



Program Update

Reducing Air Pollution from Nonroad Engines

In response to environmental and public health concerns, the U.S. Environmental Protection Agency (EPA) has established emission standards for most categories of nonroad engines. These engines operate in a wide variety of applications, including construction equipment, marine vessels, lawn and garden equipment, and locomotives. As a whole, these emission-control programs significantly reduce the impact of nonroad engines and equipment on the nation's air quality.

Background

Since the early 1970s, EPA has set increasingly stringent emission standards for highway cars and trucks. After making much progress in controlling highway emissions, the Agency turned to the wide variety of nonroad engines, which also contribute significantly to air pollution. These emission standards reduce harmful air pollution and help states meet the National Ambient Air Quality Standards, as required by the Clean Air Act.

“Nonroad” is a term that covers a diverse collection of engines, equipment, vehicles, and vessels. Sometimes referred to as “off-road” or “off-highway,” the nonroad category includes outdoor power equipment, recreational vehicles, farm and construction machinery, lawn and garden equipment, marine vessels, locomotives, and many other applications.¹ Until the mid-1990s, emissions from these engines were largely uncontrolled.

The 1990 amendments to the Clean Air Act directed EPA to study the contribution of nonroad engines to urban air pollution, and regulate them if they contributed to air quality problems. In 1991, EPA published a report showing that nonroad equipment emitted large amounts of nitrogen oxides (NO_x), hydrocarbons (HC), carbon monoxide (CO) and particulate matter (PM). In general, the report showed that nonroad engines had total emissions almost as high as highway motor vehicles. In the case of diesel particulate matter, nonroad emissions were significantly higher than highway emissions.²

In response, EPA has adopted emission standards for most categories of new nonroad engines. The following sections summarize the status of these programs for the various nonroad equipment categories.

Land-Based Diesel Engines

Diesel engines dominate the market for nonroad engines. They currently contribute about 44 percent of diesel PM emissions and 12 percent of total NO_x emissions from mobile sources nationwide.³ Examples of land-based nonroad applications using diesel engines include the following: construction equipment such as backhoes, agricultural equipment such as tractors, material handling equipment such as heavy forklifts, industrial equipment such as airport service vehicles, and utility equipment such as generators and pumps.

In 1994, EPA adopted the first set of emission standards (“Tier 1”) for all new nonroad diesel engines greater than 37 kilowatts (50 horsepower), except those used in locomotives and marine vessels.⁴ The Tier 1 standards were phased in for different engine sizes between 1996 and 2000, reducing NO_x emissions from these engines by 30 percent.

EPA has since adopted more stringent emission standards for NO_x, HC, and PM from new nonroad diesel engines. This program includes the first set of standards for nonroad diesel engines less than 37 kW (phasing in between 1999 and 2000), including marine engines in this size range. It also phases in more stringent “Tier 2” emission standards from 2001 to 2006 for all engine sizes and adds yet more stringent “Tier 3” standards for engines between 37 and 560 kW (50 and 750 hp) from 2006 to 2008. These standards will further reduce nonroad diesel engine emissions by 60 percent for NO_x and 40 percent for PM from Tier 1 emission levels.

Recent developments of advanced emission-control technologies have made it possible to consider an new round of standards, with the potential to reduce PM and NO_x emissions by an additional 90 percent. These technologies can be damaged by sulfur in diesel fuel, so EPA has proposed a comprehensive program for low-sulfur fuels in combination with the more stringent emission standards, with a plan to finalize these requirements in 2004.

Land-Based Spark-Ignition Engines

EPA divided land-based spark-ignition engines into three broad categories—(1) small engines typically used for lawn and garden applications, (2) large engines used in industrial applications, and (3) specialty engines used in recreational applications

Small SI Engines

Nonroad spark-ignition engines below 19 kW (25 horsepower), which usually run on gasoline, are used primarily in lawn and garden equipment. Lawnmowers, string trimmers, leaf blowers, chain saws, commercial turf equipment, and lawn and garden tractors fall within this category, but engines used for marine propulsion, recreational vehicles, or hobby applications (such as remote-control airplanes) are treated separately. These engines currently contribute about 16 percent of HC emissions and 21 percent of CO emissions from mobile sources nationwide.

