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Final Regulatory Support Document: Control of Emissions from Highway Motorcycles

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Final Regulatory Support Document: Control of Emissions from Highway Motorcycles

Assessment and Standards Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

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Executive Summary

This Final Regulatory Support Document provides economic, technical, cost, and environmental analyses of the new permeation evaporative and exhaust emission standards for highway motorcycles. The anticipated emission reductions will translate into meaningful, long-term improvements in air quality in many areas of the U.S. Overall, the new requirements will reduce individual exposure to dangerous pollutants and provide much needed assistance to states and regions facing ozone and particulate air quality problems that are causing a range of adverse health effects, especially in terms of respiratory impairment and related illnesses.

Chapter 1 reviews information related to the health and welfare effects of the pollutants of concern. Chapter 2 contains an overview of the affected manufacturers, including some description of the range of vehicles/engines involved and their place in the market. Chapter 3 covers a broad description of engine and permeation evaporative emission control technologies, including a wide variety of approaches to reducing emissions. Chapter 4 summarizes the available information specifically providing a technical justification for the feasibility of the standards. Chapter 5 applies cost estimates to the projected technologies. Chapter 6 presents the calculated contribution of these sources to the nationwide emission inventories with and without the new standards. Chapter 7 compares the costs and the emission reductions for an estimate of the cost-effectiveness of the rulemaking. Chapter 8 presents our Small Business Flexibility Analysis, which evaluates the impact of the rule on small businesses.

Market Overview

This regulation is designed to achieve emission reductions from highway motorcycles. Even though there are tangible and intangible benefits associated with reducing emissions from this source, control to the levels in these regulations has generally not been brought about by market forces. From an overall perspective these are a relatively small portion of the overall inventory for HC and NOx. This document will show that technology exists to achieve these significant reductions from motorcycles and demonstrates that this control would be inexpensive on a cost per ton basis. Presented below is a brief summary of the key factors pertaining to this analysis and reference to more substantive discussions in later chapters when available.

Emissions Overview

The primary source of evaporative emissions is permeation through the walls of plastic fuel tanks and rubber hoses. Fewer than ten percent of motorcycles use plastic fuel tanks, although there is an indication that a larger fraction of motorcycles may be using plastic fuel tanks in the future. Motorcycles generally use rubber fuel hose which has permeation rates several orders of magnitude higher than typical automotive fuel lines.

Exhaust emissions from motorcycles have been the subject of a Federal emission control program for about twenty-five years. However, it has been over two decades since EPA last reviewed these requirements. Technology has progressed over these years and indeed the nature of the business and market forces are substantially different. The technology used and available for most highway motorcycles now is far advanced beyond that called for by the 1980 era Federal standards. Thus, there is a need for an update. Also, today, highway motorcycles are predominantly a national and international commodity and importing and exporting of product is the norm. Thus, harmonization of emission standards and control requirements is a key need for industry with the added benefit of lower consumer cost.

Alternatives

In developing the permeation evaporative emission standards we looked at several alternatives for potential emission control strategies and programs. In considering alternatives, we investigated a wide range of technologies and considered various test procedures and implementation dates. In addition, we established a emission credit program designed to give manufacturers flexibility in what technology they use to comply with the standards. As required by section 202(a)(3)(E) of the Clean Air Act (CAA, or "the Act"), we also considered "the need to achieve equivalency of emission reductions between motorcycles and other motor vehicles to the maximum extent practicable."

For permeation emission control of plastic fuel tanks, we identified a number of technologies that could be used to meet the standards. These technologies include surface treatments such as fluorination or sulfonation, low permeability barrier materials, and construction using low permeability materials. In some cases manufacturers will be able to certify to the permeation standards by design, if they elect to do so, by implementing designs consistent with available data. For permeation emission control through hoses, we identify a number of low permeability materials that could be used as either barriers or as construction materials for the fuel lines. Hoses using these materials are used in automotive applications today.

With regard to highway motorcycle exhaust emissions, the alternatives focus primarily on meeting statutory requirements while at the same time tailoring the program to the way motorcycles are produced, sold, and used. The evaluation of program alternatives focused heavily on identifying options that would lead to the largest emission reductions available at the lowest cost taking into account these factors. Consultations with industry made it clear that harmonization with the California program was critical and that international harmonization was also valuable when possible. From the engineering and users perspective, optimal design meant establishing a program which permitted manufacturers and users technology choices to be applied within the program. The alternatives considered by EPA looked at harmonization, lead time, and emission credit averaging programs. For under 50cc motorcycles international harmonization and adequate lead time were key as these drove cost and emission control technology considerations. For 50 cc and larger motorcycles, California harmonization and emission credit averaging had a first order impact on cost and consumer choice. The actual program and control technology options are discussed further in later chapters of this document.

Emission Standards

Evaporative Emissions

We are finalizing new permeation emission standards for motorcycle fuel tanks and hoses that begin in 2008. These standards are presented in Table 1 and represent more than a 90 percent reduction in permeation from new motorcycles.

