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NONROAD VEHICLE EMISSIONS REQUIREMENTS AROUND THE WORLD

A 2005 STATUS REPORT

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1. Introduction and Overview

In every corner of the world, for every type of road vehicle, there is a clear trend toward lower and lower emissions levels. Over the next decade, this pattern will move toward similar controls on off road vehicles and fuels and will finally address the last holdouts – aircraft and marine vessels. Driving these trends are several factors:

- Continued growth in the production and use of vehicles (especially in China and other parts of Asia) and their concentration in urban areas where pollution levels remain unacceptably high,
- The growing accumulation of health studies which show adverse impacts at lower and lower levels and in the case of PM at virtually any level,
- Advances in vehicle technology and clean fuels which are making it possible to achieve lower and lower levels at reasonable costs.

On the regulatory front, vehicle emissions standards and fuel requirements continue to be tightened in every corner of the globe. Major developments in the last few years include the following:

- The European Union has mandated the widespread availability of near zero sulfur levels in both gasoline and diesel fuel by 2005 and its universal use by 2009. It is in the process of implementing the already adopted Euro 4 standards for light duty vehicles and the Euro 4 and 5 standards for heavy duty vehicles. Finally it is already far along in developing so called Euro 5 standards for light duty vehicles and Euro 6 standards for heavy duty engines with proposals expected from the Commission during 2005. Whatever Euro 5 standards are adopted will likely go into effect earlier than the mandated date in many countries since several Member States will encourage early introduction through tax incentives. So called pseudo-Euro 5 PM standards have been adopted by the Commission to provide a common EU-wide basis for these tax schemes.

- In the US, the Tier 2 and LEV 2 standards are gradually being phased in across the nation and California, respectively. The number of states opting in to the California requirements continues to grow with New Jersey and Rhode Island the most recent additions. In spite of a series of Court challenges and political battles, the 2007-10 heavy duty engine requirements and low sulfur fuel standards remain on track and are expected to go into effect on schedule. EPA has also adopted very stringent requirements for off road diesel engines and fuels which will require the same degree of controls for most categories as the on road standards. This will be discussed in more detail below.

- The California Air Resources Board (ARB) has voted to make significant modifications and upgrades to the state's zero emission vehicles (ZEV) regulations. The most important modification creates a new ZEV pathway, giving manufacturers a choice of two options for meeting their ZEV requirements.

- In other North American developments, Canada has adopted virtually identical standards for vehicles and fuels as the US on the same approximate schedule. Mexico has phased in Tier 1 light duty vehicle standards and is in discussion with industry regarding Tier 2. A key determinant of the outcome from these discussions as well as the prospects for

significant tightening of the heavy duty requirements is whether fuel quality will be improved. PEMEX has developed a detailed plan to phase in fuels meeting US sulfur standards in almost the same timeframe as in the US and it is undergoing serious discussion at this time.

- Australia has recently harmonized its requirements with the EU and will largely be on a par with the EU by the end of the decade.

- China has already adopted Euro 2 standards for both light and heavy vehicles and will likely introduce Euro 3 standards in Beijing and Shanghai as early as next year. Euro 3 and Euro 4 standards have been drafted with the ultimate schedule for national introduction still under discussion.

- Thailand has decided to proceed to Euro 4 standards by the end of the decade. Agreement has been reached with the fuels industry to reduce sulfur levels in both diesel and gasoline to a maximum of 50 ppm by 2010 and discussions are ongoing regarding a possible reduction to 10 ppm maximum.

- South Korea will introduce ULEV standards for gasoline fuelled cars and Euro 4 standards for diesel cars by 2006. Maximum sulfur levels for gasoline and diesel will be reduced to a maximum of 50 ppm and 30 ppm, respectively, in the same timeframe. They intend to tighten emissions standards by an additional 50% by 2010.

- Taiwan will reduce the maximum sulfur levels in both gasoline and diesel to 50 ppm by 2007. At the same time, they will introduce Tier 2 light duty vehicle and 2004 US heavy duty vehicle standards; Euro 4 standards for both light and heavy duty diesels will be deemed equivalent.

- The Japanese Ministry of the Environment has begun drafting new regulations on tailpipe emissions that would require reducing nitrogen oxide emissions by as much as 90 percent by fiscal 2010 from the current levels. The Automobile Emission Gas Expert Committee, which advises the Central Environment Council, began drafting a new diesel vehicle emission standard that would significantly reduce NOx and particulate matter. Proposals are under final review.

- The New Zealand government, the last OECD country without emissions standards for new vehicles, has adopted a new rule that applies to new and used gasoline and diesel light vehicles that enter New Zealand from Jan. 1, 2004. Heavy vehicles must comply with the rule by Jan. 1, 2005. The rule requires vehicles imported into New Zealand to be built to the version of the emissions standard that was current in Australia, the United States, Japan, or Europe at the date the vehicle was manufactured.

- India has adopted Euro 2 standards for 2005 and Euro 3 by 2010. The major cities will be on a faster schedule, moving to Euro 4 by 2010. Currently, 11 cities are required to meet Euro II norms: New Delhi, Mumbai (Bombay), Kolkata (Calcutta), Bangalore, Chennai, Hyderabad, Ahmedabad, Pune, Surat, Kanpur, and Agra. Under the new policy, vehicles in the 11 cities now operating under Euro II standards will be required to meet Euro III norms by April 1, 2005, and Euro IV standards by 2010.

- Brazil will phase in US Tier 1 standards during the period from 2005-2007 jumping to

Tier 2 in 2009. Diesel Cars will continue to be banned throughout the country. With regard to heavy duty trucks and buses, Euro 3 will be phased in during 2004-2006 and Euro 4 in 2009. Fuel quality remains under discussion with 50 ppm sulphur likely to be required in the major cities by 2009 or 2010.

2. Non Road Vehicles and Engines: The Remaining Challenge

As the road vehicle sector has been cleaned up, the non road sector increasingly stands out as the mobile source with the weakest limits. One result is that it is becoming an increasingly important component of the overall emissions inventory.

