Environment Canada Environnement Canada

Future Canadian Emission Standards for Vehicles and Engines and Standards for Reformulation of Petroleum-Based Fuels

Canada

Introduction

The use of internal combustion engines to power vehicles and equipment and the combustion of fuel oils contribute significantly to air pollution in Canada, particularly in urban areas. Emissions of concern include nitrogen oxides (NOx), volatile organic compounds (VOCs), sulphur oxides (SOx), carbon monoxide (CO), greenhouse gases, fine particulate matter, benzene, 1,3-butadiene, formaldehyde, acetaldehyde and other toxic or potentially toxic substances.

Vehicle and engine emission control technology is evolving rapidly and the fuels that power these products will have to advance in parallel. It is therefore timely to look forward and consider how vehicle and engine emission standards and fuel reformulation should be improved together. The standards for vehicle and engine emissions and fuels each have a number of dimensions requiring a comprehensive assessment of both agendas rather than considering only one dimension at a time. It also makes sense to consider vehicles and fuels as an integrated system.

The purpose of this discussion paper is to initiate a dialogue on what the next decade might hold in regards to vehicle emissions standards and fuel product standards. With this paper, Environment Canada's intent is to identify the issues that need to be addressed and start the process of determining how best to resolve them. Subsequently, and in consideration of stakeholder comments, the Department plans to publish a formal Notice of Intent in Part I of the Canada Gazette. The Notice of Intent would lay out an agenda of planned measures and future activities in support of reducing pollution from these sources and the time frames anticipated for their implementation. Ultimately, new vehicle, engine and fuel standards will be considered in consultation with stakeholders through normal regulatory processes.

Background

Canadian emission standards for new vehicles generally match those of the U.S. and are among the most stringent in the world. Canada has fuel quality standards that are comparable in many respects with standards in Europe and the U.S. although there are differences. Fuels quality standards and vehicle emissions standards have tended to evolve separately throughout the world although recently the U.S. EPA has begun to link fuel quality standards explicitly with vehicle standards.

In Canada, the key drivers for emission reductions from both vehicles and other sources of combustion are the health and environmental effects of those emissions. It is recognized that as vehicle technology evolves to respond to the need for reduced emissions, fuel formulations will also have to evolve to be compatible with new vehicles technologies and to meet emission requirements.

In September 1999, Parliament approved the revised Canadian Environmental Protection Act (CEPA). The renewed legislation, known as CEPA 1999, establishes timelines for actions to control releases of substances that are determined to be toxic under section 90. It also includes new provisions which broaden the federal government's ability to regulate standards for vehicles, engines and fuels in order to

reduce emissions (Divisions 4 and 5). An important element of the new CEPA is the consolidation of most federal authorities for setting environmental requirements for vehicles, engines and fuels under a single federal Act. Pursuant to the new authorities, Environment Canada plans to develop new regulations to control emissions from on-road and non-road vehicles and non-road engines. Environment Canada is also considering the need for future Canadian standards for petroleum-based fuels (gasoline, diesel fuel and light and heavy fuel oils).

Effects of Air Pollution and Contribution to Emissions

Health Canada and others have identified air pollution as a compelling health problem. Air pollution is responsible for 5000 premature deaths each year in 11 major Canadian cities. Although it is difficult to extrapolate this to the entire population of Canada, clearly the total number of premature deaths is significantly greater than 5000 per year. Other health impacts associated with air pollution include cardio-vascular ailments and respiratory distress. Air pollution results in increased emergency hospital visits and hospital admissions for Canadians. Clearly, there is a strong need to act quickly to provide a healthier environment for Canadians.

For many pollutants, scientists have found that there appear to be some degree of adverse effects at any concentration in the air. Since adverse health impacts are found at even low concentrations, further measures to reduce pollution throughout Canada are worthy of consideration.

The use of vehicles, engines and petroleum fuels contributes significantly to air pollution in Canada and consequently has major impacts to the environment and on the health of Canadians. Emissions from vehicles and engines are primarily a function of vehicle/engine technology and the properties of the fuels. Since the performance of vehicle emission control systems can be impaired without the right fuels, fuel standards and vehicle/engine emission standards must be considered as an integrated system in developing policies and programs to reduce emissions. In recent years because of more sophisticated equipment being installed in new vehicles, fuels have become more of an issue in the challenge to reduce vehicle emissions. In some cases, vehicle technology to achieve lower vehicle emission standards requires cleaner fuels.

Emissions from gasoline and diesel-powered vehicles and engines are a major source of air pollution, on a national basis contributing 65% of carbon monoxide, 50% of nitrogen oxide, 25% of VOCs, 25% of greenhouse gases and 65% of benzene emissions. In urban areas, the vehicle contribution to air pollution is higher.

Emissions of fine particulates come directly from the exhaust of engines, and also result from secondary formation of aerosols from SOx, NOx and VOC emissions. In urban areas vehicles are a major contributor (greater than 20%) to emissions of fine particulates.

The table below presents the contribution of the sources of interest as a percentage of national inventories. The contributions of vehicles and light fuel oil combustion (primarily in residential furnaces) are much larger in urban areas. It should also be noted that

heavy fuel oils are almost entirely combusted in central and eastern Canada - areas that are sensitive to acidic deposition.

Percent Contribution to Total Canadian Emissions in 1995 [1]						
	Direct $PM_{2.5}$	**SO_2**	**NOx**	**VOCs**	**CO**	**CO_2 equiv.**
On-Road Vehicles	9	2	35	22	54	21
Off-Road Engines	5	1	10	3	11	3
Rail	4	n/a	5	n/a	n/a	1
Light Fuel Oil Combustion	n/a	1	n/a	n/a	n/a	n/a
Heavy Fuel Oil Combustion	n/a	12	n/a	n/a	n/a	n/a

Notes: Open sources are excluded. Contributions to total $PM_{2.5}$ are larger.
"n/a" means not available.