Table 1
Evaporative Emission Standards

Evaporative Emission Component	Emission Standard	Test Gasoline	Test Temperature
Fuel Tank Permeation	1.5 $g/m^2/day$	10% Ethanol	40°C (104°F)
Hose Permeation	15 $g/m^2/day$	10% Ethanol	23°C (73°F)

Exhaust Emissions

We are adopting new exhaust emission standards for highway motorcycles. Motorcycles come in a variety of two- and three-wheeled configurations and styles, but for the most part they are two-wheeled, self-powered vehicles. Federal regulations currently define a motorcycle as "any motor vehicle with a headlight, taillight, and stoplight and having: two wheels, or three wheels and a curb mass less than or equal to 793 kilograms (1749 pounds)" (see 40 CFR 86.402-98). Note that if any motorcycle or motorcycle-like vehicle that can't be defined as a motor vehicle (for example, if its top speed is less than 25 miles per hour), it would fall under requirements that apply to nonroad recreational vehicles. Highway motorcycles include a category referred to as "dual use" or "dual-sport," meaning that their designs incorporate features that allow riders to use them both for street and off-highway application. Highway motorcycles are operated on public roadways predominantly during warmer weather and often in or near urban areas where they can contribute to ozone formation and ambient CO and PM levels. Table 2 shows the new standards for highway motorcycles.

Table 2
Highway Motorcycle Exhaust Emission Standards

Class	Engine Size (cc)	Implementation Date	HC (g/km)	HC+NOx (g/km)	CO (g/km)
Class I	0-169	2006	1.0	1.4 (optional)	12.0
Class II	170-279	2006	1.0	1.4 (optional)	12.0
Class III	280 and above	2006	—	1.4	12.0
		2010	—	0.8	12.0

Projected Impacts

The following paragraphs and tables summarize the projected emission reductions and costs associated with the new emission standards. See the detailed analysis later in this document for further discussion of these estimates. Table 3 contains the projected emissions from motorcycles. Projected figures compare the estimated emission levels with and without the emission standards (both the exhaust and permeation standards) for 2020.

Table 3
2020 Projected Emissions Inventories
(thousand short tons)

Exhaust and Permeation HC			Exhaust NOx		
base case	with standards	percent reduction	base case	with standards	percent reduction
79	31	61%	14	7	50%

Table 4 summarizes the projected costs to meet the new emission standards. This is our best estimate of the cost associated with adopting new technologies to meet the new emission standards. The analysis also considers total operating costs, including maintenance and fuel consumption. All costs are presented in 2001 dollars.

Table 4
Estimated Average Cost Impacts of the New Emission Standards

Category	Standard Date	Increased Production Cost per Vehicle*	Lifetime Operating Costs per Engine (NPV)
tank permeation hose permeation **aggregate**	2008	\$0.17 \$1.68 **\$1.85**	(\$0.30) (\$6.23) **(\$6.52)**
Highway motorcycles <50cc	2006	\$44	(\$8)
Highway motorcycles >50cc	2006	\$30	—
Highway motorcycles >50cc	2010	\$45**	—

* The estimated long-term costs for highway motorcycles >50cc decrease by about 35 percent.

** Costs presented are incremental to the first-phase standards.

We also calculated the cost per ton of emission reductions for the new standards. We attributed the entire cost of the program to the control of ozone precursor emissions (HC or NOx or both). Table 5 presents the discounted cost-per-ton estimates for the various engines factoring in the effect of reduced operating costs such as fuel savings.

Table 5
Estimated Cost-per-Ton of the New Emission Standards

Engine Type	Date	Pollutant	Discounted Reductions per Vehicle (short tons)	Discounted Cost per Ton	
				Without Fuel Savings	With Fuel Savings
tank permeation hose permeation **aggregate**	2008	HC	0.003 0.017 **0.02**	\$205 \$98 **\$103**	(\$158) (\$265) **(\$260)**
Highway Motorcycles <50cc	2006	HC	0.02	\$2,130	\$1,750
Highway Motorcycles >50cc	2006	HC+NOx	0.03	\$1,150	\$1,150
Highway Motorcycles >50cc	2010	HC+NOx	0.03	\$1,550	\$1,550

Table 6 presents the annualized emission reductions, cost to manufacturers and fuel savings for the twenty year period after the standards take effect based on a seven percent discount rate. Because of the different implementation dates for the exhaust and permeation evaporative emission standards, the aggregate is based on a 22 year (rather than twenty year) annualized cost. Therefore, the aggregate is not equal to the sum of the costs for the two different standards.

Table 6
Estimated Annualized Emission Reductions, Costs to Manufacturers, and Annualized Fuel Savings Due to the New Motorcycle Standards

Standard	Annualized Emission Reductions (tons/year)	Annualized Cost to Manufacturers (millions/year)	Annualized Fuel Savings (millions/year)
Exhaust	18,100 HC+NOx	$32.0	$0.2
Permeation Evap	11,400 HC only	$1.4	$4.2
Aggregate	29,000 HC+NOx	$33.4	$3.7

CHAPTER 1: Air Quality, Health and Welfare Concerns

Highway motorcycles generate a complex mixture of HC and NOx emissions that contribute to the formation of ground-level ozone. Along with SOx emissions from the sulfur content of gasoline, these emissions are also involved in atmospheric transformation of secondary particle formation. Highway motorcycle emissions also contribute to direct PM and air toxic emissions. These pollutants cause a range of adverse health and welfare effects, especially in terms of respiratory impairment and related illnesses. This chapter describes the health and environmental effects related to these emissions. This chapter also presents our estimates of the contribution these engines make to our national air inventory.[1]

Air quality modeling and monitoring data presented in this chapter indicate that a large number of our citizens are affected by these emissions. Based on the most recent monitoring data available (1999-2001), ozone and PM air quality problems are widespread in the United States. There are about 111 million people living in counties exceeding the 8-hour ozone National Ambient Air Quality Standard (NAAQS) and over 70 million people living in counties with $PM_{2.5}$ levels exceeding the $PM_{2.5}$ NAAQS,. Figure 1-1 illustrates the widespread nature of these problems by showing the areas that exceed the 8-hour ozone and the $PM_{2.5}$ NAAQS. Also shown are Class 1 areas, which have particular needs for reductions in haze.