For example, in the United States, baseline emission inventory estimates for the year 2000 are summarized in Table 1. This table shows the relative contributions of the different mobile-source categories to the overall national mobile-source inventory. Of the total emissions from mobile sources, large non road diesel engines contribute about 4 percent, 20 percent, 2 percent, and 36 percent of HC, NOx, CO, and PM emissions, respectively, in the year 2000.

Emission projections for 2020 for the nonroad diesel engines and vehicles show that emissions from these categories are expected to increase over time without further control. The projections for 2020 are summarized in Table 2 and indicate that nonroad vehicles will emit more NOx and PM than on road vehicles with non-road diesel vehicles the dominant contributor. Nonroad diesels are expected to contribute 2 percent, 29 percent, 2 percent, and 41 percent of HC, NOx, CO, and PM emissions in the year 2020. Population growth and the effects of other regulatory control programs are factored into these projections.

Table 1 Annual Emission Levels for Mobile-Source Categories in 2000

(thousand short tons)

Category	NOx		HC		CO		PM	
	tons	percent of mobile source	Tons	percent of mobile source	tons	percent of mobile source	tons	percent of mobile source
Nonroad Large SI > 19 kW	306	2%	247	3%	2,294	3%	1.6	0.2%
Recreational SI	13.0	0.10%	737	10%	2,572	3%	5.7	0.9%
Recreation Marine CI	24	0.2%	1	0%	4	0%	1	0%
Highway Motorcycles	8	0%	84	1%	329	0%	0.4	0.1%
Marine SI Evap	0	0.0%	89	1%	0	0%	0	0%
Marine SI Exhaust	32	0.2%	708	9%	2,144	3%	38	5%
Nonroad SI < 19 kW	106	0.8%	1,460	19%	18,359	24%	50	7%
Nonroad CI	2,625	20%	316	4%	1,217	2%	253	36%
Commercial Marine CI	977	7%	30	0%	129	0.2%	41	6%
Locomotive	1,192	9%	47	1%	119	0.2%	30	4%
Total Nonroad	5,275	39%	3,635	48%	26,838	35%	420	60%
Total Highway	7,981	59%	3,811	50%	49,811	64%	240	36%
Aircraft	178	1%	183	2%	1,017	1%	39	6%

Category	NOx		HC		CO		PM	
	tons	percent of mobile source	Tons	percent of mobile source	tons	percent of mobile source	tons	percent of mobile source
Total Mobile Sources	13,434	100%	7,629	100%	77,666	100%	660	100%
Total Man-Made Sources	24,538	--	18,575	--	99,745	--	3,095	--
Mobile Source percent of Total Man-Made Sources	55%	--	41%	--	78%	--	23%	–

Table 2 Annual Emission Levels for Mobile-Source Categories in 2020

(thousand short tons)

Category	NOx		HC		CO		PM	
	tons	percent of mobile source	tons	percent of mobile source	tons	percent of mobile source	tons	percent of mobile source
Nonroad Large SI >19 kW	486	8%	348	6%	2,991	3%	2.4	0.4%
Recreational SI	27.0	0.40%	1,706	28%	5,407	3%	7.5	1.2%
Recreation Marine CI	39	0.6%	1	0%	6	0%	2	0%
Highway Motorcycles	14	0%	144	2%	569	1%	0.8	0.1%
Marine SI Evap	0	0.0%	102	1%	0	0%	0	0%
Marine SI Exhaust	58	0.9%	284	5%	1,985	2%	28	4%
Nonroad SI < 19 kW	106	1.7%	986	16%	27,352	31%	77	12%
Nonroad CI	1,791	29%	142	2%	1,462	2%	261	41%
Commercial Marine CI	819	13%	35	1%	160	0.2%	46	7%
Locomotive	611	10%	35	1%	119	0.1%	21	3%
Total Nonroad	3,937	63%	3,639	59%	39,482	44%	444	70%
Total Highway	2,050	33%	2,278	37%	48,903	54%	145	23%
Aircraft	232	4%	238	4%	1,387	2%	43	7%
Total Mobile Sources	6,219	100%	6,155	100%	89,772	100%	632	100%
Total Man-Made Sources	16,195	--	16,215	--	113,440	--	3,016	--
Mobile Source percent of Total Man-Made Sources	38%	--	38%	--	79%	--	21%	–

Similarly in Japan nonroad vehicles are estimated to be responsible for approximately 15% of the mobile sources PM and 32% of the NOx in the year 2000. This fraction is expected to grow in future years as the onroad vehicle sector faces more stringent controls.

In view of the serious public health and environmental concerns associated with ozone, particulate and NO2, and the increasingly dominant contribution that nonroad vehicles and engines make to emissions that cause these problems, it is critically important that these sources be controlled to the same degree as on road diesel vehicles. Starting during the mid to late 1990's, the US, EU and Japan initiated control efforts. In stark contrast with the on road efforts in each of these regions, there was a clear effort to coordinate and harmonize these efforts right from the beginning. As a result, it appears likely that at the conclusion of the process, globally harmonized non road requirements will largely be in place.

3. The US Program

Section 213 (a)(3) of the US Clean Air Act requires EPA to establish nonroad engine standards that provide for the "greatest degree of emission reduction achievable through the application of technology which the Administrator determines will be available for the engines or vehicles to which such standards apply, giving appropriate consideration to the cost of applying such technology within the period of time available to manufacturers and to noise, energy, and safety factors associated with the application of such technology". Both the US EPA and the California Air Resources Board have proceeded to introduce controls on a variety of non road sources as summarized in the tables below.