Clearly, initiatives to reduce emissions from vehicles, engines and fuels can have significant positive effects on smog, acid rain, hazardous air pollutants and may also contribute towards reductions in greenhouse gases.

Canadians continue to consider air pollution to be one of the most important environmental issues for Canadians. Fifty percent of Canadians have cited air pollution as one of the two most pressing environmental problems. In addition, 63% of Canadians believe smog and air pollution are the leading transportation-related causes of environmental degradation and 86% of Canadians indicated a high level of concern with the smog and air pollution resulting from transportation [2] .

Progress To Date

The federal government is committed to protecting the environment and the health of Canadians from the adverse impacts of emissions from vehicles, engines and fuels. In cooperation with provincial governments, the federal government is putting in place a multi-facetted cleaner vehicles and fuels program to reduce harmful emissions from vehicles.

In recent years, the federal government has introduced regulations to reduce the allowable level of exhaust, evaporative and refuelling emissions from new on-road vehicles, to lower the sulphur content of diesel fuel, to reduce the amounts of sulphur and benzene in gasoline and to limit the dispensing flow rate of gasoline and gasoline blends. Environment Canada has also been working with manufacturers of a variety of non-road engines with the objective of ensuring that Canada will receive equipment meeting the applicable U.S. emission standards at the earliest possible time.

Provinces control gasoline vapour pressure and some are developing or have already introduced vehicle inspection and maintenance programs. British Columbia also has regulations controlling vehicle emissions and the quality of gasoline and on-road diesel

fuel. The Montreal Urban Community controls the sulphur level in on-road and off-road diesel [3] .

The above initiatives have resulted in improvements in fuel quality, and significant reductions in emissions on a per-vehicle basis. However, the resulting emission reductions will be significantly offset by increases in the number, use, and power of motor vehicles [4] . Canada's air quality will suffer in the absence of further government action.

As we move into the 21st century, progressive jurisdictions are setting requirements for advanced-technology vehicles and their associated fuels. California, long recognized as the leading jurisdiction in combating air pollution, has the most stringent requirements in the world for vehicle emission standards and fuels. Recently, Europe and the U.S. have adopted standards for advanced-technology vehicles and the fuels that enable them to perform effectively. Automotive manufacturers around the world have developed common recommendations for fuel quality based on the level of vehicle emission standards in a market.

Links to Other Programs

Provinces and the federal government are developing Canada-wide standards (CWS) for particulate matter, ozone and benzene [5] under the Canada-wide Environmental Standards Sub-Agreement. Set under the framework of the Canada-wide Accord on Environmental Harmonization, the Standards Sub-Agreement provides a framework for federal, provincial, and territorial Environmental Ministers to work together to address environmental protection and health risk reduction issues in the form of common standards across the country.

The initiatives that will be addressed in the Notice of Intent are important measures towards achieving the CWS for particulate matter and ozone that are being established by provinces, territories and the federal government pursuant to the 1998 Sub-Agreement. They are also likely to be key measures of any actions on smog.

Environment Canada is taking a multi-pollutant approach in identifying initiatives to be addressed in this process. These initiatives can reduce emissions of smog precursors, acid rain and of substances that have been declared toxic under CEPA (or are being assessed for toxicity. These include benzene, 1,3-butadiene, formaldehyde, acetaldehyde, acrolein and PM-10. At the same time, the measures may reduce barriers to action on climate change (e.g. allow the introduction of advanced-technology vehicles). The national scope of the initiatives can help all regions of Canada to reduce air pollution. This aligns with principles of continuous improvement, pollution prevention and "keeping clean areas clean" as set out in the CWS for particulate matter and ozone [6] .

A New and Stronger CEPA

On March 31, 2000, CEPA 1999 was proclaimed, after receiving Royal Assent in September 1999. CEPA 1999 includes new legislative provisions which broaden the

federal government's ability to establish standards for vehicles, engines and fuels in order to reduce emissions that adversely affect Canadian air quality.

In Canada, progressively more stringent national emission standards have been promulgated for on-road vehicles under the authority of Transport Canada's Motor Vehicle Safety Act since 1971. The provisions of the renewed CEPA effectively transfer the legislative authority for controlling emissions from on-road vehicles from the Motor Vehicle Safety Act to CEPA 1999. Division 5 of the renewed CEPA also provides the federal government with the legislative authority to establish regulations to limit emissions from a much broader range of engines than was possible in the past [7] .

With respect to fuels, the renewed CEPA broadens the authority and applicability for possible regulations [8] . Previously, fuels could only be regulated where their combustion significantly contributed to air pollution. Under CEPA 1999, fuels regulations can now be passed provided that they significantly reduce pollution resulting from the fuel, its components, or its effect on operation, performance or introduction of engine technology or emission control equipment. Fuels regulations can now set requirements for fuels based on formulae, and can distinguish among fuel according to their source, properties, or place or time of use. New provisions also provide authority to establish a "national fuels mark" with accompanying requirements for fuels that are imported or transported between provinces.

Pursuant to the provisions of the renewed CEPA, Environment Canada plans to consider development of new regulations to control emissions from vehicles, engines, equipment and fuels.

Part 1 - Vehicles and Engines

A Regulatory Framework for Vehicles, Engines and Equipment

When brought into force, the provisions of Division 5 of CEPA 99 will enable the federal government to establish a regulatory program to control emissions from a broad range of vehicles and engines. A sound regulatory framework must be developed to ensure that such a program can be implemented and enforced in an effective and efficient manner.

