EPA APPROACHES TO DIESEL ENGINE EMISSIONS CONTROLS

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The Environmental Protection Agency (EPA) has several current programs related to diesel engine emission controls, including changes to the National Ambient Air Quality Standards and a variety of proposed and final rules setting new emission standards. If the standards are implemented as proposed, the resulting emission reductions would translate into significant, long-term improvements in air quality in many areas of the U.S. Overall, these programs would provide much-needed assistance to states facing ozone and particulate air quality problems that are causing a range of adverse health effects for their citizens, especially in terms of respiratory impairment and related illnesses.

For current information on several of these and other projects, EPA maintains a large collection of files on its internet home page. This information can be found under http://www.-epa.gov/OMSWWW. EPA also provides a notification service to inform individuals via E-mail messages as new information is posted.

NAAQS

Particulate Matter

EPA finalized new standards for particulate matter (PM) under the national ambient air quality standards (NAAQS). After reviewing hundreds of peer-reviewed scientific studies, the EPA has determined that these changes are necessary to protect public health and the environment. EPA is revising the primary (health-based) PM standards by adding a new annual $PM_{2.5}$ standard set at 15 micrograms per cubic meter ($\mu g/m^{3}$) and a new 24-hour $PM_{2.5}$ standard set at 65 $\mu g/m^3$. EPA is retaining the current annual PM_{10} standard of 50 $\mu g/m^3$ and adjusting the PM_{10} 24-hour standard of 150 $\mu g/m^3$ by changing the form of the standard. EPA is revising the secondary (welfare-based) standards by making them identical to the primary standards. EPA believes that the $PM_{2.5}$ and PM_{10} standards, combined with the Clean Air Act-required regional haze program, will provide protection against the major PM-related welfare effects, including visibility impairment, soiling and materials damage.

EPA is issuing new rules related to PM monitoring requirements under the new standards. One rule addresses the monitoring network design needed for the new $PM_{2.5}$ standards. Other rules establish a new federal reference and equivalent methods for monitoring $PM_{2.5}$. Also, in a separate action, EPA is proposing rules to improve visibility by requiring states to develop programs to help reduce regional haze.

EPA changes the suite of PM_{10} standards by adding two new primary $PM_{2.5}$ standards set at 15 $\mu g/m^3$, annual arithmetic mean, and 65 $\mu g/m^3$, 24-hour average, to provide increased protection against the PM-related health effects found in the community studies. EPA's scientific review concluded that fine particles are a better surrogate for those components of PM most likely linked to mortality and morbidity effects at levels below the previous standards, while high concentrations of coarse fraction particles are linked to effects such as aggravation of asthma. The Clean Air Scientific Advisory Committee made a near unanimous (19 of 21 members) recom-mendation that new standards for $PM_{2.5}$ be added while retaining PM_{10} standards as an indicator for coarse fraction particles.

EPA has set $PM_{2.5}$ standards with 24-hour and annual averaging times to protect against effects from short- and long-term exposure identified in the community studies. In developing a suite of $PM_{2.5}$ standards designed to protect public health, EPA considered the combined effect of the standards rather than an approach that weighed short- and long-term exposure evidence, analyses, and standards independently. EPA concluded that much of the total annual risk associated with short-term exposures is likely to result from days when the PM levels are in the low- to mid-range, below the 24-hour peaks. As a result, lowering a wide range of $PM_{2.5}$ concentrations through an annual standard, as opposed to focusing on controlling peak 24-hour concentrations, is the best way to reduce total $PM_{2.5}$ risk. EPA also believes that the 24-hour standard will provide additional protection for days with high $PM_{2.5}$ concentrations, localized "hot spots," and risks arising from seasonal emissions, such as woodsmoke in the winter.

The final rule establishes a new form for the annual $PM_{2.5}$ standard. Areas will be in compliance with the new annual $PM_{2.5}$ standard when the 3-year average of the annual arithmetic mean $PM_{2.5}$ concentrations, from single or multiple community-oriented monitors, is less than or equal to 15 $\mu g/m^3$. The use of averages from single or multiple community-oriented sites is more closely linked to the underlying health effects information, which relates area wide health statistics to averaged measurements of area wide air quality. EPA believes this more protective annual standard, with the supplemental protection afforded by the 24-hour standard, which is directed at peak concentrations and localized hot spots, will provide a protective target that will reduce area-wide population exposure to fine particles.

