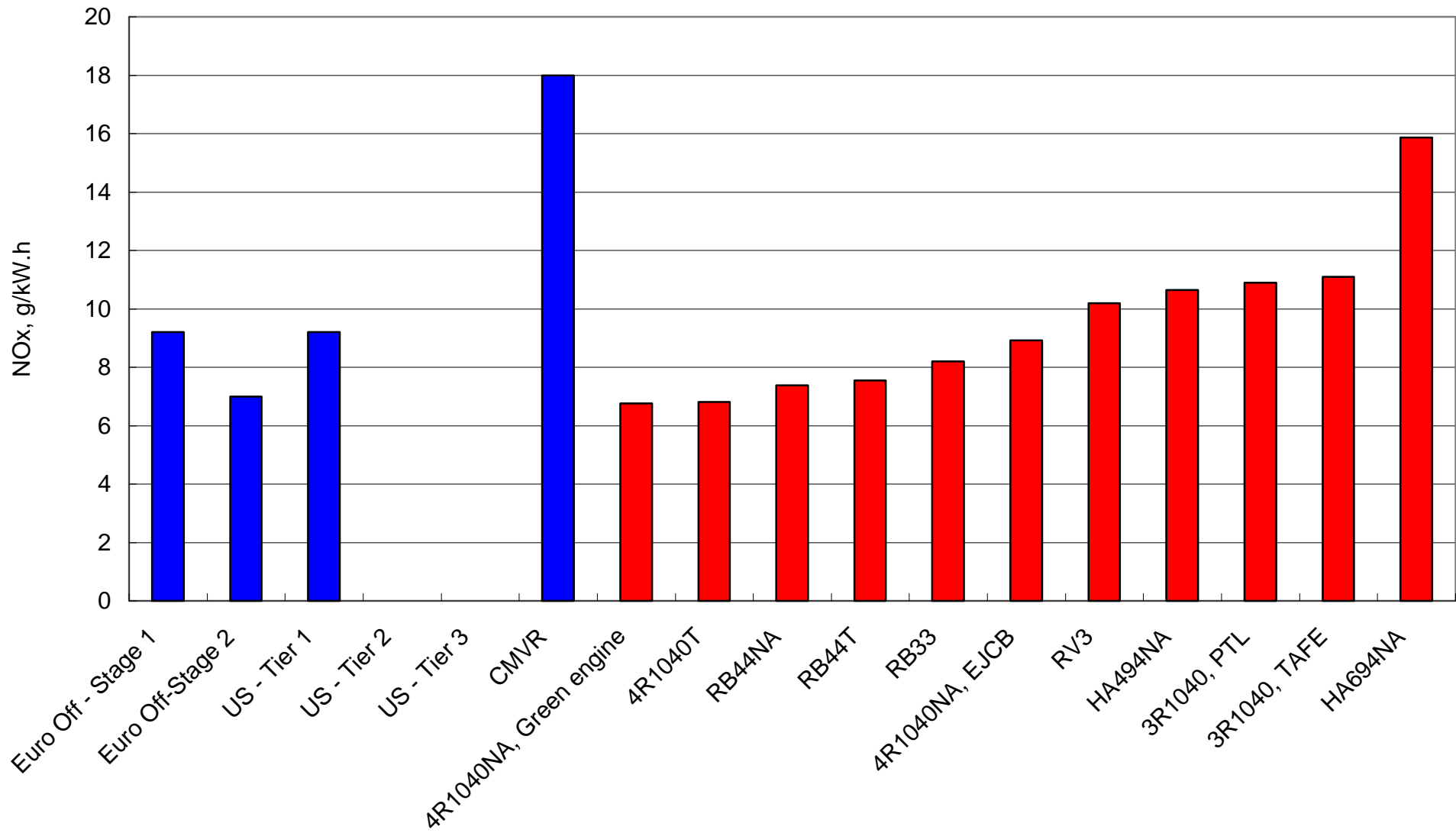
Germany

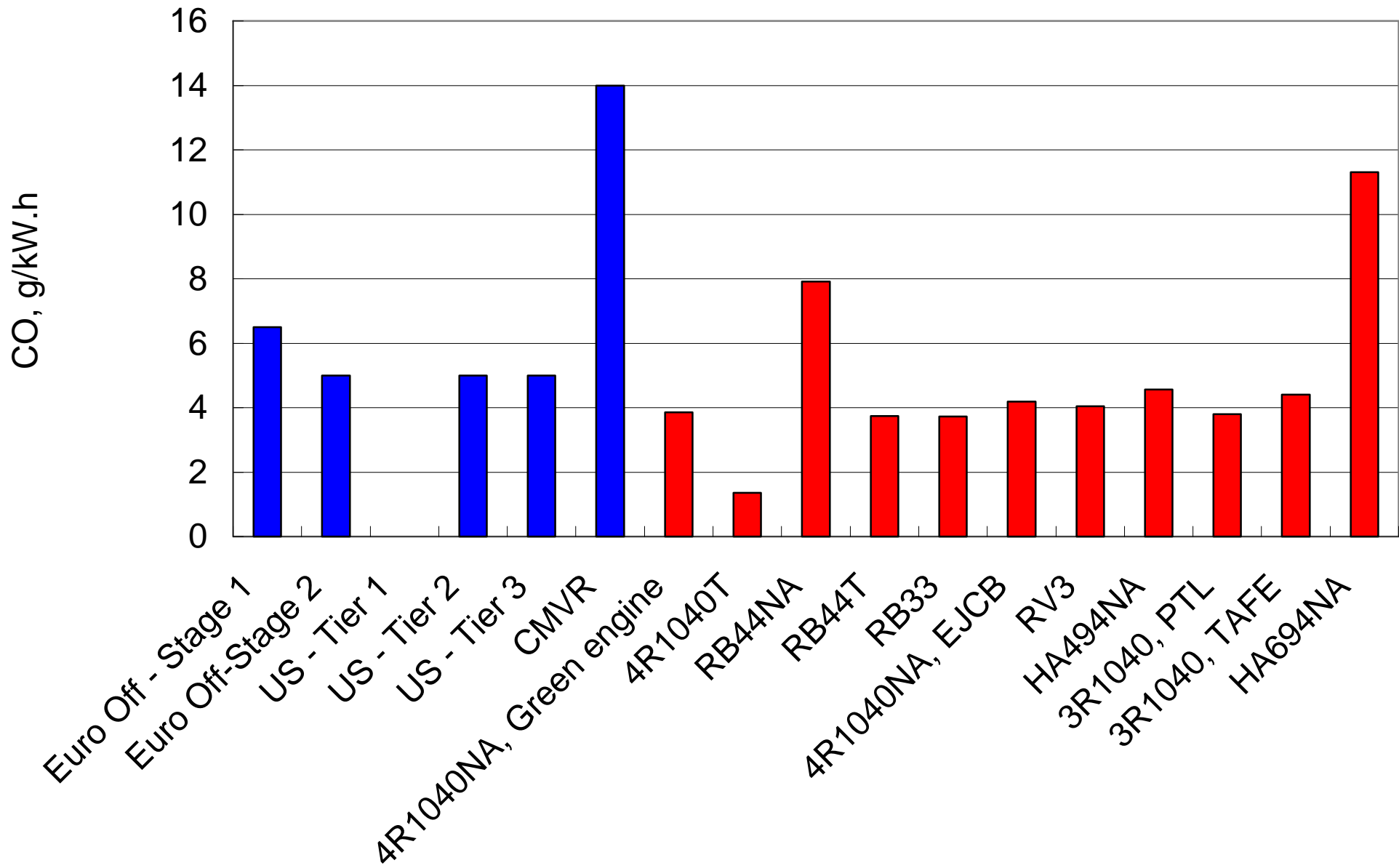
In the absence of stationary power emission regulation in Europe, the German power plant emission standard TA-Luft (Technische Anleitung zur Reinhalt der Luft) is used as a national regulation in Europe. Emissions are measured at steady state operation at max. 5% exhaust oxygen content. This standard is applied in Germany, Austria, Luxembourg, Switzerland and the Netherlands and is gaining acceptance in other European countries.