The new federal highway motorcycle emission standards are another component of the effort by Federal, State, local and Tribal governments to reduce the health related impacts of air pollution and to reach attainment of the National Ambient Air Quality Standard (NAAQS) for ozone and PM. They will also help reduce exposure to air toxics and improve other environmental conditions such as atmospheric visibility.

1.1 - Ozone

1.1.1 - General Background

This section reviews health and welfare effects of ozone and describes the air quality information that forms the basis of our conclusion that ozone concentrations in many areas across the country face a significant risk of exceeding the ozone standard into the year 2030. Information on air quality was gathered from a variety of sources, including monitored ozone concentrations from 1999-2001, air quality modeling forecasts conducted for this rulemaking and other state and local air quality information.

Ground-level ozone, the main ingredient in smog, is formed by the reaction of volatile organic compounds (VOCs) and nitrogen oxides (NOx) in the atmosphere in the presence of heat and sunlight. These pollutants, often referred to as ozone precursors, are emitted by many types of pollution sources, including on-highway and nonroad motor vehicles and engines, power plants, chemical plants, refineries, makers of consumer and commercial products, industrial

Figure 1-1. Air Quality Problems are Widespread

Air quality data derived from AQS (1999-2001) with data handling per Agency guidance except PM2.5 data includes monitors with complete data in at least 10 quarters.

facilities, and smaller "area" sources. VOCs are also emitted by natural sources such as vegetation. Hydrocarbons are a set of compounds that are very similar to, but slightly different from, VOCs, and to reduce mobile-source VOC levels we set maximum limits for HC emissions.[2] Oxides of nitrogen are emitted largely from motor vehicles, off-highway equipment, power plants, and other sources of combustion.

The science of ozone formation, transport, and accumulation is complex. Ground-level ozone is produced and destroyed in a cyclical set of chemical reactions involving NOx, VOC, heat, and sunlight. Many of the chemical reactions that are part of the ozone-forming cycle are sensitive to temperature and sunlight. When ambient temperatures and sunlight levels remain high for several days and the air is relatively stagnant, ozone and its precursors can build up and produce more ozone than typically would occur on a single high temperature day. Further complicating matters, ozone also can be transported into an area from pollution sources found hundreds of miles upwind, resulting in elevated ozone levels even in areas with low VOC or NOx emissions. As a result, differences in NOx and VOC emissions and weather patterns contribute to daily, seasonal, and yearly differences in ozone concentrations and differences from city to city.

These complexities also have implications for programs to reduce ozone. For example, relatively small amounts of NOx enable ozone to form rapidly when VOC levels are relatively high, but ozone production is quickly limited by removal of the NOx. Under these conditions, NOx reductions are highly effective in reducing ozone while VOC reductions have little effect. Such conditions are called "NOx-limited." Because the contribution of VOC emissions from biogenic (natural) sources to local ambient ozone concentrations can be significant, even some areas where man-made VOC emissions are relatively low can be NOx-limited.

When NOx levels are relatively high and VOC levels relatively low, NOx forms inorganic nitrates (i.e., particles) but relatively little ozone. Such conditions are called "VOC-limited." Under these conditions, VOC reductions are effective in reducing ozone, but NOx reductions can actually increase local ozone under certain circumstances. Even in VOC-limited urban areas, NOx reductions are not expected to increase ozone levels if the NOx reductions are sufficiently large. The highest levels of ozone are produced when both VOC and NOx emissions are present in significant quantities on clear summer days.

Rural areas are almost always NOx-limited, due to the relatively large amounts of biogenic VOC emissions in such areas. Urban areas can be either VOC- or NOx-limited, or a mixture of both, in which ozone levels exhibit moderate sensitivity to changes in either pollutant.

Ozone concentrations in an area also can be lowered by the reaction of nitric oxide with ozone, forming nitrogen dioxide (NO_2); as the air moves downwind and the cycle continues, the NO_2 forms additional ozone. The importance of this reaction depends, in part, on the relative concentrations of NOx, VOC, and ozone, all of which change with time and location.

1.1.2 - Health and Welfare Effects of Ozone and Its Precursors

Exposure to ambient ozone contributes to a wide range of adverse health effects, which are discussed in detail in the EPA Air Quality Criteria Document for Ozone.[3] Effects include lung function decrements, respiratory symptoms, aggravation of asthma, increased hospital and emergency room visits, increased medication usage, inflammation of the lungs, as well as a variety of other respiratory effects. People who are particularly at risk for high ozone exposures include healthy children and adults who are active outdoors. Susceptible subgroups include children, people with respiratory disease, such as asthma, and people with unusual sensitivity to ozone.