For the new 24-hour $PM_{2.5}$ standard, the form is based on the 98th percentile of 24-hour $PM_{2.5}$ concentrations in a year (averaged over 3 years), at the population-oriented monitoring site with the highest measured values in an area. The 24-hour standard will limit peak concentration in areas with high seasonal concentrations and in areas with localized hot spots due to particular sources. This form will reduce the impact of a single high exposure event that may be due to unusual meteorological conditions, and thus would provide a more stable basis for effective control programs. The percentile form compensates for missing data and less-than-every-day monitoring, thereby reducing or eliminating the need for complex procedures previously required for the PM_{10} attainment test. The forms of both the 24-hour and annual standard were adjusted to provide additional protection for community settings with higher than average concentrations within an area.

EPA establishes an annual $PM_{2.5}$ standard level of 15 $\mu g/m^3$, to protect public health with an adequate margin of safety. Although health effects at lower annual concentrations are possible, the evidence for effects at such levels is highly uncertain and the likelihood of significant health risk becomes smaller at concentrations well below the 15 $\mu g/m^3$ level and approaching background levels.

After carefully reviewing public comments on the proposed standards, EPA changed the level of the 24-hour $PM_{2.5}$ standard from 50 $\mu g/m^3$ in the proposal to 65 $\mu g/m^3$. In conjunction with greater protection afforded by the changes to the forms and associated monitoring requirements, EPA believes that a 24-hour $PM_{2.5}$ standard set at 65 $\mu g/m^3$ will provide an appropriate supplement to the annual standard and provides an adequate margin of safety in communities that meet the annual standard, but have infrequent or isolated 24-hour peaks. The resulting suite of PM standards will give greater flexibility to individual sources of pollution while still ensuring that public health is protected.

Based on its assessment of the health and other available information, EPA retains the annual PM_{10} standard of 50 $\mu g/m^3$ to protect against effects from both long- and short-term

exposure to coarse fraction particles.

EPA revises the PM_{10} 24-hour standard of 150 $\mu g/m^3$ by replacing the 1-expected-exceedance form with a 99th percentile form, averaged over 3 years, to protect against short-term exposure to coarse fraction particles. The concentration-based percentile form is a more stable target for control programs and eliminates the need for complex data handling for missing values.

With the addition of fine particle standards, EPA has found that the original quantitative basis for the level of the previous 24-hour PM_{10} standard is no longer appropriate. However, the new health studies and information on coarse particles do not provide a basis for a lower standard level.

Based on careful review of public comments, many of which expressed concern that a 98th percentile might not provide adequate protection against larger particles, EPA changed the form of the PM_{10} 24-hour standard from the 98th percentile to the 99th percentile concentration-based form.

Ozone

EPA has set new national ambient air quality standards for ground-level ozone, the primary constituent of smog. After a lengthy scientific review process, including extensive external scientific review, EPA has determined that these changes are necessary to protect public health and the environment. EPA is phasing out and replacing the previous 1-hour primary ozone standard (health-based) with a new 8-hour standard to protect against longer exposure periods. In establishing the 8-hour standard, EPA is setting the standard at 0.08 parts per million (ppm) and defines the new standard as a "concentration-based" form, specifically the 3-year average of the annual 4th-highest daily maximum 8-hour ozone concentrations.

EPA has also replaced the previous secondary standard (to protect the environment, including agricultural crops, national parks, and forests) with a standard identical to the new primary standard. The 0.12 ppm 1-hour standard will not be revoked in a given area until that area has achieved 3 consecutive years of air quality data meeting the 1-hour standard. The purpose of retaining the current 1-hour standard is to ensure a smooth, legal, and practical transition to the new standard.

EPA concluded that the 1-hour primary standard did not adequately protect the public from adverse health effects. Therefore, EPA replaces the previous standard with an 8-hour standard set at 0.08 ppm; an area will attain the standard when the 3-year average of the annual 4th-highest daily maximum 8-hour concentrations is below 0.08 ppm. As the Clean Air Scientific Advisory Committee unanimously recommended, EPA is changing the ozone standard averaging time to 8-hours. Although 1- to 3-hour and 6- to 8-hour ozone exposures can be addressed through 1-hour or 8-hour standards, the 8-hour standard is more directly associated with the health effects of most concern cited in recent 6- to 8-hour exposure studies. These studies were conducted at more typical exercise levels and at lower exposure levels (0.08 ppm) than the 1-hour studies.