The provisions of Division 5 prohibit any company from transporting a prescribed vehicle, engine or equipment within Canada, if the prescribed vehicle, engine or equipment does not have a national emissions mark (NEM) applied to it. In addition, the provisions prohibit a company applying a NEM to any vehicle, engine or equipment, from selling any such items to which a NEM has been applied, or import any of these items unless specific conditions are met. These conditions, to be specified by regulations, could include that:

- the vehicle, engine or equipment conforms to the prescribed standards which govern the design, construction, functioning or marking for the purpose of controlling or monitoring emissions;
- evidence of conformity had been obtained and produced in the prescribed form and manner
- prescribed information relating to standards for emissions has been submitted to the Minister
- prescribed information is marked on the vehicle, engine or equipment

- prescribed documentation or accessories accompany the vehicle, engine or equipment;
- prescribed information relating to the operation or use of the vehicle, engine or equipment is disseminated in the prescribed form and manner
- records are maintained and furnished in the prescribed form and manner
- a registration system be maintained in the prescribed form and manner.

In addition to the above, the regulatory framework under Division 5 would likely include regulations to prescribe the following program elements:

- the establishment of the NEM, the conditions of its use and the manner of its application
- the form and content of a company's application to be exempt from compliance with a prescribed standard;
- the form and manner in which companies shall cause a notice to be given regarding a defect in the design, construction or functioning of a vehicle, engine or equipment that affects or is likely to affect its compliance with a prescribed standard;
- the details of an emission credit system and related information reporting requirements.

It is important to note that the legislative framework of Division 5 is largely based on the model which exists in the Motor Vehicle Safety Act. To the extent that is practical and appropriate, the Department intends to develop a regulatory framework that is similar to that which exists for emissions under the MVSA. This approach should make the transition from having to meet emission standards under the MVSA as seamless as possible for manufacturers and importers of on-road vehicles. However, since the NEM forms the cornerstone of CEPA's legislative framework, use of the new mark will have to be accommodated by affected companies.

A General Policy for Emission Performance Standards:

The previous section, provided a general description of the administrative-type requirements provided for under CEPA 1999. While these are essential elements of the program, most of public discussion has traditionally focused on the establishment of the technical standards which set the required emission performance for vehicle and engines. In the past, Canada has generally sought to align its national vehicle emission requirements with those of the United States Environmental Protection Agency (US EPA).

In 1995, the Task Force on Cleaner Vehicles and Fuels, working under the Canadian Council of Ministers of the Environment, reviewed options for a national approach to new vehicle emission standards, including the adoption of California emission standards. In its evaluation of possible control options for new vehicles, the Task Force found that continuing to align Canada's national vehicle emission standards with stringent U.S. federal standards represented the preferred approach as it would provide Canada with emission reductions from this sector in the most cost-effective way [9] .

Historically, the United States Environmental Protection Agency (EPA) has put in place an aggressive program to control emissions from new on-road vehicles in order to address air quality problems and its emission standards have generally been recognized as the most stringent national standards in the world. Since the automotive industry is highly integrated on a North American basis, a harmonized approach to setting vehicle

emission standards has, over the years, provided Canadians with advanced emission control technology at a low cost. As described in the following sections, the EPA is continuing to develop stringent national emission standards for on-road vehicles for the 2004 and later time frame.

As required by the U.S. Clean Air Act [10] , in recent years the U.S. EPA has also been very active in promulgating stringent emission standards for engines used in most non-road applications. These standards include requirements for compression-ignition and spark-ignition internal combustion engines used in a wide range of applications including agricultural and construction equipment, recreational marine engines and utility, lawn and garden equipment.

In view of the above, Environment Canada plans to continue aligning Canadian federal emission requirements for on-road vehicles with those of the EPA and to consider new requirements to align standards for off-road engines.

While Canada's current emission standards for on-road vehicles are aligned with those of the US, our regulations do not institute any corresponding phase-in schedules or programs for averaging, banking, trading (ABT) of emission credits for any vehicle or engine that has an equivalent model that is certified by the US EPA and is sold concurrently in the United States. Instead, the regulations require that these vehicles and engines comply with emission standards referred to in the applicable certificate of conformity issued by the US EPA. The regulations were developed on the basis that, as a result of the highly integrated North American automotive market, the relative proportion of cleaner vehicles should not differ significantly between the two countries. Accordingly, it was determined that requiring compliance with standards for phase-in or emission averages in Canada could have limited the vehicle model availability to Canadian consumers and resulted in significant administrative costs to both government and industry while providing little additional environmental benefits.

In the past, participation in the US programs for ABT of emission was largely optional for manufacturers and its application focused primarily on the certification of heavy-duty engines. However, recent EPA emission control programs and proposals are relying increasingly on corporate fleet-average standards and complex emission credit systems in order to provide companies with more compliance flexibility, to create incentives for the early introduction of new technology and allow the adoption of more stringent standards that might otherwise be possible under a single standard . For example, this is evidenced in the Tier 2 standards for light-duty vehicles and light-duty trucks and emission standards for certain classes of non-road engines (to be discussed in more detail in a subsequent section). In the Tier 2 standards, an annual sales-weighted corporate fleet average for NOx emissions is not an optional element but is the centrepiece of the compliance program.

In view of the above, there may be a greater need to adopt and enforce corresponding emissions corporate fleet-average emission requirements and ABT programs in future Canadian emission programs to ensure that the emission performance of Canadian new vehicle/engine fleets will not be significantly compromised relative to the US.