A. US Standards

Table 3 US EPA Initial Standards For Large Nonroad CI Engines

Net Power (kW)	HC (g/kW-hr)	CO (g/kW-hr)	NOX (g/kW-hr)	PM (g/kW-hr)	Smoke (A/L/P)	Implementation Data
<560?	1.3	11.4	9.2	0.54	20/15/50	January 1, 2000
?**130 to** ?**560**						January 1, 1996
?**75 to <130**			9.2		20/15/50	January 1, 1997
?**37 to <75**			9.2		20/15/50	January 1, 1998

Table 4 Subsequent Emission Standards For CI Non Road Engines in g/kW-hr (g/hp-hr)

Engine Power	Tier	Model Year	NMHC + NOx	CO	PM
kW<8 (hp<11)	Tier 1	2000	10.5 (7.8)	8.0 (6.0)	1.0 (0.75)
	Tier 2	2005	7.5 (5.6)	8.0 (6.0)	0.80 (0.60)
8?kW<19 (11?hp<25)	Tier 1	2000	9.5 (7.1)	6.6 (4.9)	0.80 (0.60)
	Tier 2	2005	7.5 (5.6)	6.6 (4.9)	0.80 (0.60)
19?kW<37 (25?hp<50)	Tier 1	1999	9.5 (7.1)	5.5 (4.1)	0.80 (0.60)
	Tier 2	2004	7.5 (5.6)	5.5 (4.1)	0.60 (0.45)
37?kW<75 (50?hp<100)	Tier 2	2004	7.5 (5.6)	5.0 (3.7)	0.40 (0.30)
	Tier 3	2008	4.7 (3.5)	5.0 (3.7)	—

75?kW<130 (100?hp<175)	Tier 2	2003	6.6 (4.9)	5.0 (3.7)	0.30 (0.22)
	Tier 3	2007	4.0 (3.0)	5.0 (3.7)	—
130?kW<225 (175?hp<300)	Tier 2	2003	6.6 (4.9)	3.5 (2.6)	0.20 (0.15)
	Tier 3	2006	4.0 (3.0)	3.5 (2.6)	—
225?kW<450 (300?hp<600)	Tier 2	2001	6.4 (4.8)	3.5 (2.6)	0.20 (0.15)
	Tier 3	2006	4.0 (3.0)	3.5 (2.6)	—
450?kW<560 (600?hp<750)	Tier 2	2002	6.4 (4.8)	3.5 (2.6)	0.20 (0.15)
	Tier 3	2006	4.0 (3.0)	3.5 (2.6)	—
kW?560 (hp?750)	Tier 2	2006	6.4 (4.8)	3.5 (2.6)	0.20 (0.15)

Table 5 Exhaust Emissions Standards For Locomotives

Tier & Duty Cycle	Gaseous and Particulate Emissions (g/bhp-hr)			
	HC	CO	NOx	PM
Tier 0 Line-Haul Duty Cycle	1.00	5.0	9.5	0.60
Tier 0 Switch Duty Cycle	2.10	8.0	14.0	0.72
Tier 1 Line-Haul Duty Cycle	0.55	2.2	7.4	0.45
Tier 1 Switch Duty Cycle	1.20	2.5	11.0	0.54
Tier 2 Line-Haul Duty Cycle	0.30	1.5	5.5	0.20
Tier 2 Switch Duty Cycle	0.60	2.4	8.1	0.24

Table 6 Emissions Standards for Marine Diesel Engines

Category	**Displacement (liters/cylinder)**	**Starting Date**	**NOx-HC (g/kW-hr)**	**PM (g/kW-hr)**	**CO (g/kW-hr)**
1	**Power > 37kW Disp <0.9**	**2005**	**7.5**	**0.40**	**5.0**
	0.9 to 1.2	**2004**	**7.2**	**0.30**	**5.0**
	1.2 to 2.5	**2004**	**7.2**	**0.20**	**5.0**
	2.5 to 5.0	**2007**	**7.2**	**0.20**	**5.0**
2	**5.0 to 15**	**2007**	**7.8**	**0.27**	**5.0**
	15 to 20 and Power<3300 kW	**2007**	**8.7**	**0.50**	**5.0**

	15 to 20 and Power> 3300 kW	**2007**	**9.8**	**0.50**	**5.0**
	20 to 25	**2007**	**9.8**	**0.50**	**5.0**
	25 to 30	**2007**	**11.0**	**0.50**	**5.0**

Table 7 Recreational Marine Diesel Emissions Standards

Engine Size (Liters/cylinder)	Implementation Date	HC + NOx g/kW-hr	PM g/kW-hr	CO g/kW-hr
0.5 to 0.9	**2007**	**7.5**	**0.40**	**5.0**
0.9 to 1.2	**2006**	**7.2**	**0.30**	**5.0**
1.2 to 2.5	**2006**	**7.2**	**0.20**	**5.0**
Above 2.5	**2009**	**7.2**	**0.20**	**5.0**

Table 8 Emissions Standards for Large SI Engines

Tier/Year	HC + NOx	CO
Tier 1 starting in 2004	4.0 g/kW-hr	50 g/kW-hr
Tier 2 starting in 2007	2.7 g/kW-hr	4.4 g/kW-hr

Table 9 Phase 1 Standards For Small SI Utility Engines at or below 25 hp (19 kilowatts)[1], [2]

Class	Application	Displacement	HC+NOx	HC	CO	NOx
I	nonhandheld	<225	16.1		469	
II	nonhandheld	?225	13.4		469	
III	handheld	<20		295	805	5.36
IV	handheld	? 20, <50		241	805	5.36
V	handheld	? 50		161	603	5.36

Table 10 Phase 2 HC + NOx Emission Standards for Nonhandheld Engines (in g/kW-hr)

Engine Class	Model Year 2001	Model Year 2002	Model Year 2003	Model Year 2004	Model Year 2005
Class I	25.0	25.0	25.0	25.0	25.0

[1] Applies to engines manufactured from the 1997 model year (except Class V engines which have until January 1, 1998)

[2] Applies to all SI engines at or below 25 hp, except for those used in aircraft, marine vessels, and recreational equipment.

Class II	18.0	16.6	15.0	13.6	12.1

Table 11 Phase 2 HC + NOx Emission Standards for Handheld Engines (in g/kW-hr) Showing Phase-in by Percentage of Production

Engine Class	HC + NOX Emission Standard	Model Year 2002	Model Year 2003	Model Year 2004	Model Year 2005
Class III	210	20%	40%	70%	100%
Class IV	172				
Class V	116				

When compared to Phase 1 standards, Phase 2 standards may not *appear* more stringent in all cases. This is because Phase 1 standards are "new engine" standards and Phase 2 standards are in-use standards.