EPA is changing the form of the standard from an expected-exceedance form to a concentration-based form because it more directly relates to ozone concentrations associated with health effects; it avoids exceedances, regardless of size, from being counted equally in the attainment tests. In November 1996, EPA proposed that the annual 3rd-highest daily maximum 8-hour concentrations, averaged over 3 years, be the basis to determine whether or not an area was in attainment with the standards. After carefully examining public comment on the issue, EPA changed the form of the standard from the annual 3rd- to 4th-highest daily maximum concentration. This form will provide greater stability in the designation of areas, consistent with providing

strong public health protections.

In setting the 8-hour standard at 0.08 ppm, the EPA recognizes that since there is no discernible threshold below which no adverse health effects occur, no level would eliminate all risk. Thus, a zero-risk standard is not possible, nor is it required by the Clean Air Act. The selected 0.08 ppm level is based on the judgment that at this level public health will be protected with an adequate margin of safety.

The new 8-hour standard will become effective 60 days after promulgation, while the existing 1-hour standard, for most purposes, will remain in effect until EPA determines that an area has air quality meeting the 1-hour standard.

EPA believes attainment of the new primary standard will substantially protect vegetation. Therefore, EPA is setting the secondary standard identical to the primary standard. Although the Agency is not setting a separate seasonal secondary standard at this time, the Agency is committed to enhancing rural ozone monitoring, working in conjunction with other federal agencies, and considering long-term cumulative effects of ozone on plants as additional information becomes available.

HIGHWAY ENGINE FINAL RULE

EPA is adopting a new combined emission standard for NOx and NMHC for heavy-duty diesel engines used in trucks and buses, beginning in 2004. The new standard represents a NOx level about 50 percent lower than is required for new engines in the 1998 model year, which will significantly assist States in meeting and maintaining National Ambient Air Quality Standards. The consultation and consensus-building activities which EPA undertook in this initiative culminated in widespread support from the engine and trucking industries, States, and the environmental community for the new standard.

In response to the need for additional pollution reduction measures at the national level, EPA held a series of discussions with the California Air Resources Board (CARB) and representatives of the heavy-duty engine manufacturing industry to exchange views on the appropriateness and feasibility of new emission standards for highway and nonroad heavy-duty engines. Based on these discussions, an historic Statement of Principles regarding highway heavy-duty engines was signed by these parties in July 1995. EPA issued an Advance Notice of Proposed Rulemaking on August 31,1995, which requested comment on the Statement of Principles and the Agency's plans to formally propose new heavy-duty engine emission standards consistent with the agreement. EPA formally proposed the standard on June 27, 1996. During the comment period for the rulemaking, stakeholders continued their strong support for the new standards.

The new emission standard is in the form of combined nonmethane hydrocarbons (NMHC) plus NOx and is presented in units of grams emitted per brake horsepower-hour (g/bhp-hr). It applies to diesel engines and becomes effective in model year 2004. Manufacturers have the choice of certifying their engines to either:

2.4 g/bhp-hr NMHC + NOx or
2.5 g/bhp-hr NMHC + NOx with a limit of 0.5 g/bhp-hr on NMHC.

EPA also proposed the above standard for gasoline-fueled engines, but is not finalizing the standard at this time. The Agency is continuing to evaluate new standards for gasoline-fueled engines and is planning a supplemental rulemaking to address gasoline-fueled engines specifically.

EPA is simultaneously adopting provisions to further encourage engine manufacturers to use emission controls that will have a high degree of durability, performing well in use without an unreasonable degree of owner involvement. EPA is finalizing other basic provisions to help encourage the maintenance and repair of emission controls after the end of regulatory

life is reached and to ensure that emission controls are addressed properly during engine rebuilding.

EPA is finalizing changes to the averaging, banking, and trading program to enhance the feasibility and cost-effectiveness of the standards and encourage the early introduction of cleaner engines, thus securing emission benefits earlier than would otherwise be the case.

A technology review will be undertaken in 1999 to assess industry progress and propose changes in the standards if necessary. The potential role of fuels in achieving low heavy-duty engine emissions is being evaluated now as part of a technical working group comprised of representatives from EPA, the engine manufacturers, the oil industry and other stakeholders. The results of these technical evaluations will be considered as a part of the 1999 technology review.