Based on a large number of scientific studies, EPA has identified several key health effects caused when people are exposed to levels of ozone found today in many areas of the country. Short-term (1 to 3 hours) and prolonged exposures (6 to 8 hours) to higher ambient ozone concentrations have been linked to lung function decrements, respiratory symptoms, increased hospital admissions and emergency room visits for respiratory problems.[4, 5, 6, 7, 8, 9] Repeated exposure to ozone can make people more susceptible to respiratory infection and lung inflammation and can aggravate preexisting respiratory diseases, such as asthma.[10, 11, 12, 13, 14] It also can cause inflammation of the lung, impairment of lung defense mechanisms, and possibly irreversible changes in lung structure, which over time could lead to premature aging of the lungs and/or chronic respiratory illnesses, such as emphysema and chronic bronchitis.[15, 16, 17, 18]

Adults who are outdoors and active during the summer months, such as construction workers and other outdoor workers, also are among those most at risk of elevated exposures.[19] This is because they typically are active outside, playing and exercising, during the summer when ozone levels are highest.[20, 21] For example, summer camp studies in the Eastern U.S. and southeastern Canada have reported significant reductions in lung function in children who are active outdoors.[22, 23, 24, 25, 26, 27, 28, 29] Further, children are more at risk of experiencing health effects than adults from ozone exposure because their respiratory systems are still developing. These individuals, as well as people with respiratory illnesses such as asthma, especially asthmatic children, can experience reduced lung function and increased respiratory symptoms, such as chest pain and cough, when exposed to relatively low ozone levels during prolonged periods of moderate exertion.[30, 31, 32, 33]

The 8-hour NAAQS is based on well-documented science demonstrating that more people experience adverse health effects at lower levels of exertion, over longer periods, and at lower ozone concentrations than addressed by the 1-hour ozone standard.[34] Attaining the 8-hour standard will greatly limit ozone exposures of concern for the general population and populations most at risk, including children active outdoors, outdoor workers, and individuals with pre-existing respiratory disease, such as asthma.

New research suggests additional serious health effects beyond those that were known when the 8-hour ozone standard was set. Since 1997, over 1,700 new health and welfare studies have been published in peer-reviewed journals.[35] Many of these studies investigate the impact of ozone exposure on such health effects as changes in lung structure and biochemistry, inflammation of the lungs, exacerbation and causation of asthma, respiratory illness-related school absence, hospital and emergency room visits for asthma and other respiratory causes, and premature mortality. EPA is currently evaluating these and other studies as part of the ongoing review of the air quality criteria and NAAQS for ozone. A revised Air Quality Criteria Document for Ozone and Other Photochemical Oxidants will be prepared in consultation with the EPA's Clean Air Scientific Advisory Committee (CASAC).

Key new health information falls into four general areas: development of new-onset asthma, hospital admissions for young children, school absence rates, and premature mortality. Examples of new studies in these areas are briefly discussed below.

Aggravation of existing asthma resulting from short-term ambient ozone exposure was reported prior to the 1997 decision and has been observed in studies published since.[36, 37] More recent studies now suggest a relationship between long-term ambient ozone concentrations and the incidence of new-onset asthma. In particular, such a relationship in adult males (but not in females) was reported by McDonnell et al. (1999).[38] Subsequently, McConnell et al. (2002) reported that incidence of new diagnoses of asthma in children is associated with heavy exercise in communities with high concentrations of ozone (i.e., mean 8-hour concentration of 59.6 ppb).[39] This relationship was documented in children who played three or more sports and was not statistically significant for those children who played one or two sports.[1] The larger effect of high activity sports than low activity sports and an independent effect of time spent outdoors also in the higher ozone communities strengthened the inference that exposure to ozone may modify the effect of sports on the development of asthma in some children.

Previous studies have shown relationships between ozone and hospital admissions in the general population. A new study in Toronto reports a significant relationship between 1-hour maximum ozone concentrations and respiratory hospital admissions in children under two.[40] Given the relative vulnerability of children in this age category, we are particularly concerned about the findings from the literature on ozone and hospital admissions.

Increased respiratory disease that are serious enough to cause school absences has been associated with 1-hour daily maximum and 8-hour average ozone concentrations in studies conducted in Nevada in kindergarten to 6th grade [41] and in Southern California in grades 4 to 6.[42] These studies suggest that higher ambient ozone levels may result in increased school absenteeism.

The ambient air pollutant most clearly associated with premature mortality is PM, with dozens of studies reporting such an association. However, repeated ozone exposure may be a contributing factor for premature mortality, causing an inflammatory response in the lungs which may predispose elderly and other sensitive individuals to become more susceptible to the adverse health effects of other air pollutants, such as PM.[43, 44] Although the findings in the past have been mixed, the findings of three recent analyses suggest that ozone exposure is associated with increased mortality. Although the National Morbidity, Mortality, and Air Pollution Study (NMMAPS) did not find an effect of ozone on total mortality across the full year, Samet et al. (2000), who conducted the NMMAPS study, did report an effect after limiting the analysis to summer when ozone levels are highest.[45] Similarly, Thurston and Ito (1999) have reported associations between ozone and mortality.[46] Toulomi et al., (1997) reported that 1-hour maximum ozone levels were associated with daily numbers of deaths in 4 cities (London, Athens, Barcelona, and Paris), and a quantitatively similar effect was found in a group of 4 additional cities (Amsterdam, Basel, Geneva, and Zurich).[47]

In 2002, questions were raised about the default convergence criteria and standard error calculations made using generalized additive models (GAM), which has been commonly used in recent time-series epidemiologic studies. A number of time-series studies were reanalyzed using alternative methods, typically GAM with more stringent convergence criteria and an alternative

---

[1] In communities with high ozone (i.e., mean 8-hour concentration of 59.6 ppb) the relative risk of developing asthma in children playing three or more sports was 3.3. (95% CI 1.9 - 5.8) compared with children playing no sports.