Table 12 Recreational Vehicle Exhaust Emissions Standards

Vehicle	Model Year	Emissions Standards		Phase In
		HC g/kW-hr	CO g/kW-hr	
Snowmobile	2006	100	275	50%
	2007-09	100	275	100%
	2010	75	275	
	2012	75	200	
		HC+NOx g/km	CO g/km	
Off-highway Motorcycle	2006	2.0	25.0	50%
	2007 and later	2.0	25.0	100%
ATVs	2006	1.5	35.0	50%
	2007 and later	1.5	35.0	100%

B. California Standards

Table 13 Specialty Vehicle Engines (less than 25 horsepower) in California

Year	Displacement	HC and NOx	CO	PM
1995-98	<225cc	12.0 g/bhp-hr	300 g/bhp-hr	0.9 g/bhp-hr
1995-98	225cc and greater	10.0	300	0.9
1999 and later	All	3.2	100	0.25

Table 14 Specialty Vehicle Engines and Go-Carts (greater than 25 horsepower) in California

Year	Displacement	HC and NOx	CO	PM
1997 and later	all	3.2	100	0.25

Table 15 Off-Road Motorcycles and All-Terrain Vehicles in California

At a useful life of 5 years or 10,000 km

Year	Displacement	HC	CO
1997-98	greater than 90 cc	1.2 g/km *	15.0 g/km
1999 and later	all	1.2 *	15.0

***Can be applied as a corporate average**

Table 16 All-Terrain Vehicles (Engine Test Option)

At a useful life of 5 years or 10,000 km equivalent

Year	Displacement	HC and NOx	CO
1997 and later	90 - 225cc	12.0 g/bhp-hr*	300 g/bhp-hr
1999 and later	< 90 cc		
1997 and later	225cc and greater	10.0*	300

*Can be applied as a corporate average

Table 17 Golf Carts in California

Year	HC	CO	NOx	PM
1997 and later	Zero	Zero	Zero	Zero

Table 18 California Exhaust Emission Standards for Large Off-Road SI Engines

(grams per brake horsepower-hour)

Model Year	Engine Displacement	Durability Period (hours)	Hydrocarbon plus Oxides of Nitrogen	Carbon Monoxide
2002 and Subsequent	<1.0 liter	1000	9.0	410

2001 through 2003	1.0 liter or greater	N/A	3.0	37.0
2004 through 2006	1.0 liter or greater	Zero Hours and 3500 hours (as shown by deterioration factor)	3.0[1]	37.0[1]
2007 and Subsequent	1.0 liter or greater	5000 hours or 7 years	3.0	37.0

1. For 2004 through 2006 model-year engine families, in-use compliance standards shall be 4.0 g/bhp-hr Hydrocarbon plus Oxides of Nitrogen and 50 g/bhp-hr Carbon Monoxide for a durability period of 5000 hours or 7 years.

Table 19. Small Off-Road Engine Exhaust Emission Standards (≤ 19 kW), HC+NOx / CO / PM in g/kW-hr

<table>
<tr><th>Displacement Category</th><th>1995</th><th>1996</th><th>1997</th><th>1998</th><th>1999</th><th>2000</th><th>2001</th><th>2002</th><th>2003</th><th>2004</th><th>Displacement Category</th><th>2005</th><th>2006</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013+</th></tr>
<tr><td>< 20 cc</td><td colspan="5">HC: 295 / NOx: 5.36 / CO: 805</td><td colspan="5" rowspan="3">72 / 536 / 2.0[b]</td><td rowspan="2">< 50 cc</td><td colspan="9" rowspan="2">50 / 536 / 2.0[b]</td></tr>
<tr><td>≥ 20cc - < 50cc</td><td colspan="5">HC: 241 / NOx: 5.36 / CO: 805</td></tr>
<tr><td>≥ 50cc - ≤ 65cc</td><td colspan="5">HC: 161 / NOx: 5.36 / CO: 402</td><td>≥ 50cc - ≤ 80cc</td><td colspan="9">72 / 536 / 2.0[b]</td></tr>
<tr><td rowspan="2">> 65cc - < 225cc</td><td rowspan="2">16.1402 1.2[a]</td><td colspan="4" rowspan="2">16.1 / 467 / 1.2[a]</td><td rowspan="2">16.1/467/ -</td><td>16.1 / 549 / - Horizontal-shaft</td><td>> 80cc - < 225cc Horizontal-shaft</td><td>16.1 / 549 / -</td><td colspan="8" rowspan="2">10 / 549 / -</td></tr>
<tr><td>16.1 / 467 / - Vertical-shaft</td><td>> 80cc - < 225cc Vertical-shaft</td><td>16.1/467/ -</td></tr>
<tr><td>≥ 225 cc</td><td>13.4402 1.2[a]</td><td colspan="4">13.4 / 467 / 1.2[a]</td><td>13.4/467/ -</td><td>12.1 / 549 / -</td><td>≥ 225 cc</td><td colspan="3">12.1 / 549 / -</td><td colspan="6">8.0 / 549 / -</td></tr>
</table>

a) HC+NOx, CO and PM standards applicable to all diesel-cycle engines. PM standard is not applicable to spark-ignition engines.

b) PM standard applicable to all two-stroke engines.