Under Phase 1 regulations, new Small SI engines have been meeting standards for HC, CO, and NO_x emissions since 1997. The Phase 1 standards have resulted in a 32 percent reduction in HC levels from these engines.

EPA adopted Phase 2 standards for Small SI engines in two separate rulemakings:

- For nonhandheld applications (such as lawn and garden tractors and lawnmowers), the second set of emission standards phases in between 2001 and 2007 and will result in an additional 60 percent reduction in HC and NO_x emissions.
- For handheld applications (such as leaf blowers and chainsaws), the second set of emission standards phases in between 2002 and 2007 and will result in an additional 70 percent reduction in HC and NO_x emissions.

Standards requiring control of evaporative emissions do not yet apply to Small SI engines.

Large SI Engines

Nonroad SI engines above 19 kW (25 hp), which are usually car and truck engines installed in industrial equipment, are used in many different applications, including forklifts, airport service equipment, generators, compressors, welders, aerial lifts, and ice-grooming machines. These engines—which may operate on liquefied petroleum gas, gasoline, or natural gas—currently contribute about 2 percent of NO_x emissions, and 3 percent of HC and CO emissions from mobile sources nationwide. Many of them operate indoors, where high exhaust concentrations can expose workers to elevated levels of CO emissions.

EPA has adopted emission standards for Large SI engines that take effect for new engines starting in 2004. Manufacturers will rely on well-established emission-control technologies from automotive engines, including three-way catalysts and electronic fueling systems, to meet these emission standards. Starting in 2007, manufacturers will need to use optimized engines, including new diagnostic systems, to meet more stringent standards calling for a 90-percent reduction in NO_x, HC, and CO emissions. Additional control technologies will reduce evaporative HC emissions from gasoline fuel tanks.

Recreational Vehicles

This category includes off-highway motorcycles, all-terrain vehicles, and snowmobiles that operate on gasoline. This category may also include some motorized scooters, mini-bikes, and mopeds. Recreational vehicles currently contribute about 5 percent of HC emissions and 2 percent of CO emissions from mobile sources nationwide. These estimated HC emissions include combined exhaust and evaporative emissions. In November 2002, EPA adopted emission standards for new recreational vehicles that will be phased in starting in 2006. These new standards will reduce HC emissions from these vehicles by 67 percent and will reduce CO emissions by 28 percent. Manufacturers are likely to meet the new standards primarily by increasing their use of 4-stroke engine technology. Manufacturers are also likely to use advanced two-stroke engine system designs in some applications. In addition, improved materials and barrier treatments will reduce the permeation of gasoline through fuel tanks and hoses.

Marine Engines and Vessels

A wide variety of engines are used in marine applications, including gasoline engines for personal watercraft and outboard applications and diesel engines used on recreational and commercial vessels ranging from tugboats to very large ocean-going vessels. Because it is not possible to

apply the same set of standards to all of these applications, EPA has divided programs for reducing marine engine emissions into two broad categories: (1) marine spark-ignition engines, including outboard engines and personal watercraft, as well as gasoline-fueled sterndrive and inboard engines and (2) marine diesel engines, including auxiliary engines and both recreational and commercial propulsion engines.

Marine Spark-ignition Engines

These engines, many of which have typically used simple two-stroke technology, contribute about 10 percent of HC and 3 percent of CO emissions from mobile sources nationwide. However, their contribution to total emissions in and around marinas and harbors is significantly higher. Also, CO in the exhaust from these engines poses an ongoing safety threat to boaters.

Emission standards for outboard and personal watercraft engines call for manufacturers to meet increasingly stringent HC levels over a nine-year phase-in period starting in 1998. By 2006, manufacturers will produce all their engines with 75 percent lower HC emissions on average. The gradually decreasing emission standard lets manufacturers determine the best approach to achieving the targeted reductions over time by allowing them to phase in the types of control technologies in the most sensible way, while minimizing the cost impact to the consumer.