model such as generalized linear models (GLM) with natural smoothing splines, and the results of the reanalyses have been compiled and reviewed in a recent Health Effects Institute (HEI) publication.[48] In most, but not all, of the reanalyzed studies, it was found that risk estimates were reduced and confidence intervals increased with the use of GAM with more stringent convergence criteria or GLM analyses; however, the reanalyses generally did not substantially change the findings of the original studies, and the changes in risk estimates with alternative analysis methods were much smaller than the variation in effects across studies. The HEI review committee concluded:

> a. While the number of studies showing an association of PM with mortality was slightly smaller, the PM association persisted in the majority of studies.
> b. In some of the large number of studies in which the PM association persisted, the estimates of PM effect were substantially smaller.
> c. In the few studies in which investigators performed further sensitivity analyses, some showed marked sensitivity of the PM effect estimate to the degree of smoothing and/or the specification of weather.[49]

It is important to note that the estimates derived from the long-term exposure studies and the time-series studies employing generalized linear models or other parametric methods, as well as case-crossover studies, are not affected.

In addition to human health effects, ozone adversely affects crop yield, vegetation and forest growth, and the durability of materials. These effects are discussed in the Ozone Criteria Document and Staff Paper. Because ground-level ozone interferes with the ability of a plant to produce and store food, plants become more susceptible to disease, insect attack, harsh weather and other environmental stresses. Ozone causes noticeable foliage damage in many crops, trees, and ornamental plants (i.e., grass, flowers, shrubs) and causes reduced growth in plants. Studies indicate that current ambient levels of ozone are responsible for damage to forests and ecosystems (including habitat for native animal species). Ozone chemically attacks elastomers (natural rubber and certain synthetic polymers), textile fibers and dyes, and, to a lesser extent, paints. For example, elastomers become brittle and crack, and dyes fade after exposure to ozone.

1.1.3 - Additional Health and Welfare Effects of VOC and NOx Emissions

Volatile organic compounds emissions are detrimental not only for their role in forming ozone, but also for their role as air toxics. Some VOCs emitted from highway motorcycles are toxic compounds. At elevated concentrations and exposures, human health effects from air toxics can range from respiratory effects to cancer. Other health impacts include neurological developmental and reproductive effects. The toxicologically significant VOCs emitted in substantial quantities from the engines that are the subject of this rule are discussed in more detail in Section 1.3, below.

In addition to NOx's role as an ozone and PM precursor, NOx emissions by themselves are associated with a wide variety of other health and welfare effects.[50] [51] Nitrogen dioxide can irritate the lungs and lower resistance to respiratory infection (such as influenza). NOx emissions are an important precursor to acid rain that may affect both terrestrial and aquatic ecosystems. Atmospheric deposition of nitrogen leads to excess nutrient enrichment problems ("eutrophication") in the Chesapeake Bay and several nationally important estuaries along the East and Gulf Coasts. Eutrophication can produce multiple adverse effects on water quality and the aquatic environment, including increased algal blooms, excessive phytoplankton growth, and low or no dissolved oxygen in bottom waters. Eutrophication also reduces sunlight, causing losses in submerged aquatic vegetation critical for healthy estuarine ecosystems. Deposition of nitrogen-containing compounds also affects terrestrial ecosystems. Nitrogen fertilization can alter growth patterns and change the balance of species in an ecosystem. In extreme cases, this process can result in nitrogen saturation when additions of nitrogen to soil over time exceed the capacity of plants and microorganisms to utilize and retain the nitrogen. These environmental impacts are discussed further in Sections 1.5.1 and 1.5.2, below.

Elevated levels of nitrates in drinking water pose significant health risks, especially to infants. Studies have shown that a substantial rise in nitrogen levels in surface waters is highly correlated with human-generated inputs of nitrogen in those watersheds.[52] These nitrogen inputs are dominated by fertilizers and atmospheric deposition. Nitrogen dioxide and airborne nitrate also contribute to pollutant haze, which impairs visibility and can reduce residential property values and the value placed on scenic views.

1.1.4 - Attainment and Maintenance of the 1-Hour and 8-Hour Ozone NAAQS

As illustrated in Figure 1-1, unhealthy ozone concentrations – i.e., those exceeding the level of the 8-hour standard which is requisite to protect public health with an adequate margin of safety – occur over wide geographic areas, including most of the nation's major population centers. Highway motorcycle emissions contribute to ozone precursors in metropolitan areas during the ozone season.

In analyzing ozone concentrations in counties, we calculate design values. An ozone design value is the concentration that determines whether a monitoring site meets the NAAQS for ozone. Because of the way they are defined, design values are determined based on 3 consecutive-year monitoring periods. For example, an 8-hour design value is the fourth highest daily maximum 8-hour average ozone concentration measured over a three-year period at a given monitor. The full details of these determinations (including accounting for missing values and other complexities) are given in Appendices H and I of 40 CFR Part 50. As discussed in these appendices, design values are truncated to whole part per billion (ppb). Due to the precision with which the standards are expressed (0.08 parts per million (ppm) for the 8-hour), a violation of the 8-hour standard is defined as a design value greater than or equal to 0.085 ppm. We follow this convention in these analyses.