Small Off-Road Engine Evaporative Emissions - Performance and Design Standards

Displacement Category	Requirements		2006	2007	2008	2009	2010	2011	2012	2013+
≤ 80cc	Fuel Tank Permeation g ROG/m^2/day		-	2						
Walk-Behind Mowers > 80cc - < 225cc	Performance Requirements*	Diurnal Standard Grams HC/day	-	1.3			1.0			
	Design Requirements	Fuel Hose Permeation g ROG/m^2/day	15	-					-	
Non Walk-Behind Mowers > 80cc - < 225cc	Performance Requirements*	Diurnal Standard Grams HC/day	-	1.20 + 0.056 × tank vol.(L)					0.95+0.056×tank vol.	
	Design Requirements	Fuel Hose Permeation g ROG/m^2/day	15							
		Fuel Tank Permeation g ROG/m^2/day	-	2.5					1.5	
		Carbon Canister or Equivalent Butane Working Capacity Grams HC	-	1.4 g/L (tanks ≥ 3.78L) or 1.0 g/L (tanks < 3.78L)						
≥ 225cc**	Performance Requirements*	Diurnal Standard Grams HC/day	-	1.20 + 0.056 × tank vol.(L)						
	Design Requirements	Fuel Hose Permeation g ROG/m^2/day	15							
		Fuel Tank Permeation g ROG/m^2/day	-	2.5						1.5
		Carbon Canister or Equivalent Butane Working Capacity Grams HC	-	1.4 g/L (tanks ≥ 3.78L) or 1.0 g/L (tanks < 3.78L)						

* For model year 2006 only, all engines and equipment with displacements > 80 cc - <225 cc must comply with the fuel hose permeation design requirement. Engines and equipment with displacements ≥ 225 cc must comply with the fuel hose permeation design requirement for model years 2006 and 2007 only.

** Small production volume engines or equipment are exempted from the diurnal standards and the fuel tank permeation standard. In addition, these engines or equipment are not required to be configured with low permeation fuel hoses and carbon canisters until model year 2010.

C. Tier 4 Requirements For Non Road Diesel Engines

During the late 1990's and into the early 21st Century, EPA adopted stringent regulations for on road diesel trucks and buses to be phased in from 2007 to 2010 that will result in the

introduction of advanced PM and NOx control technologies. In parallel, EPA required the introduction of low sulfur diesel fuel with a maximum of 15 PPM sulfur, starting in 2006. In light of the progress being made in the development of these advanced technologies to reduce emissions from highway diesel engines and the continuing concerns about nonroad diesel impacts on air quality discussed above, EPA concluded that it is necessary to look once again at what is the "greatest degree of emission reduction achievable". The highway diesel engine and fuel rulemaking demonstrated that a "systems" approach was likely to be the most cost-effective way to pursue this goal. The systems approach recognizes that significant further reductions in nonroad emissions will require fuel quality improvements that enable advanced aftertreatment technologies and so it entails adopting nonroad fuel and engine changes in a single coordinated program.

On May 11, 2004, the EPA adopted a comprehensive national program to reduce emissions from nonroad diesel engines. Based in large part on the 2007 highway diesel program, the proposal sets out 1) new engine exhaust emissions standards and emissions test procedures, including not-to-exceed requirements, for nonroad engines used in most kinds of construction, agricultural, and industrial equipment, and 2) sulfur control requirements for nonroad, locomotive, and marine diesel fuels.

EPA states that exhaust standards associated with the nonroad rule would result in particulate matter (PM) and nitrogen oxide (NOx) emissions levels that are in excess of 95 percent and 90 percent, respectively, below comparable levels today. These standards will begin to take effect in the 2008 model year, with a phase-in of standards across five different engine power rating groupings. Diesel fuel used in nonroad, locomotive, and marine applications would meet a 500 ppm sulfur cap starting in June 2007, a reduction of approximately 90 percent. In June 2010, sulfur levels in nonroad diesel fuel (excluding locomotive or marine diesel fuel) would meet a 15 ppm cap, for a total reduction of over 99 percent.

The final rule contains all of the important features contained in the proposed rule issued by EPA in April 2003 with two significant exceptions. Most importantly, the final nonroad rule includes the introduction of ultra-low sulfur diesel fuel for locomotive and marine engines beginning in June 2012, two years after the introduction of ultra-low sulfur diesel fuel for other nonroad diesel engines. Requiring ultra-low sulfur fuel for locomotive and marine engines will provide dramatic reductions in particulate and sulfur dioxide emissions from these engines and enable the application of high performance emission controls to these engines. In concert with finalizing the nonroad diesel program, EPA also issued an Advanced Notice of Proposed Rulemaking (ANPRM) indicating their intent to propose and finalize more stringent emission standards for locomotive and marine engines. A formal proposal is expected in 2006.

A second area of departure from the 2003 proposed rule is with respect to the emission standards for the largest nonroad engine category – horsepower levels above 750. Emission standards for this category of nonroad engines depend on whether these engines are used in generator sets or mobile machinery. For generator sets rated greater than 1200 hp, NOx emission control-based standards are required in 2011 with PM emission control-based standards required starting in 2015. For smaller generator sets (over 750 hp, up to 1200 hp), PM and NOx-based emission control standards are required in 2015. For large mobile machinery, only a PM-based emission control standard has been set starting in 2015. These standards pull ahead NOx-based emission controls for the large generators, delay the implementation of PM-based emission controls on all of the largest engine applications, and

defer a decision on NOx-based emission controls for mobile machinery compared to standards included in the April 2003 proposal.

EPA expects the entire nonroad diesel engine inventory to comply with these new nonroad standards by 2030 (based on estimated fleet turnover). The program's estimated environmental benefits include reductions of 738,000 tons of NOx and 129,000 tons of particulate emissions annually by 2030. The anticipated health benefits of these emission reductions are enormous and include the annual prevention of 12,000 premature deaths, 15,000 heart attacks, and more than 280,000 cases of respiratory symptoms in children. EPA has estimated the costs of the program to average from one to three percent of the total purchase price of most nonroad diesel equipment, with the net cost of ultra-low sulfur fuel averaging about four cents per gallon.

Important provisions of the final rule and highlights of the locomotive/marine ANPRM are summarized below.

D. Nonroad Diesel Engine Inventory

EPA anticipates that more than 650,000 pieces of new nonroad equipment annually will be subject to the nonroad rulemaking. Therefore, based on year 2000 nonroad diesel engine population data, the projected breakdown of the number of engines to be affected annually by EPA's nonroad rule would be as shown in Table 20, using an annual sales volume of 800,000 nonroad diesel engines.