Sterndrive and inboard gasoline engines typically use four-stroke automotive engines that have been modified for sport boats. Uncontrolled emission levels from these engines are usually considerably lower than from outboard engines, but there is still an opportunity to significantly reduce NO_x, HC, and CO emissions. EPA is in the process of developing emission standards that would require manufacturers to use catalysts and other available emission-control technology on their new engines.

In addition, EPA has proposed requirements that would address evaporative emissions from all types of vessels using gasoline engines. These requirements would reduce venting of evaporated gasoline from fuel tanks and reduce the permeation of fuel through the walls of fuel tanks and hoses.

Marine Diesel Engines

Marine diesel engines are used for propulsion and auxiliary power in a variety of marine applications, including recreational yachts, fishing boats, tug and towboats, dredgers, and coastal and ocean-going vessels. These engines currently contribute about 8 percent of NO_x emissions and 9 percent of diesel PM emissions from mobile sources, though the contribution is greater in areas with commercial ports.

Internationally, emissions from marine diesel engines are controlled by Annex VI of the International Convention for the Prevention of Pollution from Ships (known as the MARPOL convention). The NO_x limits, contained in Regulation 13 of Annex VI apply to marine diesel engines rated above 130 kW and are similar in stringency to the first tier of emission standards adopted for land-based nonroad diesel engines (described above). These standards apply to any engine rated above 130 kW installed on a vessel constructed on or after January 1, 2000. The standards are also triggered if an engine is substantially modified (it is adjusted in such a way that its emissions may be increased) on or after January 1, 2000, regardless of when the engine was made or installed on a vessel. As of the date of this publication, the international standards have not yet gone into effect. However, EPA adopted requirements earlier this year to make these standards enforceable beginning January 2004 for engines above 2.5 liters per cylinder installed on vessels flagged in the United States. The MARPOL standards are expected to be enforceable back to January 1, 2000 for all vessels, once enough nations have ratified the Annex for it to go into effect.

In addition to the international standards, EPA has adopted more stringent national standards for certain categories of marine diesel engines installed on vessels flagged in the United States. The levels of the standards and their application dates vary depending on engine size:

- Engines below 37 kW: the standards are the same as for land-based nonroad diesel engines of that size, and begin in 1999 or 2000 for Tier 1 and 2004 or 2005 for Tier 2, depending on engine size.
- Engines above 37 kW with per-cylinder displacement below 5 liters: these are Category 1 marine diesel engines. The national standards begin in 2004 or 2005, depending on engine size; the MARPOL standards apply voluntarily until then for engines above 130 kW.
- Engines with per-cylinder displacement between 5 and 30 liters: these are Category 2 marine diesel engines. The national standards begin in 2007; the MARPOL standards apply voluntarily until 2004, and are mandatory from 2004 until 2007.
- Engines with per-cylinder displacement above 30 liters: these are Category 3 marine diesel engines and are subject only to the MARPOL standards. These standards are voluntary until 2004 and mandatory after 2004.
- Recreational marine diesel engines: these are marine diesel engines with per-cylinder displacement up to 5 liters per cylinder used in recreational vessels. They are subject to the same numerical standards as Category 1 marine diesel engines, beginning in 2006.

In the February 2003 rulemaking related to marine diesel engines, EPA made a commitment to consider additional standards for Category 3 marine diesel engines and to finalize standards by April 27, 2007. That rulemaking may also include more stringent standards for Category 1 and Category 2 marine diesel engines.

Locomotives

Locomotives contribute about 7 percent of NO_x emissions and 5 percent of diesel PM emissions from mobile sources nationwide. These engines are generally larger than any land-based nonroad diesel engines in displacement volume and total power and may last for 40 years or longer. New emission standards will reduce NO_x emissions by two-thirds, while HC and PM emissions from these engines will decrease by 50 percent.

EPA has adopted three separate sets of emission standards, with the standards taking effect depending on the date a locomotive is first manufactured.

- The first set of standards (Tier 0) apply to locomotives and locomotive engines originally manufactured from 1973 through 2001 any time they are manufactured or remanufactured. This unique feature of the locomotive program is critical, because locomotives are generally remanufactured five to ten times during their total service lives of 40 years or more.
- The second set of standards (Tier 1) apply to locomotives and locomotive engines originally manufactured from 2002 through 2004. These locomotives and locomotive engines must meet the Tier 1 standards at the time of original manufacture and at each subsequent remanufacture.
- The final set of standards (Tier 2) apply to locomotives and locomotive engines originally manufactured in 2005 and later. Tier 2 locomotives and locomotive engines must meet the applicable standards at the time of original manufacture and at each subsequent remanufacture.