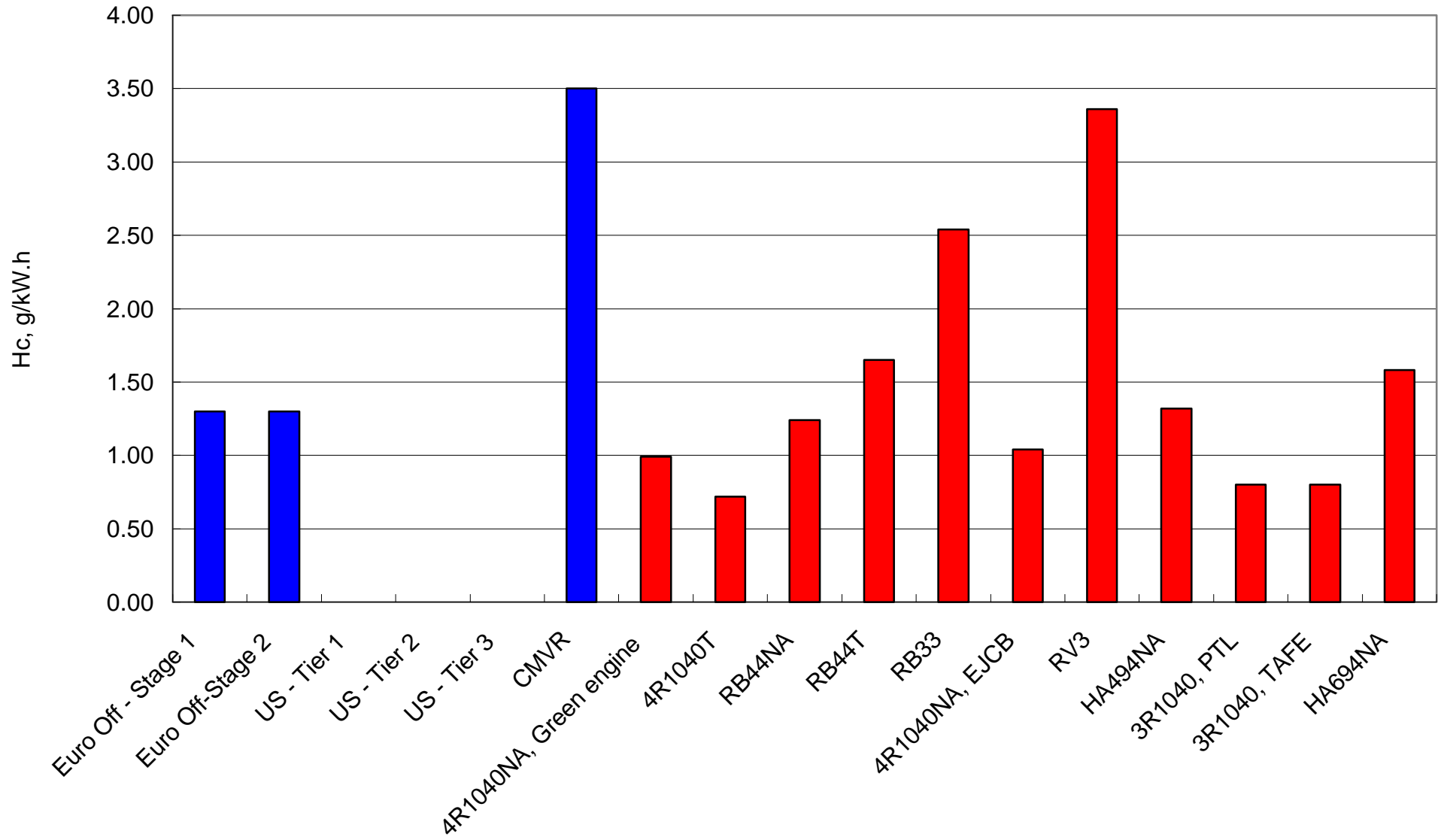
TA-Luft emission regulation at full load

Model	Emission limits, g/Nm ³ at 100% load			
	CO	HC	NOx	PM
Stationary diesel engines < 3 MW	0.65	0.15	4.0	0.13