Table 20 Projected Breakdown of the Number of Engines to Be Affected Annually by EPA's Nonroad Rule

Rated Power	Percentage Breakdown of 2000 Population	Number of Engines
<11 hp	6%	48,000
11-25 hp	13%	104,000
25-50 hp	17%	136,000
50-70 hp	12%	96,000
70-100 hp	20%	160,000
100-175 hp	16%	128,000
175-750 hp	16%	128,000
>750 hp	0.3%	2,400

E. Exhaust Emission Standards

Tables 21 and 22 show the proposed "Tier 4 emission standards" for PM, NMHC, and NOx for different rated power categories of nonroad diesel engines. Table 23 summarizes the phase-in schedule for Tier 4 NMHC and NOx emission standards as a function of engine rated power. The emission levels and phase-in requirements contained in these tables are identical to those originally proposed by EPA in April 2003.

Table 21 Table 2 Tier 4 PM Emission Standards (g/bhp-hr)

Rated Power	Model Year					
	2008	2009	2010	2011	2012	2013

<25 hp	0.30[a]					
25 to <75 hp	0.22[b]					0.02
75 to <175 hp					0.01	
175 to 750 hp				0.01		

Notes:

a) For air-cooled, hand-startable, direct injection engines under 11 hp, a manufacturer may instead delay implementation until 2010 and demonstrate compliance at a PM standard of 0.45 g/bhp-hr.

b) A manufacturer has the option of skipping the 0.22 g/bhp-hr PM standard for all 50-75 hp engines; the 0.02 g/bhp-hr PM standard would then take effect in 2012 for all 50-75 hp engines.

Table 22 Table 3 Tier 4 NOx and NMHC Emission Standards (g/bhp-hr)

Rated Power	NOx	NMHC
25 to <75 hp	3.5 NMHC + NOx[a]	3.5 NMHC + NOx[a]
75 to <175 hp	0.30	0.14
175 to 750 hp	0.30	0.14

Notes:

a) This is the existing Tier 3 combined NMHC+NOx standard for the 50-75 hp engines in this category; in 2013 it would apply to the 25-50 hp engines as well.

Table 23 Table 4 Tier 4 NOx and NMHC Phase-in Schedule

Rated Power	Model Year			
	2011	2012	2013	2014
25 to <75 hp			100%	
75 to <175 hp		50%[a]	50%[a]	100%[a]
175 to 750 hp	50%	50%	50%	100%

Notes:

a) Manufacturers may use banked Tier 2 NMHC+NOx credits to demonstrate compliance with the proposed 75-175 hp engine NOx standard in this year. Alternatively, manufacturers may forego this special banked credit option and meet an alternative phase-in schedule.

All proposed Tier 4 PM standards would require 100 percent compliance in the model year shown in Table 21. Manufacturers may also choose to skip the 2008 0.22 g/bhp-hr PM standard for 50-75 hp engines and instead meet the more severe 0.02 g/bhp-hr PM standard for these same engines in 2012, one year earlier than the 2013 compliance requirement shown in Table 21. The 0.02 g/bhp-hr and 0.01 g/bhp-hr PM standards are expected to require the use of particulate filter technology over all nonroad diesel engines with rated power of 25 hp or greater. The longest lead time for the use of filter technologies is provided for the smaller 25-75 hp engines since the application of filters to these small engines is viewed as more challenging than larger nonroad engines that have more commonality with onroad diesel engines. The 0.22 g/bhp-hr and 0.30 g/bhp-hr PM standards for smaller engines that would be implemented in 2008 are expected to be met with either advanced engine designs, the application of diesel oxidation catalysts, or the combination of advanced engine designs with oxidation catalysts.

The Tier 4 NOx and NMHC standards shown in Table 22 for engines rated at 75 hp and larger are similar in stringency to the final standards included in the 2007 highway diesel program and

are expected to require the use of high-efficiency NOx emission control technology systems (e.g., NOx adsorbers or SCR catalysts) to ensure compliance. EPA is phasing in many of these standards over a period of three years in order to address lead time, workload, and feasibility considerations. This phase-in approach for NMHC and NOx is modeled after the NOx phase-in provisions of the 2007-2010 highway diesel program. As in the highway program, engine manufacturers may choose to certify their engines to an intermediate NOx emission level during these phase-in years. This intermediate NOx emission level is 1.7 g/bhp-hr NOx for engines rated from 75 hp but less than 175 hp, and 1.5 g/bhp-hr NOx for engines rated from 175 to 750 hp. The final program does not include any Tier 4 NOx standards for the smallest categories of engines (<75 hp), but the program does include provisions for a technology review in 2007 to review the feasibility of tighter NOx emission standards on these smaller engines. This 2007 technology review will also consider if a more stringent, long-term PM standard for engines under 25 hp is appropriate.

For the largest nonroad engine segment (over 750 hp), EPA has established the emission standards summarized in Table 24 that require 100 percent compliance for new engines in 2011 and 2015, depending on whether these engines are used as stationary power generators or in mobile machinery.

Table 24 Tier 4 Emission Standards for Engines Over 750 hp (g/bhp-hr)

Application Class	2011 PM	2011 NOx	2011 NMHC		2015 PM	2015 NOx	2015 NMHC
Generator sets up to 1200 hp	0.075	2.6	0.30		0.02	0.50	0.14
Generator sets > 1200 hp	0.075	0.50	0.30		0.02	0.50	0.14
Mobile machinery	0.075	2.6	0.30		0.03	2.6	0.14

For these largest engines, the 0.50 g/bhp-hr NOx standard is expected to require the use of NOx-based emission controls (e.g., NOx adsorbers or SCR), while the 2.6 g/bhp-hr NOx level is expected to be achieved using engine-based controls. The 0.02 and 0.03 g/bhp-hr PM standards that are required in 2015 are expected to require the use of PM-based emission controls (e.g., DPFs). As can be seen from the table, EPA has decided not to include NOx catalyst-based emission standards for mobile machinery in the final rule due in part to concerns raised by engine manufacturers about the feasibility of NOx emission controls for these very large engines used in mobile machinery. All application segments would be expected to use particulate filter technologies starting in 2015. The choice of a 0.03 g/bhp-hr PM standard for mobile machinery is based on EPA's prediction that these large vehicles will rely on wire or fiber mesh-based particulate filter technology rather than ceramic-based wall-flow filters. This represents a departure from the standards included in the 2003 EPA nonroad proposal in which both PM-based and NOx-based emission control-based standards were proposed for all these engines. EPA indicates in the final rule that it will continue to consider evaluating the appropriateness of a more stringent long-term NOx standard for mobile machinery. This future action may take place as early as 2007 (the time of the scheduled nonroad technology review).