For a county, the design value is the highest design value from among all the monitors with valid design values within that county. If a county does not contain an ozone monitor, it does not have a design value. Thus, our analysis may underestimate the number of counties with design values above the level of NAAQS. For the purposes of defining the current design value of a given area, the 1999-2001 design values were chosen to provide the most recent set of air quality data for identifying areas likely to have an ozone problem in the future. The 1999-2001 design values are listed in the air quality technical support document prepared for our recent Notice of Proposed Rulemaking proposing more stringent emission standards for nonroad diesel engines and the diesel fuel used in those engines (the Nonroad proposal, 68 FR 28328, May 23, 2003).[53]

1.1.4.1 - 1-Hour Ozone Nonattainment Areas and Concentrations

The 1-hour ozone NAAQS is 0.12 ppm daily maximum 1-hour concentration, not to be exceeded more than once per year on average. Currently, there are about 114 million people living in 53 1-hour ozone nonattainment areas covering 223 counties.[54]

Table 1.1-1
1-Hour Ozone Extreme and Severe Nonattainment Areas

Nonattainment Area	Attainment Date	2000 Population (millions)	1999-2001 Measured Violation?
Los Angeles South Coast Air Basin, CA[a]	December 31, 2010[a]	14.6	Yes
Chicago-Gary-Lake County, IL-IN	December 31, 2007	8.8	No
Houston-Galveston-Brazoria, TX	December 31, 2007	4.7	Yes
Milwaukee-Racine, WI	December 31, 2007	1.8	No
New York-New Jersey-Long Island, NY-NJ-CT	December 31, 2007	19.2	Yes
Southeast Desert Modified AQMA, CA	December 31, 2007	1.0	Yes
Baltimore, MD	2005	0.8	Yes
Baton Rouge, LA	2005	0.6	Yes
Philadelphia-Wilmington-Trenton, PA-NJ-DE-MD	2005	6.3	Yes
Sacramento, CA	2005	2.0	Yes
San Joaquin Valley, CA	2005	3.2	Yes
Ventura County, CA	2005	0.7	Yes
Washington, DC-MD-VA	2005	4.5	Yes
Total Population	70 million		

[a] Extreme 1-Hour nonattainment areas. All other areas are severe nonattainment areas.
Source: "One-hour Ozone and PM 10 Nonattainment Status and Air Quality Data Update," Memorandum from Patricia Koman to Docket A-2000-2, August 11, 2003, Docket A-2000-02, Document IV-B-07

Of the 53 areas in nonattainment for the 1-hour ozone NAAQS, there are 1 extreme and 12 severe 1-hour ozone nonattainment areas with a total affected population of 70 million. These areas are shown in Table 1.1-1. Each of the areas is adopting additional measures to address specific emission reduction shortfalls in attainment. State Implementation Plans submitted for New York, Houston, the South Coast Basin, Philadelphia, and Baltimore are based on the local ozone modeling and other evidence. The San Joaquin Valley will need additional reductions to attain and maintain the standards. There is some risk that New York will fail to attain the standard by 2007, and thus a transferred risk that Connecticut will also fail. A similar situation exists in Southern California, where attainment of the South Coast is a precondition of the ability of downwind to reach attainment by their respective attainment dates.

The Los Angeles (South Coast Air Basin) ozone attainment demonstration is fully approved, but it is based in part on reductions from new technology measures that have yet to be identified (as allowed under CAA Section 182(e)(5)). The 2007 attainment demonstration for the Southeast Desert area is also approved. However, a transport situation exists between the Southeast Desert areas and the South Coast Air Basin, such that attainment in the Southeast Desert depends on progress in reducing ozone levels in the South Coast Air Basin.

Even if the SIPs were approved and all shortfalls were filled in an area, there would still be a risk that ozone levels in that area could still exceed the NAAQS. EPA's approval of an attainment demonstration generally indicates our belief that a nonattainment area is reasonably likely to attain by the applicable attainment date with the emission controls in the SIP. However, such approval does not indicate that attainment is certain. Moreover, no ozone forecasting is 100 percent certain, so attainment by these deadlines is not certain, even though we believe it is more likely than not. There are significant uncertainties inherent in predicting future air quality, such as unexpected economic growth, unexpected vehicle miles traveled (VMT) growth, the year-to-year variability of meteorological conditions conducive to ozone formation, and modeling approximations. There is at least some risk in each of these areas that even assuming all shortfalls are filled, attainment may not be reached by the applicable dates without further emission reductions. The Agency's mid-course review in the SIP process—as well as the Clean Air Act's provisions for contingency measures—is part of our strategy for dealing with some of these uncertainties, but does not ensure successful attainment.

Many other 1-hour ozone nonattainment areas continue to experience exceedances.[55] Approximately 51 million people are living in counties with measured air quality violating the 1-hour NAAQS in 1999-2001.[2] In addition, the ability of states to maintain the ozone NAAQS once attainment is reached has proved challenging, and the recent recurrence of violations of the NAAQS in some other areas increases the Agency's concern about continuing maintenance of the standard. Recurrent nonattainment is especially problematic for areas where high population growth rates lead to significant annual increases in vehicle trips and vehicle miles traveled (VMT). Moreover, ozone modeling conducted for Nonroad Diesel proposal predicts exceedances in 2020 and 2030 (without additional controls), which adds to the Agency's uncertainty about the prospect of continued attainment for these areas. These highway motorcycle standards will help these areas reduce their levels of ambient ozone concentrations and maintain the NAAQS.

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[2] Typically, county design values (and thus exceedances) are consolidated where possible into design values for consolidated metropolitan statistical areas (CMSA) or metropolitan statistical areas (MSA). Accordingly, the design value for a metropolitan area is the highest design value among the included counties, and counties that are not in metropolitan areas would be treated separately. However, for this section, we examined data on a county basis, not consolidating into CMSA or MSA. Designated nonattainment areas may contain more than one county, and some of these counties are experiencing recent exceedances, as indicated in the table. Further, the analysis is limited to areas with monitors. See US EPA 2003. Air Quality Data Analysis 1999-2001: Technical Support Document for Regulatory Actions. Table 1. Docket Number A-2001-28, Number II-A-196

The serious and extreme 1-hour ozone nonattainment areas described above are expected to need additional reductions to attain the ozone standard. While the standards in this rule will take effect after the date by which some of these areas are expected to attain the ozone standard and will not be fully phased-in until later, they will assist states in maintaining the standard in later years.