Figure 1 Emissions of off-road diesel vehicles, Test cycle - ECE R 96, 8-mode cycle







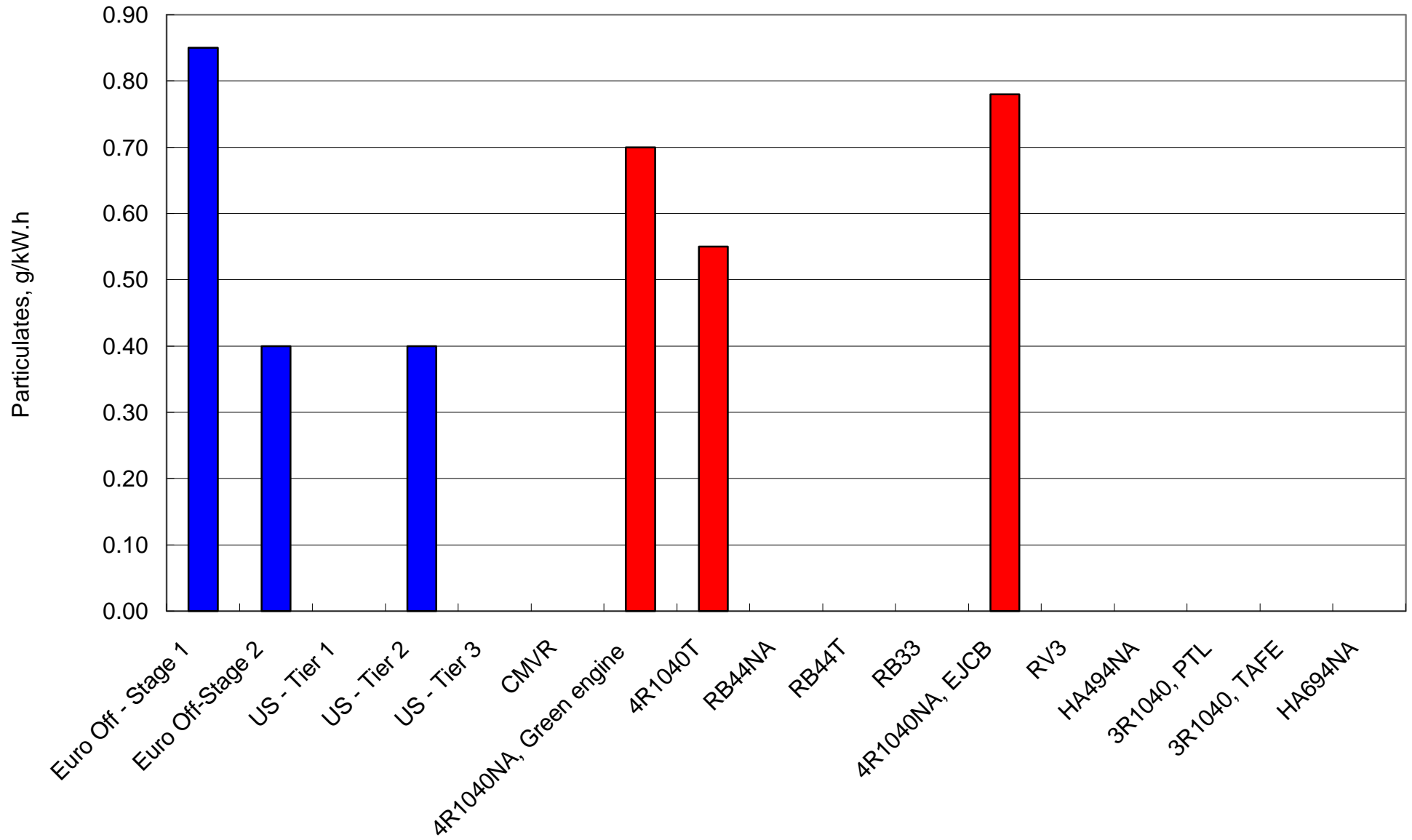


Figure 2 Comparison of Power generation engine emissions with IDEMA proposed norms, D2 cycle