CO emission standards for all ranges of engine power remain unchanged from Tier 3 levels.

F. Durability Requirements

Useful life durability requirements for nonroad diesel engines remain unchanged from current durability requirements:

- <25 hp, any speed: 5 years or 3,000 hours
- 25 - <50 hp, constant speed 3,000 rpm or higher: 5 years or 3,000 hours
- 25 - <50 hp, constant speed <3,000 rpm: 7 years or 5,000 hours
- 25 - <50 hp, variable speed: 7 years or 5,000 hours
- 50 hp or higher: 10 years or 8,000 hours

G. Test Procedures

EPA is also including new test procedures and related certification requirements to better ensure emissions control over real-world engine operation and to help provide for effective compliance determination. The agency is requiring that Tier 4 PM and NOx emission standards will be met on both current steady-state duty cycles and a new transient test cycle: the Nonroad Transient Composite (NRTC) test cycle. This new transient cycle has been under development for a number of years in collaboration with nonroad engine manufacturers and regulatory bodies in the U.S., Europe, and Japan. Transient testing will begin in the model year that Tier 4 PM and/or NOx standards first apply (i.e., 2011 for 175-750 hp engines, 2012 for 75-175 hp engines [optionally 2012 for 50-75 hp engines], and 2013 for engines under 75 hp). Transient tests will include both cold-start and hot-start testing with cold start emissions results weighted 5 percent and hot start results weighted 95 percent (a change from the 10 percent cold start weighting proposed in April 2003). A new steady-state test cycle has also been included for certifying transportation refrigeration units (TRUs).

The nonroad program includes not-to-exceed (NTE) specifications based largely on NTE specifications included in the 2007 highway diesel program: emissions cannot exceed 1.25 X or 1.5 X the applicable standard depending on the level of the standard. NTE requirements will be implemented in the same model year that transient testing is initiated. The final rule does not include a manufacturer-run in-use test program, but EPA plans to propose such a program by 2005. Similarly on-board diagnostic systems for nonroad applications will be the subject of a future rulemaking activity.

H. Crankcase Emissions

EPA, as proposed, has included turbocharged diesels in the existing prohibition on crankcase emissions from nonroad diesel engines, effective in the same year that the proposed Tier 4 standards first apply in each power category. This change was driven by the development of closed crankcase filtration systems specifically designed for turbocharged engines. Such systems are already required in parts of Europe under existing Euro III emission standards and are expected to be used with onroad diesel engines starting in 2007.

I. Averaging, Banking, and Trading

EPA is also proposing to continue the averaging, banking, and trading nonroad emissions credits provisions to demonstrate compliance with the standards. This program is limited within the nonroad sector with no inter-sector trading allowed (e.g., with onroad engines or stationary sources). The detailed final rule provides family emission limit (FEL) caps for each engine power category that can be used in any averaging, banking, and trading transactions by the engine manufacturers.

In the April 2003 proposal, EPA included a provision that would have allowed nonroad retrofits to earn credits that could be used as part of the averaging, banking, and trading provisions of the certification process. The final rule does not include this retrofit credit option, but EPA indicates that they intend to explore a voluntary nonroad retrofit credit program at a later date.

J. Nonroad Diesel Fuel Sulfur Levels

US nonroad diesel fuel currently has sulfur levels of about 3,400 ppm on average. Beginning June 1, 2007, refiners will be required to produce nonroad, locomotive and marine diesel fuels that meet a maximum sulfur level of 500 ppm. This does not include diesel fuel for home heating, industrial boiler, or stationary power uses or diesel fuel used in aircraft. Then, beginning in June 1, 2010, fuel used for nonroad diesel applications (excluding locomotive and marine engines) will be required to meet a maximum sulfur level of 15 ppm since all 2011 and later model year nonroad diesel-fueled engines with advanced emission control technology must be refueled with this new ultra-low sulfur diesel fuel. This sulfur standard is based on EPA's assessment of the impact of sulfur on advanced exhaust emission control technologies, in which MECA played a key role, and a corresponding assessment of the feasibility of ultra-low sulfur fuel production and distribution.

The program also includes a combination of provisions available to refiners, especially small refiners, to ensure a smooth transition to ultra-low sulfur nonroad diesel fuel. In addition, the final program includes unique provisions for implementing the ultra-low sulfur diesel fuel program in the State of Alaska. EPA is also allowing certain U.S. territories to be excluded from both the nonroad engine standards and diesel fuel standards. Similar actions were taken as part of the 2007 highway diesel program.

In the final rule, EPA indicated that, with respect to locomotive and marine application, it is their intent to propose new future emission standards for these engines that could require the use of high efficiency exhaust emission control technology and thus the use of 15 ppm sulfur diesel fuel. The subject of future standards for locomotive and marine engines is discussed in the Advance Notice of Proposed Rulemaking (ANPRM) that was issued together with the final nonroad rule. EPA did, however, choose to include in the final nonroad rule the requirement for the production of ultra-low sulfur diesel fuel for locomotive and marine applications starting in June 2012, two years after the introduction of 15 ppm sulfur fuel for other nonroad applications.