The following sections provide a brief description of the initiatives that would be pursued under this general harmonization policy. While the US EPA is still in the process of completing their regulatory process for some of these initiatives and some aspects may ultimately be modified, the description is intended to provide a general outline of the potential regulatory landscape for the mid-2000 time frame and to assist in raising potential issues in the Canadian context at an early stage in our process.

On-Road Light-duty Vehicles and Light-Duty Trucks

Currently, Canadian emission regulations for new light duty vehicles and light-duty trucks are aligned with U.S. federal regulatory requirements under the Clean Air Act, including Tier 1 exhaust emission standards, enhanced evaporative emission standards, refuelling emission standards and on-board diagnostic requirements.

In order to further mitigate the air quality impacts of the light-duty vehicle and light-duty truck classes of on-road vehicles, the EPA first entered into voluntary arrangements with companies for the interim National Low Emission Vehicle (NLEV) program. More recently, it adopted a more stringent regulatory emission control program for these classes of on-road vehicles, known as the "Tier 2" program [11] . Light-duty vehicles are essentially passenger cars while light-duty trucks incorporate mini vans, pick-up trucks and sport utility vehicles having a gross vehicle weight rating of up to 8,500 lbs. The tighter emission standards for these classes under the new program are referred to as "Tier 2" standards and will be phased in by the EPA beginning with the 2004 model year.

The Tier 2 standards are based on a system where companies will have the option of certifying any particular vehicle to one of eight emission categories referred to as "bins". Each bin has specified standards of differing stringency for NOx, non-methane organic gases, CO, formaldehyde and particulate matter. Vehicle manufacturers must meet an annual sales-weighted corporate fleet average NOx standard of 0.07 g/mile which represents a 77% reduction for light-duty vehicles and a 95% reduction for light-duty trucks.

Under the EPA's Tier 2 program, light-duty vehicles, light-duty trucks and medium-duty passenger vehicles will eventually be subject to the same emission standards beginning with the 2009 model year. "Medium-duty passenger vehicle" is a new class of vehicles created under the Tier 2 program which consists primarily of passenger vehicles having a gross vehicle weight rating in the 8,500-10,000 lb. range (mostly large sport utility vehicles and large passenger vans). Currently, these vehicles are classified as heavy-duty vehicles and are subject to less stringent emission standards However, since it is recognized that compliance with the Tier 2 standards will present a greater technological challenge for the heavier classes of light-duty trucks and medium-duty passenger vehicles, a different phase-in schedule will be implemented depending on the weight of vehicles.

For light-duty vehicles and those light-duty trucks having a gross vehicle weight rating less than 6,000 lbs., manufacturers will be required to certify an increasing percentage of their new vehicles to the more stringent Tier 2 standards. Generally, for these classes

the phase-in for compliance with Tier 2 standards will be based on the following schedule: 25% in 2004, 50% in 2005, 75% in 2006, and 100% in 2007.

In the case of light-duty trucks having a gross vehicle weight rating between 6,000 and 8,500 lbs. (i.e., heavy light-duty trucks) and medium-duty passenger vehicles, 50% of these vehicles must comply with Tier 2 standards in 2008 and 100% in 2009. EPA believes that this delayed phase-in should provide vehicle manufacturers with sufficient lead time to meet the more stringent emission requirements.

The Tier 2 program also includes interim emission standards for those vehicles that would not be certified to the Tier 2 emission standards beginning in the 2004 model year. The interim standards are more stringent than the current regulated requirements but not as stringent as the final Tier 2 standards. The interim standards represent a reasonable step toward the Tier 2 standards and are intended to achieve meaningful control of emissions in the near term while allowing more time for manufacturers to meet the final requirements, particularly for the heavier light-duty trucks.

In its Tier 2 program, EPA has adopted a system for generating, banking and trading of NOx credits to provide additional flexibility for vehicle manufacturers. Under this system, when a company's average NOx emissions fall below the corporate average NOx standard, it could generate NOx credits that it could save for later use (banking) or sell to another manufacturer (trading). EPA indicates that this type of system allows the adoption of more stringent standards than might otherwise be possible and creates incentive for the early introduction of new technology. In order to provide a stronger incentive for companies to develop and introduce the advanced vehicles on an early basis, the Tier 2 program gives extra credits for selling vehicles from the two "cleanest" bins in the 2001-2005 model years.

Other notable issues that are included as part of the Tier 2 program include:

- the Tier 2 emission standards are fuel neutral in that they will apply to any vehicle regardless of the fuel it is designed to use;
- more stringent evaporative emission standards (about 50% tighter) will be phased-in on the same schedule as the Tier 2 exhaust emission standards;
- requirements for most medium-duty passenger vehicles to meet on-board diagnostic system requirements beginning in 2004 and to phase-in on-board vapor recovery systems through 2004-2006; and
- the useful life for which emission standards must be met would be extended from 100,000 miles to 120,000 miles.

It is important to note that, in its final rule, the US EPA stated its belief that "there are not (and will not be in the foreseeable future) emission control devices available for gasoline powered vehicles that can meet the proposed Tier 2 emission standards that would not be significantly impaired by gasoline with sulfur levels common today". Further, the EPA indicated that "we believe that for these standards to be feasible for gasoline LDVs and LDTs, low sulfur gasoline must be available". Accordingly, EPA set a gasoline sulphur standard of 30 ppm average/80 ppm cap to be phased-in as part of its Tier 2 package.