1.1.4.2 - 8-Hour Ozone Levels: Current and Future Concentrations

As described above in Section 1.1.2, the 8-hour NAAQS is based on well-documented science demonstrating that more people experience adverse health effects at lower levels of exertion, over longer periods, and at lower ozone concentrations, than addressed by the 1-hour ozone standard.[56] The 8-hour standard greatly limits ozone exposures of concern for the general population and sensitive populations. This section describes the current measured 8-hour concentrations and describes our modeling to predict future 8-hour ozone concentrations.

1.1.4.2.1 - Current 8-hour Ozone Concentrations

Based upon the measured data from years 1999 - 2001, there are 291 counties with measured values that violate the 8-hour ozone NAAQS, with a total affected population of about 111 million.[57] These areas are shown in Figure 1-1. Of these, 61 million people live in counties that meet the 1-hour standard but violate the 8-hour standard. There may be additional areas above the level of the NAAQS for which no monitoring data are available. An additional 37 million people live in 155 counties that have air quality measurements within 10 percent of the level of the standard. Finally, approximately 48 million people lived in counties with at least a week (7 days) of 8-hour ozone concentrations measurements at or above 0.085 ppm in 2000. Approximately 8 million people lived in counties experiencing 20 days and 4 million experienced 40 days of 8-hour ozone concentrations at or above 0.085 ppm in 2000. See the Air Quality Technical Support Document (AQ TSD) prepared for our Nonroad proposal for more details about the counties and populations experiencing various levels of measured 8-hour ozone concentrations.[58]

1.1.4.2.2 - Risk of Future 8-Hour Ozone Violations

Based on our air quality modeling performed for our Nonroad Diesel proposal, we anticipate that there will continue to be a need for reductions in ozone concentrations in the future. In this section we briefly describe that air quality modeling including the non-emission inventory inputs. We then discuss the results of the modeling. This modeling is described in more detail in Chapter 3 of the draft Regulatory Impact Analysis for our Nonroad Diesel proposal.[59]

Method

The air quality modeling performed for our Nonroad Diesel proposal was based upon the same modeling approach used in the EPA's air quality assessment of the Clear Skies legislation, with the addition of updated inventory estimates for 1996, 2020 and 2030. Further discussion of this modeling, including evaluations of model performance relative to predicted future air quality, is provided in the Air Quality Modeling Technical Support Document (AQ Modeling TSD) for our Nonroad Diesel proposal.[60]

The Comprehensive Air Quality Model with Extension (CAMx) was utilized to estimate base and future-year ozone concentrations over the Eastern and Western U.S. for the various emissions scenarios. CAMx simulates the numerous physical and chemical processes involved in the formation, transport, and destruction of ozone. CAMx is a photochemical grid model that numerically simulates the effects of emissions, advection, diffusion, chemistry, and surface removal processes on pollutant concentrations within a three-dimensional grid. This model is commonly used for purposes of determining attainment/non-attainment as well as estimating the ozone reductions expected to occur from a reduction in emitted pollutants.

The regional ozone analyses used the modeling domains are those used previously for the Ozone Transport Assessment Group (OTAG) and the on-highway passenger vehicle Tier 2 rulemaking.

The simulation periods modeled by CAMx included several multi-day periods when ambient measurements were representative of ozone episodes over the eastern and western U.S. A simulation period, or episode, consists of meteorological data characterized over a block of days that are used as inputs to the air quality model. Three multi-day meteorological scenarios during the summer of 1995 were used in the model simulations over the Eastern U.S.: June 12-24, July 5-15, and August 7-21. Two multi-day meteorological scenarios during the summer of 1996 were used in the model simulations over the western U.S.: July 5-15 and July 18-31. In general, these episodes do not represent extreme ozone events but, instead, are generally representative of ozone levels near local design values. Each of the emissions scenarios were simulated for the selected episodes.

The meteorological data required for input into CAMx (wind, temperature, vertical mixing, etc.) were developed by separate meteorological models. For the eastern U.S., the gridded meteorological data for the three historical 1995 episodes were developed using the Regional Atmospheric Modeling System (RAMS), version 3b.

The modeling results provide information on our calculations of the number of people estimated to live in counties in which ozone monitors are predicted to exceed design values or to be within 10 percent of the design value in the future. We also provide specific information about the number of people who would repeatedly experience levels of ozone of potential concern over prolonged periods, i.e., over 0.085 ppm ozone 8-hour concentrations over a number of days.

The determination that an area is at risk of exceeding the ozone standard in the future was made for all areas with current design values greater than or equal to 0.085 ppm (or within a 10 percent margin) and with modeling evidence that concentrations at and above this level will persist into the future. Additional details for this analysis are provided in the AQ TSD and AQ Modeling TSD for the Nonroad Diesel Proposal.[61]

The inventories that underlie the ozone modeling conducted for this rulemaking include reductions from all current or committed federal, State and local controls. The modeling does not examine the prospect of areas attaining or maintaining the ozone standard with possible future controls (i.e., controls beyond current or committed federal, State and local controls). Therefore, Tables 1.1-2 and 1.1-3 below should be interpreted as indicating what areas are at risk of ozone violations in 2020 or 2030 without additional federal or State measures that may be adopted and implemented after this rulemaking is finalized. We expect many of the areas listed in Table 1.1-1 will adopt additional emission reduction programs, but we are unable to quantify or rely upon future reductions from additional State programs since they have not yet been adopted.