K. ANPRM for Locomotive and Marine Engines

In their locomotive/marine ANPRM, EPA indicated their intent to establish future emission standards modeled in large part on the 2007-2010 highway diesel and Tier 4 nonroad diesel programs (e.g., significant reductions in PM and NOx emissions through the use of advanced emission control technologies). These future locomotive and marine standards could start as early as 2011. This future rulemaking process will include all locomotive engines and marine diesel engines up to 30 liters displacement per cylinder. The ANPRM reviews current emission standards for both locomotive and marine diesel engines and discusses briefly the feasibility and issues with applying emission controls such as particulate filters, NOx adsorber catalysts, and SCR catalysts to diesel engines used in these applications. Important issues include exhaust temperatures observed on these engines, the scale-up of emission technologies to some of the large engines used in locomotive and marine applications, and the space limitations associated with packaging these advanced emission controls in these applications. The

ANPRM seeks stakeholder comments on a wide range of topics associated with these engines, including whether and how future standards should be phased-in for these engines.

4. European Union

The file of Non-Road Mobile Machinery[3] (NRMM) currently contains 3 directives, the mother directive 97/68/EC, the amendment directive 2002/88/EC and the last amendment directive 2004/26. The directives regulate exhaust emissions from and test procedure for the different types of engines.

The mother directive, 97/68/EC, was published in the 28th of February 1998. This directive covers diesel fuelled engines for common NRMM. It became effective from the 1st of January 1999 for certain types of engines. The first stages presented in 97/68/EC, stage I (1st of January 1999) and stage II (1st of January 2001) covers diesel fuelled engines between 37 and 560 kW.

Table 25 Emissions Standards in Directive 97/68/EC (g/kW-Hr)

	Stage 1 (1999)		Stage 2 (2001-2003)	
	NOx	PM	NOx	PM
18<kW<37			8.0	0.8
37<kW<75	9.2	0.85	7.0	0.4
75<kW<130	9.2	0.70	6.0	0.3
130<kW<560	9.2	0.54	6.0	0.2

The second directive, 2002/88/EC covers spark ignited engines up to 18 kW for engines installed in handheld and non-handheld equipment. Stage I (and stage II) became effective in August 2004 with some exemptions for certain applications. The work with transposition is going on in the Member States. Only minor questions so far, concerning interpretation, have come from some manufacturers.

The third directive 2004/26/EC covers diesel fuelled engines from 19 kW to 560 kW for common NRMM and regulates the emission in 3 further stages. The directive also includes railcars and locomotives and inland waterway vessels and for the 2 latter categories there are no upper limits concerning engine power.

The different stages in the 2004/26/EC directive are as follows:

- Stage III A covers engines from 19 to 560 kW including constant speed engines, railcars, locomotives and inland waterway vessels.
- Stage III B covers engines from 37 to 560 kW including, railcars and locomotives.
- Stage IV covers engines between 56 and 560 kW.

The stage III A will be effective (place on the market) from 1st of January 2006 for certain types of engines. Stage III B from 1st of January 2011 and stage IV from 1st of January 2014.

[3] The definition of Non-Road mobile machinery means a mobile machine, transportable industrial equipment or vehicle with or without bodywork, not intended for the use of passenger – or gods-transport on the road, in which an internal combustion engine as specified in Annex I is installed.

In the directive is a flexibility scheme that allows manufacturers to place engines on the market that only fulfils the previous stage when a new stage is in force.

The directive 2004/26/EC is aligned with the US TIER IV regarding further stages of emission limit values.

There is a working group within the GRPE (UNECE in Geneva) working with a world wide harmonized test procedure. DG Enterprise and the Joint Research Council are represented.

A review is planned at the end of 2007, to consider some issues that have been highlighted, as further stages for inland waterway vessels, flexibilities, in-use-compliance, durability testing, preventing cycle beating, and cycle by-pass at testing, further exemptions etc.

5. Japan

As indicated earlier, nonroad vehicles are an important and growing source of emissions in Japan. As illustrated below, in 2000 they accounted for approximately 15% of PM and 32% of NOx emissions from the mobile sources sector.

Table 26 Japanese Motor Vehicle Emissions by Source Category (2000)

			PM	NOX
Diesel	On Road	Mid Sized Truck	55.6%	38.1%
		Small Sized Truck	10.3%	6.1%
		Car	9.3%	3.0%
		Other	9.9%	6.9%
	Nonroad	Agriculture	0.7%	1.6%
		Industrial	4.7%	9.2%
		Construction	9.6%	18.7%
Gasoline	On Road	Small		2.9%
		Car		9.1%
		Mini Truck		3.0%
	Non Road	Other		0.9%

To deal with this problem, in 2003, Japan introduced its first stage of requirements to reduce emissions from the nonroad vehicle category. Subsequently, in June 2003 the Central Environment Council (CEC) recommended a further tightening in 2006 and identified a gap in the legal authority pertaining to nonroad vehicles which is currently being addressed at the National Diet. Further in its 6th report, the CEC suggested that Japan consider the next round of emission standards beyond 2006 that corresponds to Tier 3B or Tier 4. The contents will be considered by the CEC next year.

Table 27 Japanese Off Road Vehicle Emissions Limits

	Rated power	NOx	HC	CO	PM	Start
Diesel	19kW – 37kW	6.0 (8.0)	1.0 (1.5)	5.0 (5.0)	0.4 (0.8)	2007
	37kW – 56kW	4.0 (7.0)	0.7 (1.3)	5.0 (5.0)	0.3 (0.4)	2008
	56kW – 75kW				0.25 (0.4)	
	75kW – 130kW	3.6 (6.0)	0.4 (1.0)	5.0 (5.0)	0.2 (0.3)	2007
	130kW – 560kW	3.6 (6.0)	0.4 (1.0)	3.5 (3.5)	0.17 (0.2)	2006
Gasoline	19kW – 560kW	0.6 (-)	0.6 (-)	20 (-)	—	2007

* Parenthetic numbers are the standards applied from 2003.

6. Conclusions

After years of delay, the US, Europe and Japan have started to move aggressively to reduce emissions from the nonroad vehicle and engine sector. Significantly, each region has worked closely together to harmonize requirements and it is expected that complete harmonization for nonroad diesels will eventually occur, along the lines established by the US EPA's recently adopted rule. During the next few years both the EU and Japan will be reviewing the next stages of their nonroad control efforts to determine their final requirements.