While it has been recognized that meeting the Tier 2 emission standards will be a challenge for gasoline vehicles, EPA does not expect that any major technological innovation will be required to achieve compliance. In the case of diesel-fuelled vehicles, however, the US EPA expects that complying with the final Tier 2 NOx and PM standards will necessitate new types of exhaust aftertreatment technologies such as NOx storage catalysts and continuously regenerating particulate traps, which will likely require lower-sulphur diesel fuel. The EPA has released an Advanced Notice of Proposed Rulemaking (ANPRM) to initiate discussion on appropriate future diesel fuel specifications. In the meantime, however, the EPA believes that the structure of the Tier 2 program (i.e., available bins, phase-in periods) will allow the orderly development of clean diesel technologies and that the interim standards are feasible for diesel-fuelled vehicles at current levels of sulphur in diesel fuel.

(A more detailed discussion of fuel quality issues is provided in Part 2 of this document.)

Finally, the voluntary emission program agreed to by U.S. vehicle manufacturers is being implemented in most northeast states in 1999 and nationwide in 2001. This program, known as the "National Low Emission Vehicle (NLEV) Program" applies to light-duty vehicles and light-duty trucks. The emission standards under the NLEV program are more stringent than Tier 1 standards but less stringent than those under the Tier 2 program.

On-Road Heavy-duty Vehicles and Engines

Currently, Canadian emission standards for on-road heavy-duty vehicles are aligned with those of the U.S. EPA. The most recent tightening of the standards applicable to this class of vehicles came into effect with the 1998 model year, when the allowable level of NOx exhaust emissions was reduced from 5.0 g/bhp-hr to 4.0 g/bhp-hr.

In 1997, the U.S. EPA adopted more stringent emission regulations for diesel-fuelled on-road heavy-duty vehicles (i.e., used mostly in trucks and buses) which were scheduled to come into effect in the 2004 model year. The new requirements introduced a standard of 2.4 g/bhp-hr for combined emission of NOx+NMHC and includes the option of participating in an averaging, banking and trading program. The new standard effectively represents a required reduction in NOx emissions of approximately 50% relative to the 1998 standard, as well as reductions in hydrocarbons. While the regulations for the 2004 model year maintain the existing standards for direct particulate emissions, the significant reductions in NOx emissions will also reduce secondary nitrate particulate matter. At the time that the US EPA finalized the 2004 emission standards (1997), the Agency indicated that it believed that the standards were technologically feasible without any changes to diesel fuel. However, the EPA committed to conducting, in 1999, a review of the technical and economic feasibility of achieving the 2004 emission standards, including an assessment of whether diesel fuel improvements would be needed to meet the standards.

In October, 1999, the US EPA announced a comprehensive Notice of Proposed Rulemaking (NPRM) to adopt more stringent emission standards for gasoline and diesel-fuelled heavy-duty vehicles and engines. As part of this NPRM, the US EPA reaffirmed

its earlier position that the 2004 model year NOx+NMHC emission standard for heavy-duty diesel engines is technologically feasible and that changes to the formulation of diesel fuel are not necessary for engines to meet these standards.

In addition to reaffirming the feasibility of the above standards, the US EPA proposed other significant changes to the emission standards for 2004 and later model year diesel and gasoline-fuelled heavy-duty engines. The principal elements of the proposal include:

- a new set of supplemental emission standards and associated test procedures for heavy-duty diesel engines and vehicles to ensure that real-world emissions are controlled over the broader range of in-use speed and load combinations than is represented by the current federal test procedure;
- a more stringent engine-based NOx+NMHC standard of 1.0 g/bhp-hr for Otto-cycle heavy-duty engines used in vehicles with a gross vehicle weight rating of more than 14,000 lb.;
- more stringent vehicle-based standards for NOx and NMHC for all heavy-duty vehicles with a gross vehicle weight rating from 8,500-14,000 lb. which correspond to the full useful life emission standards in place in California for low-emission vehicles (i.e., category defined as "medium-duty vehicles" in California) ;
- requirements for on-board diagnostic systems for all heavy-duty vehicles and engines with a gross vehicle weight rating from 8,500-14,000 lb.; and
- the phase-in of on-board vapour recovery standards for all complete heavy-duty vehicles up to 10,000 lb. gross vehicle weight rating.

The US EPA has also indicated its intention to propose even more stringent emission standards for heavy-duty engines that could take effect as early as the 2007 model year [12] . In their proposed strategy, EPA has indicated that NOx emissions could be reduced by between 75 and 90% beyond the 2004 levels and emissions of particulate could be reduced by 80 to 90%. As part of this second phase of work on heavy-duty emission standards, the US EPA indicated its intent to propose a reduction in the sulphur content of diesel fuel to a maximum of about 50 ppm (i.e., a reduction of about 90% from the current maximum level of 500 ppm) to enable new emission control technology on heavy-duty vehicles. As indicated previously, a more detailed discussion of fuel issues is provided in Part 2 of this document.

On-Road Motorcycles

Canada's emission standards for on-road motorcycles are currently aligned with those of the US EPA. The US EPA has not announced any action to further tighten these standards. Consequently, the Department plans to simply "roll-over" the current emission requirements for motorcycles into the regulatory framework under CEPA.

Non-Road Engines

New authorities under Division 5 of Part 7 of CEPA, 1999 provide the federal government with authority to regulate vehicles, engines and equipment [13] .

Notwithstanding the limitations contained within CEPA for certain definitions of "non-road" engines, the "non-road" sector can cover a broad range of vehicles, engines and equipment. This category, which is also referred to as the "off-road" sector, includes

outdoor power equipment, lawn and garden care equipment, recreational equipment, as well as agricultural, construction and forestry equipment. There are currently no federal emissions regulations pertaining to this sector.