Aircraft

Aircraft emissions contribute about 1 percent of NO_x emissions and 2 percent of HC emissions from mobile sources nationwide. Some cities with high airport traffic see a more pronounced impact from these en-

gines. In addition, commercial aircraft emissions are a fast-growing segment in the transportation sector. Aircraft emissions also include greenhouse gases and may contribute significantly to depletion of the stratospheric ozone layer.

Emission standards for gas turbine engines that power civil aircraft have been in place for about 20 years. These engines are used in virtually all commercial aircraft, including both scheduled and freight airlines. The standards do not apply to general aviation or military aircraft. Controls on engine smoke and prohibitions on fuel venting were established in 1974 and have been revised several times since then. Gas turbine engines have been subject to limits on hydrocarbon emissions for each landing and takeoff cycle since 1984.

The International Civil Aviation Organization (ICAO) plays an important role in defining uniform emission standards that can be adopted by individual nations. In May 1997, EPA adopted ICAO's NO_x and CO emission standards for gas turbine engines. In addition, EPA plans in the near future to adopt a second round of more stringent ICAO NO_x standards for gas turbine engines for implementation in 2004.

EPA is also exploring other ways to reduce air pollution from air transportation. Since 1998, EPA and the Federal Aviation Administration have jointly chaired a national stakeholder initiative to reduce aviation emissions through a voluntary program. Stakeholders include airlines, aircraft engine manufacturers, airports, state and local air pollution control officials, and environmental organizations. The stakeholder initiative has narrowed its focus to a two-step program—near-term emission reductions from ground-service equipment and longer-term reductions from aircraft. If stakeholders are able to reach an agreement for voluntary reductions, this would represent a big step toward establishing a comprehensive national program to reduce aviation-related emissions.

For More Information

You can access additional documents on nonroad engine programs on the Office of Transportation and Air Quality (OTAQ) Web site at:

www.epa.gov/otaq/nonroad.htm

You can also contact the OTAQ library for document information at:

U. S. Environmental Protection Agency
OTAQ Library
2000 Traverwood Drive
Ann Arbor, Michigan 48105
(734) 214-4311

The following additional fact sheets go into more detail on these nonroad engine control programs:

General:

- *How to Maintain or Rebuild Engines Certified to EPA Standards* (EPA420-F-02-035), September 2002.
- *Blue Sky Series Engines* (EPA420-F-02-036), September 2002.
- *Emission Regulations for Stationary and Mobile Engines* (EPA420-F-02-034), September 2002.

Land-Based Diesel Engines:

- *Summary of EPA's Proposed Program for Low-Emission Nonroad Engines and Fuel* (EPA420-F-03-008), April 2003.
- *Public Health and Environmental Benefits of EPA's Proposed Program for Low-Emission Nonroad Diesel Engines and Fuel* (EPA420-F-03-010), April 2003.
- *New Emission Standards for Nonroad Diesel Engines* (EPA420-F-98-034), August 1998.

Small Spark-Ignition Engines:

- *Final Phase 2 Standards for Small Spark-Ignition Handheld Engines* (EPA420-F-00-007), March 2000.
- *New Phase 2 Standards for Small Spark-Ignition Nonhandheld Engines* (EPA420-F-99-008), March 1999.
- *Small Engine Emission Standards—Answers to Commonly Asked Questions from Dealers and Distributors* (EPA420-F-98-025), September 1998.
- *Be a Grower, Not a Mower* (EPA420-F-96-018), April 1997.

Recreational Vehicles and Large Spark-ignition Engines:

- *Emission Standards for New Nonroad Engines* (EPA420-F-02-

037), September 2002. This fact sheet describes new emission standards for recreational vehicles, Large SI engines, and recreational marine diesel engines.