The new standard is expected to reduce NOx emissions from highway heavy-duty engines by 50 percent relative to the 1998 standard. In 2020, EPA projects a reduction of 1,082,000 tons per year in ozone precursors and about 43,000 tons per year of secondary nitrate PM. EPA estimates resulting near-term retail price increases between $260 and $470 per vehicle, with costs decreasing to half that amount in five years. This represents less than one percent of the cost of most new heavy-duty vehicles.

LAND-BASED NONROAD ENGINE PROPOSED RULE

Following the initial effort for highway heavy-duty engines, EPA joined CARB and the engine manufacturers in successfully developing a second Statement of Principles focusing on nonroad engines. EPA issued a Supplemental Advance Notice of Proposed Rulemaking on January 2, 1997 to request comment on the Agency's plans to propose the new emission standards contained in the Nonroad Statement of Principles.

The proposed emission standards for diesel engines include those used in most nonroad applications. The proposal covers nonroad diesel engines and equipment, except for locomotives, commercial marine engines rated above 37 kW (50 hp), and underground mining equipment. The standards, which would be implemented in two tiers over several years (1999-2008), represent a major improvement from the recently implemented first tier of nonroad engine standards and would reduce those standards by up to two-thirds (see Table 1).

The proposal includes many of the provisions developed for the rulemaking for highway engines described above, including requirements related to engine rebuilding, changes to the averaging, banking, and trading program, and a technology review that will be undertaken in 2001.

In addition, EPA is proposing (1) related provisions intended to ensure compliance with the new standards in the field, (2) flexibility provisions to ease compliance for manufacturers of the equipment into which these engines are installed, and (3) a program of voluntary standards for engines with superior control of emissions.

CI MARINE

Compression-ignition marine engines include small auxiliary and propulsion engines, medium-sized propulsion engines on coastal and harbor vessels, and very large propulsion engines on ocean-going vessels. The contribution of this source to the average national mobile source NOx inventory is approximately 2.5 percent, though the contribution is much greater in areas with commercial ports. Emissions from diesel marine engines are virtually unregulated at this time. This will change in the near future, as a result of regulatory efforts at international and national levels.

At the international level, emissions from marine vessels will be regulated by Annex VI of the International Convention on the Prevention of Pollution from Ships (MARPOL). The International Maritime Organization has been working on Nox emission standards from these vessels to be finalized in September 1997. The standards will achieve a 30 percent reduction over uncontrolled levels, and will apply beginning January 1, 2000 to all engines on all vessels used in international voyages, as well as large engines used on marine vessels that operate only domestically. On the national level, smaller domestic vessels not covered by MARPOL will be subject to a new set of CI marine engine regulations currently being developed by EPA.

LOCOMOTIVE PROPOSAL

Since locomotive emissions have not been regulated before, EPA faced the need to create a comprehensive program, including not only emission standards, but also test procedures and a full compliance program. In general terms, the overall program is similar to previously established programs for heavy-duty highway engines and other nonroad engines. One unique feature included for locomotives, however, is the regulation of the engine remanufacturing process, including the remanufacture of locomotives originally manufactured prior to the effective date of this rulemaking. Regulation of the remanufacturing process is critical because locomotives are generally remanufactured 5 to 10 times during their total service lives (typically 40 years or more). Standards that only applied to locomotives originally manufactured after the effective date of the rule would not achieve significant emission reductions in the near term, since those locomotives slowly replace the existing fleet.

Three separate sets of emission standards are proposed, with applicability of the standard dependent on the date a locomotive is first manufactured. The first set of standards (Tier 0) are proposed to apply to locomotives and locomotive engines originally manufactured from 1973 through 1999, any time they are remanufactured in calendar year 2000 or later. The second set of standards (Tier I) apply to locomotives and locomotive engines originally manufactured from 2000 through 2004. These locomotives and locomotive engines would be required to meet the Tier I standards at the time of orginal manufacture and at each subsequent remanufacture. The final set of standards (Tier II) are proposed to apply to locomotives and locomotive engines originally manufactured in 2005 and later. Tier II locomotives and locomotive engines would be required to meet the applicable standards at the time of original manufacture and at each subsequent remanufacture. Electric locomotives, historic steam-powered locomotives, and locomotives originally manufactured before 1973 do not contribute significantly to the emission problem, and thus are not included in this rulemaking.