During the consultation and legislative process leading up to the passage of CEPA 1999, Environment Canada entered into discussions with several industry groups that provide engines for non-road use. The purpose of these discussions was to apprise companies of the new authorities under CEPA 1999, and to seek means by which there could be an early introduction of advanced technology engines prior to the legislation being passed or regulations being developed. As a result of the discussions, Memoranda of Understanding have been entered into with members of: the Canadian Marine Manufacturers Association, representing manufacturers of outboard engines and personal watercraft; the Portable Power Equipment Manufacturers Association, representing manufacturers of small handheld utility engines along with some independent engine manufacturers; and the Engine Manufacturer's Association, representing manufacturers of off-road diesel engines. In addition, Memoranda of Understanding are being considered with members of the Engine Manufacturers Association, representing manufacturers of small non-handheld utility engines.

Starting in the 1990's, in the U.S., the EPA begun establishing emissions standards for several non-road engine categories following the identification of emissions from this sector as a significant source of NOx, VOCs and particulate matter. From a broad perspective, these sectors include: non-road diesel engines; small gasoline engines; and marine engine applications. The below table, illustrates the breadth of the U.S. federal non-road emission programs that have been implemented or proposed over the past number of years along with relevant examples of the types of equipment and engine applications covered by U.S. regulations. As noted in the accompanying table, the emissions control programs for some engine categories have already progressed to their second generation.

The remaining portion of this section, highlights elements of various U.S. federal emissions control programs for selected non-road engine categories. Readers are referred to the accompanying references and the appropriate U.S. federal regulation for further details.

Overview of Non-Road Engine Categories and U.S. Federal Emissions Control Programs

Non-Road Category	Examples of Engines / Equipment	U.S. Federal Program
Gasoline Powered Marine Engines	outboard engines; personal watercraft	Standards being phased-in between the 1998 and 2006 model-years.
Spark-Ignited Utility	non-handheld equipment:lawnmowers, lawn tractors, snow throwers,	non-handheld equipment:"Phase 1" standards introduced in 1997 "Phase 2" standards will be

Engines	generators, pumps, air compressorshandheld equipment:chain saws, string trimmers, brush cutters, leaf blowers, augers	phased-in beginning in 2001handheld equipment:"Phase 1" standards introduced in 1997 "Phase 2" standards to be phased-in between the 2002 and 2007 model-years
Land-Based Diesel Engines	agricultural equipment (e.g., tractors, combines),construction equipment (e.g., bulldozers, excavators), forestry equipment (e.g., industrial equipment,(e.g., pumps, generators, forklifts)	"Tier 1" standards phased-in starting in 1996; "Tier 2" standards will commence in 2001; and "Tier 3" standards will commence in 2006
Marine Diesel Engines	propulsion and auxiliary power on commercial marine vessels	Various engine classes and timing of emissions standards. Also influenced by the International Marine Organization (IMO)

Outboard Engines

The U.S. EPA introduced standards to control emissions from outboard engines and personal watercraft (PWC) starting in 1998 [14] . Rules governing this category of engines establish increasingly stringent emissions standards (i.e., grams per Kilowatt-hour [g/kW-hr]) that are being phased-in over the course of a nine-year period that begun with the 1998 model-year and will be fully implemented in the 2006 model-year.

The emission standard takes the form of a combined HC+NOx function, of a numerical value which is dependent on the rated power of the engine. The standard, which becomes progressively more stringent for each year of the phase-in period, requires manufacturers to reduce brake-specific HC emissions, on a corporate average basis, by at least 75% from pre-control levels in 2006.

The gasoline marine engine rules also contain ABT provisions to provide the industry with flexibility to obtain emissions credits for use in meeting the standards as well as for use with future model-years or for trading. A manufacturer earns positive emissions credits for an engine family with a family emissions limit below the applicable emissions standard. However, credits cannot be carried forward for more than 3 years.

The use of a corporate average standard means that the emissions from a manufacturer's product line of outboard engines and PWC can be averaged to determine compliance. As a consequence, an engine family in a manufacturer's product line could be certified to an emissions level in excess of the applicable standard (i.e., negative emissions credits) provided it would be offset by an engine family certified below the applicable emissions standard (i.e., positive emissions credits). The averaging

calculation takes into account full life emissions over the predicted life of the engine and includes such factors as engine family sales, average annual use and future survival probability of the engine. The graduated phase-in of the emissions standards, coupled with the corporate averaging provisions permit manufacturers to determine their optimal approach to achieve the targeted emissions standards.

The current U.S. standards do not presently address gasoline powered inboard engines or stern drives. These are applications where the engine (and in the case of an inboard, the drive unit too) are internal to the hull of the vessel. EPA indicated at the time of its outboard engine rule making that these engines, on a relative basis, tend to be much cleaner than outboard engines since they utilize four-stroke, automotive style engine blocks modified for marine applications. However, EPA reports that it expects to issue a proposal to regulate this category of engines in the coming year.

Small Spark-Ignited Utility Engines

This category of non-road engines comprises primarily small gasoline powered utility engines such as those used in lawn and garden care equipment, pumps, generators, and handheld equipment. Motorcycles are covered under the on-road vehicle emissions standards. To date, the U.S has implemented a number of rules for small spark-ignited (SI) utility engines at or below 19 kW power rating.

U.S. emissions standards for engines falling within this category distinguish between those engines intended for use in equipment carried by the operator during its operation (e.g., chain saws, string trimmers), referred to as handheld engines, and those engines normally used in equipment which is not carried by the operator during its operation (e.g., lawnmowers, generators), referred to as non-handheld engines. According to EPA, the distinctions between handheld and non-handheld operation is also reflective of the industry structure with few manufacturers making engines intended for both types of operation. Also, whereas handheld engine manufacturers tend, for the most part, to produce engines specifically for use in their own equipment, non-handheld engine manufacturers tend to be suppliers to the equipment industry.