- *Environmental Impacts of Newly Regulated Nonroad Engines* (EPA420-F-02-033), September 2002.
- *Frequently Asked Questions from ATV Riders* (EPA420-F-02-038), September 2002.
- *Frequently Asked Questions from Off-highway Motorcycle Riders* (EPA420-F-02-039), September 2002.
- *Frequently Asked Questions from Snowmobile Riders* (EPA420-F-02-040), September 2002.
- *Frequently Asked Questions from Facility Managers and Other Owners of Industrial Spark-ignition Engines* (EPA420-F-02-041), September 2002.
- *Emission Exemption for Racing Motorcycles and Other Competition Vehicles* (EPA420-F-02-045), September 2002.

Marine Spark-Ignition Engines:

- *Organization of Gasoline and Diesel Marine Engine Emission Standards* (EPA420-F-99-046), December 1999.
- *Emission Standards for New Gasoline Marine Engines* (EPA420-F-96-012), August 1996.
- *Emission Standards for New Spark-Ignition Marine Engines: Information for the Marine Industry* (EPA420-F-96-013), August 1996.
- *Boating Pollution Prevention Tips* (EPA420-F-96-003), July 1996.

Marine Diesel Engines:

- *Emission Standards Adopted for New Marine Diesel Engines* (EPA420-F-03-001), January 2003. This fact sheet describes the MARPOL Annex VI standards and their application to engines with per-cylinder displacement over 2.5 liters. These are the only standards that apply to Category 3 engines.
- *MARPOL 73/78 Annex VI Marine Diesel Engine Requirements* (EPA420-F-99-038), October 1999.
- *Emission Standards for New Nonroad Engines* (EPA420-F-02-037), September 2002. This fact sheet describes new emission standards for recreational vehicles, Large SI engines, and recreational marine diesel engines.
- *Frequently Asked Questions from Owners of Recreational Boats*

with Diesel Engines (EPA420-F-02-042), September 2002.

- *Emission Standards for new Commercial Marine Diesel Engines* (EPA420-F-99-043), November 1999. This fact sheet describes the Tier 2 standards that apply to Category 1 and Category 2 marine diesel engines.
- *Emission Standards for Marine Diesel Engines: Scope of Application* (EPA420-F-00-006), February 2000.
- *Responsibilities for Marine Vessel Operators with EPA-Certified Engines* (EPA420-F-99-044), December 1999.
- *Organization of Gasoline and Diesel Marine Engine Emission Standards* (EPA420-F-99-046), December 1999.
- *Reducing Marine Vessel and Port Emissions in the South Coast* (EPA420-F-96-011), July 1996.

Locomotives:

- *Final Emission Standards for Locomotives* (EPA420-F-97-048), December 1997.
- *Requirements for Railroads Regarding Locomotive Exhaust Emission Standards* (EPA420-F-99-036), September 1999.
- *Applicability of Locomotive Emission Standards* (EPA420-F-99-037), September 1999.
- *Federal Preemption of State and Local Control of Locomotives* (EPA420-F-97-050), December 1997.
- *Environmental Benefits of Emission Standards for Locomotives* (EPA420-F-97-049), December 1997.
- *Emission Factors of Locomotives* (EPA420-F-97-051), December 1997.

Aircraft:

- *Evaluation of Air Pollutant Emissions from Subsonic Commercial Aircraft* (EPA420-R-99-013), April 1999.
- *Reducing Aircraft and Airport Emissions in the South Coast* (EPA420-F-96-010), July 1996.
- *Adopted Aircraft Engine Emission Standards* (EPA420-F-97-010), April 1997.

¹ This fact sheet also describes emission standards that apply to aircraft engines, even though EPA does not consider these to be nonroad engines under the Clean Air Act.

² EPA refers to the combined set of highway and nonroad engines as mobile sources. This does not include engines used in stationary

applications, which are regulated by separate programs, usually at the state level.

³ Diesel engines may also be referred to as compression-ignition or CI engines. These engines typically operate on diesel fuel, but other fuels may be also be used. In contrast, spark-ignition (or SI) engines generally operate on gasoline, natural gas, or liquefied petroleum gas.

⁴ The U.S. Mine Safety and Health Administration sets requirements related to emissions from underground mining equipment.