EPA is proposing a production line testing program that would require manu-facturers and, in some cases, remanufacturers of locomotives to perform production line testing of newly manufactured and remanu-factured locomotives as they leave the point where the manufacturer or remanufacture is completed. The production line testing pro-gram for freshly manufactured units would be based on actual testing, while the program for remanufactured units would be based on an audit of the remanufacture kit's installation, with EPA having the ability to require testing if in-use data indicates a possible problem with production.

A critical element in the success of the proposed locomotive program is ensuring that manufacturers and remanufacturers produce locomotives that continue to meet emission standards beyond certification and production stages, during operation and use in the field. EPA is proposing to adopt an in-use compliance program with two distinct components. The first program would require the manufacturers and remanufacturers to test representative locomotives from all engine families using the full Federal Test Procedure. This testing would

occur at about 75 percent of useful life. Actual repair in the event of a determination of noncompliance or recall action, however, would apply to all locomotives of that family, regardless of whether the locomotives have exceeded their useful lives. Second, EPA is proposing to require that Class I railroads annually test 10 perrcent of their locomotives which have met or exceeded their useful lives using a modified version of the Federal Test Procedure.

EPA is proposing averaging, banking, and trading provisions to allow manufacturers and remanufacturers the flexibility to meet overall missions goals at the lowest cost, while allowing EPA to set emission standards at levels more stringent than they would be if each and every engine family had to comply with the standards. Averaging, banking, and trading is also designed to encourage early introduction of cleaner engines, which would secure emission benefits earlier than would otherwise be the case.

EPA is proposing regulation that would codify and clarify Clean Air Act preemption of certain state and local requirements relating to the control of emissions from new locomotives and new locomotive engines. This preemption was included in the Clean Air Act because of the inherent interstate nature of the railroad industry. Moreover, EPA believes that a strong federal program that addresses manufacturing, remanufacturing, and in-use compliance is the best way to achieve the necessary emission reductions.

The primary focus of this rulemaking is on reducing NOx and PM emissions, although there are also reductions in HC and CO. NOx emis-sions from locomotives will be reduced almost 60 percent by 2040, compared to 1990 baseline levels. This would be about 600,000 tons per year. Most of these reductions will come early in the program (e.g., 39 percent reduction by 2010), due to the standards that apply to pre-2000 locomotives when they are remanufactured. In addition to the NOx benefits of the proposed rule, the proposal will provide some PM benefits through the Tier II standards. A PM reduction of 42 percent is expected by 2040, compared to 1994 baseline levels. This reduction is over 10,000 tons per year, and amounts to over one percent of national PM emissions from mobile sources.

LIGHT-DUTY VEHICLES

The Clean Air Act directs EPA to set new emission standards for light-duty vehicles (or passenger cars) and light-duty trucks. Federal Tier 1 emission standards were established for 1994 model year vehicles. Table 2 shows the current Tier 1 and projected Tier 2 emission standards for the various classes of light-duty vehicles and trucks.

The Clean Air Act is very specific for passenger cars and the LDT1 category of light-duty trucks. The Act set the current Tier 1 numbers, which provide a substantial break for diesel engines. The Act also strongly suggests that diesel vehicles meet the same standards as for gasoline starting in the 2004 model year. In separate language, the Act lays out presumptive Tier 2 standards for this category, which would take effect unless EPA justifies some other le. While EPA intends to conduct the study to evaluate the appropriate Tier 2 standards, the language in the Act sets a clear guideline for targeting emission reductions. This study will include considera-tion of the energy and global warming benefits of diesel engines.

The Clean Air Act is less specific about emission standards for the bigger light trucks. Analysis has shown, though, that 70% of light-duty NOx emissions come from light-duty trucks in the LDT2, LDT3, and LDT4 categories. The dominant emission contribution of these ve-hicles can be attributed partly to the less stringent standards and partly to the big increase in population in recent years. For any effective emission reductions, then, EPA will need to focus on

setting more stringent standards for these light trucks.

Table 1
Proposed Land-Based Nonroad Diesel
Engine Emission Standards 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 2
Full Life NOx Standards (g/mi)

Category	Fuel	Current Tier 1	Presumptive Tier 2
LDV, LDT1	gasoline	0.6	0.2
	diesel	1.25	0.2
LDT2, LDT3	gas/diesel	1.0	—
LDT4	gas/diesel	1.5	—