In addition to the distinction between the intended operation of the engine (handheld versus non-handheld), U.S. emissions regulations for this category of engines establish separate engine classes based on engine displacement. This approach was implemented in recognition that it is technologically more challenging to meet a given level of emissions as engine displacement is decreased. The table below summarizes the engine displacement classes within this non-road engine category.

Summary of Small SI Engine Displacement Classes

Category	Engine Class	Engine Displacement(cubic centimeters)
Non-Handheld	Class I-A	< 66
	Class I-B	< 100 and > 66
	Class I	< 225 and > 100

	Class II	> 225
Handheld	Class III	< 20
	Class IV	< 50 and > 20
	Class V	> 50

Note: Classes 1-A and 1-B were created as part of the March 2000 Phase 2 handheld rulemaking.

The first set of regulations for these classes of engines, commonly referred to as "Phase 1" emissions standards took effect, for most engines beginning in 1997. These standards, which established HC, NOx and CO emissions limits on a brake specific basis for the five engines classes, were expected to result in a 32% reduction in HC emissions from this category of engines.

In March 1999, the U.S. EPA adopted new standards for non-handheld engines [15] (i.e., Class I and Class II). These new standards, referred to as "Phase 2" standards, established a combined HC+NOx emissions limit which will be phased in over the coming years. Specifically, Class I engines will be required to meet a 16.1 gm/KW-hr standard by August 1, 2007 while Class II engines will be required to meet a 12.1 gm/KW-hr standard that will be phased-in over the 2001 through the 2005 model years. These standards can be met on a corporate average basis. However, in the case of Class I engines, new families first produced on or after August 1, 2003 will have to meet the 12.1 gm/KW-hr standard. This provision pertaining to new Class I engines was implemented to ensure that new engine designs, introduced close to the 2007 time frame, would be required to meet the 12.1 gm/KW-hr standard. This in turn, would hasten the deployment of cleaner technology engines.

The Phase 2 standards also established durability limits for the non-handheld engines. EPA has assigned the responsibility to manufacturers to declare the appropriate useful life category for each engine. EPA has established three useful life categories for the these engines corresponding to: 125, 250 and 500 hours for Class I engines; and 250, 500 and 1000 hours for Class II engines. The useful life period determines the emissions compliance period for a particular engine family and factors into the emissions credit determination for the ABT program. The approach of assigning manufacturers the responsibility to declare a useful life category, is based in part, on the engine manufacturer's knowledge of their particular engine and the expected useful life of the equipment into which it will be installed. Notwithstanding this latitude accorded to manufacturers, the EPA expects to periodically review manufacturers decisions concerning useful life categories.

EPA estimates that the Phase 2 standards will result in an additional 59% annual reduction in combined HC+NOx emissions from these engines, compared with the Phase 1 standard, once the Phase 2 rule is fully phased-in.

The EPA has also established a comprehensive ABT program for Phase 2 non-handheld engines (Phase 1 did not contain this provision). The ABT program will be available for HC+NOx emissions and will permit a cross-class exchange of ABT credits between non-

handheld engine families. Also, these credits will have an unlimited life and will not be discounted.

Although the Phase 2 rules primarily respond to gasoline-fueled small spark-ignited engines, these standards will also cover natural gas powered SI engines and LPG fueled (indoor power) equipment. The standards establish a combined non-methane hydrocarbon plus nitrogen oxide (NMHC+NOx) standard for natural gas fueled engines.

Of particular interest to Canada, the Phase 2 non-handheld standards also carry forward certain provisions contained under the Phase 1 rule which permit engine manufacturers to certify class I and II engines to less stringent emissions standards. Specifically, two-stroke engines used to power snow throwers may meet either the Class III, IV or V (i.e., handheld engine class) standards. Also, manufacturers of engines used exclusively to power products which are used solely in the wintertime (e.g., snow throwers, ice augers) may elect not to certify or to comply with the HC, NOx or HC+NOx standards. The engine would still be required to meet the applicable CO standard. However, this provision is not available if the engine is used in any equipment other than that used exclusively during the wintertime. EPA noted, at the time of its Phase 1 rule making, that ozone non-attainment is primarily a seasonal problem that occurs during warm sunny weather [16] .

Recent amendments [17] to the non-handheld engine standards have established two new small engine classes: Class 1-A and Class 1-B (Please refer to the above table). The creation of these engine classes, to cover smaller displacement non- handheld engines, responds to comments received by the EPA that it is generally more difficult for smaller displacement engines to meet the same engine standards as larger displacement engines. Additionally, at the request of small engine manufacturers, the EPA has revised its non-handheld rules to allow manufacturers the option of certifying engines rated at greater than 19 kW and having a displacement of 1 litre or less to the small SI engine Phase 2 standard [18] . In March 2000, the EPA finalized its Phase 2 emissions standards for handheld engines [19] . The rules also establish a combined HC+NOx and a CO emissions standard for the three existing handheld categories.

The handheld engine emissions control program will be gradually phased-in using a graduated corporate average HC+NOx emissions standard. Under the proposed rule, new Class III and Class IV engines would be required to meet a 50 g/kW-hr standard in 2005 and Class V engines would be required to meet a 72 g/kW-hr standard in 2007. These standards would be phased-in between the 2002 and 2005 model-years for Class III and IV engines and between the 2004 and 2007 model-years for Class V engines. This approach will allow manufacturers to transition in an orderly and an efficient manner from their existing Phase 1 engine designs and technologies.

EPA expects that the implementation of the Phase 2 standards for handheld engines will result in a 70% annual reduction of combined HC+NOx emissions once the rule is fully phased-in compared with the Phase 1 requirements.

EPA has also proposed a comprehensive ABT program similar to the program adopted for the non-handheld category. The averaging program would apply to HC+NOx

emissions. Also, manufacturers would be allowed to exchange credits across any of the small SI engine classes i.e., handheld and non-handheld.

The standards also require manufacturers to certify their engines over a useful life to one of three useful life categories for handheld engines: 50, 125 and 300 hours. Manufacturers would be responsible for certifying to the appropriate useful life, based on their understanding of the intended engine application and expected in-use operation. EPA judged the industry as being in a suitable position to make this determination recognizing that many manufacturers also produce the equipment. EPA indicated that it believes the 50-hour useful life would be appropriate for most products targeted at the home consumer, and the 300-hour useful life would be appropriate for products targeted at the commercial market. Nevertheless, EPA expects to periodically review manufacturers decisions regarding useful life.

Diesel Engines

U.S. federal emissions standards for this category of non-road engines primarily cover diesel engines used in most land-based applications as well as marine engines rated below 37 kW. Specific examples include construction, agricultural and forestry equipment as well as industrial equipment such as cranes, generators etc. Although referred to as diesel engines, these standards apply to diesel cycle (also known as compression ignition cycle) engines. While standards under this category apply, for the most part to diesel engines, these standards could also apply to alternative fueled engines (e.g., natural gas) that operate over a compression ignition cycle.

In 1998, the U.S. EPA set new emissions standards for non-road diesel engines [20] . The new emissions standards were part of a three-tiered progression of emissions standards. The first tier of emissions standards, termed "Tier 1" standards were adopted in 1994 for engines over 37 kW and were phased in from 1996 through 2000. The 1998 EPA rule making established Tier 1 emissions standards for engines under 37 kW that were phased-in between 1999 and 2000. In addition, the EPA established the next tier of emissions standards, "Tier 2", for all engine sizes in this category which will be phased-in, by power rating, from 2001 to 2006. EPA has also established a more stringent level of emissions standards, "Tier 3", for engines rated between 37 kW and 560 kW which also will be phased-in by power rating, from 2006 to 2008.

The emissions standards for engines within this category establish different HC, NOx (or NMHC+NOx), CO and PM limits, on a brake specific basis (i.e., g/kW-hr), as a function of engine power rating. The individual emissions standards correspond to one of nine engine power classifications, ranging from engines rated less than 8 kW up through engines rated at more than 560 kW. These standards are independent of the intended engine application (e.g., a 150 kW engine would be subject to the same emissions standard, whether it was destined for construction or agricultural equipment). In addition to the exhaust emissions limits, these rules also contain smoke standards for most engines falling within this category.

Overall, the Tier 2 and 3 standards are expected to approximate the level of control anticipated from the existing on-road heavy-duty diesel engine emissions standards. The

Tier 2 standards are intended to generally parallel the 1998 model-year on-road engine standards whilst the Tier 3 standards are intended to generally parallel the 2004 on-road standards. EPA has estimated that the Tier 2 and Tier 3 standards will reduce NOx and PM emissions from a typical non-road diesel engine by as much as two-thirds from the levels of previous standards.

EPA has revised its ABT for this category of engines to reflect the changes contained in its 1998 rule making. The revised ABT program will permit engine manufacturers to obtain emissions credits based for the combined NMHC+NOx emissions and for PM emissions. Other features of the revised program include:

- In recognition of the trade-off between NOx and PM, manufacturers will not be allowed to generate emissions credits against the applicable standard for one pollutant while using credits against the applicable standard for another pollutant on the same engine family; and
- The program will distinguish between those engines rated above 37 kW and those at or below 37 kW. The program will permit the exchange of credits within either of these categories (i.e., above / below 37 kW), however there are certain restrictions on trading credits for engines within the Below-37 kW category.

In addition to establishing emissions standards for new diesel engines, EPA has established anti-tampering provisions aimed at parties rebuilding or re-manufacturing engines covered under these standards. These provisions respond to concerns that during an engine rebuild, there may not be an incentive to check or repair emissions controls, or alternatively, to rebuild the engine to its original configuration.

EPA has also established a voluntary set of standards that may be used to earn the designation "Blue Sky Series" of low emitting engines. This facility was designed to encourage the early introduction of engines designed to align with the Tier 3 emission levels during the Tier 2 engine roll out.

EPA indicated at the time of its 1998 rule making that it intended to complete a review of the standards in 2001. This review would provide an opportunity to examine on-going progress and technological developments with respect to diesel engine development as well as reassess the appropriateness of the Tier 2 standards for engines rated under 37 kW and the Tier 3 standards for engines rated between 37 and 560 kW. The review would also look at PM standards for Tier 3 standards. The results of this review could lead to adjustments to the standards.

Miscellaneous

The EPA announced, in January, 1999, that it intends to propose regulations for large non-road SI engines [21] . Presently, non-road SI engines rated above 19 kW and SI engines used in land-based recreational applications are not subject to federal emissions standards in the U.S. Examples of non-road engines falling into this category include engines used to power industrial equipment, such as forklifts, construction equipment, agricultural equipment, etc., similar to those found under the diesel non-road section, as well as all-terrain vehicles (ATVs), etc.

Many of the engines that could potentially fall under this category are similar to automotive base designs. However, while engines used in automotive applications have benefited through the application of new and advanced emissions control technologies, there has been relatively little change in the case of such engines destined for non-road applications. Future U.S. federal emissions standards for engines in this category could be comparable to the emissions standards established by the California Air Resources Board for this category of engines and would likely take effect in the U.S. in 2004 [22] .

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