Results

Areas presented in Table 1.1-2 and 1.1-3 have monitored 1999-2001 air quality data indicating violations of the 8-hour ozone NAAQS, or are within 10 percent of the standard, and are predicted to have exceedances in 2020 or 2030.

Table 1.1-2 lists the counties with 2020 and 2030 projected 8-hour ozone design values (4th maximum concentration) that violate the 8-hour standard. Counties are marked with an "V" in the table if their projected design values are greater than or equal to 85 ppb. The current 3-year average design values of these counties is also listed. Because we can project future design values only for counties that have current design values, this list is limited to those counties with ambient monitoring data sufficient to calculate current design values.

Table 1.1-2. Counties with 2020 and 2030 Projected Ozone Design Values in Violation of the 8-Hour Ozone Standard[a]

State	County	1999 - 2001 Design Value (ppb)	2020	2030	Population in 2000
CA	Fresno	108	V	V	799,407
CA	Kern	109	V	V	661,645
CA	Los Angeles	105	V	V	9,519,338
CA	Orange	77	V	V	2,846,289
CA	Riverside	111	V	V	1,545,387
CA	San Bernardino	129	V	V	1,709,434
CA	Ventura	101	V	V	753,197
CT	Fairfield	97	V	V	882,567
CT	Middlesex	99	V	V	155,071
CT	New Haven	97	V	V	824,008
GA	Bibb	98	V	V	153,887
GA	Fulton	107	V	V	816,006
GA	Henry	107	V	V	119,341
IL	Cook	88	V	V	5,376,741
IN	Lake	90		V	484,564
MD	Harford	104	V	V	218,590
MI	Macomb	88		V	788,149
MI	Wayne	88	V	V	2,061,162
NJ	Camden	103	V	V	508,932
NJ	Gloucester	101	V	V	254,673
NJ	Hudson	93	V	V	608,975
NJ	Hunterdon	100	V	V	121,989
NJ	Mercer	105	V	V	350,761
NJ	Middlesex	103	V	V	750,162
NJ	Ocean	109	V	V	510,916
NY	Bronx	83			1,332,650
NY	Richmond	98	V	V	443,728
NY	Westchester	92	V	V	923,459
PA	Bucks	105	V	V	597,635
PA	Montgomery	100	V	V	750,097
TX	Galveston	98	V	V	250,158
TX	Harris	110	V	V	3,400,578
WI	Kenosha	95	V	V	149,577
Number of Violating Counties			30	32	
Population of Violating Counties[b]			42,930,060	46,998,413	

[a] Populations are based on 2020 and 2030 estimates from the U.S. Census.

Source: US EPA (2003) Air Quality Data Analysis 1999-2001, Technical Support Document for Regulatory Actions This document is available in Docket A-2001-28, Document No. II-A-196, Appendix A, “Base case.”

Table 1.1-3 lists the counties with 2020 and 2030 projected 8-hour ozone design values that do not violate the annual standard, but are within 10 percent of it. Counties are marked with an "X" in the table if their projected design values are greater than or equal to 77 ppb, but less 85 ppb. Counties are marked with a "V" in the table if their projected design values are greater than or equal to 85 ppb. The current 3-year average design values of these counties are also listed. These are counties that are not projected to violate the standard, but to be close to it.

Table 1.1-3
Counties with 2020 and 2030 Projected Ozone Design Values within Ten Percent of the 8-Hour Ozone Standard[a]

State	County	1999 - 2001 Design Value (ppb)	2020	2030	Population in 2000
AR	Crittenden	92	X	X	50,866
AZ	Maricopa	85	X	X	3,072,149
CA	Kings	98	X	X	129,461
CA	Merced	101	X	X	210,554
CA	Tulare	104	X	X	368,021
CO	Jefferson	81	X	X	527,056
CT	New London	90	X	X	259,088
DC	Washington	94	X	X	572,059
DE	New Castle	97	X	X	500,265
GA	Bibb	98	V	V	153,887
GA	Coweta	96	X	X	89,215
GA	De Kalb	102	X	X	665,865
GA	Douglas	98	X	X	92,174
GA	Fayette	99	X	X	91,263
GA	Fulton	107	V	V	816,006
GA	Henry	107	V	V	119,341
GA	Rockdale	104	X	X	70,111
IL	McHenry	83	X	X	260,077
IN	Lake	90	X	V	484,564
IN	Porter	90	X	X	146,798
LA	Ascension	86	X	X	76,627
LA	Bossier	90	X	X	98,310
LA	Calcasieu	86	X	X	183,577
LA	East Baton Rou	91	X	X	412,852
LA	Iberville	86	X	X	33,320
LA	Jefferson	89	X	X	455,466
LA	Livingston	88	X	X	91,814
LA	St Charles	86	X	X	48,072
LA	St James	83		X	21,216
LA	St John The Ba	86	X	X	43,044

State	County	1999 - 2001 Design Value (ppb)	2020	2030	Population in 2000
LA	West Baton Rou	88	X	X	21,601
MA	Barnstable	96	X	X	222,230
MA	Bristol	93	X	X	534,678
MD	Anne Arundel	103	X	X	489,656
MD	Baltimore	93	X	X	754,292
MD	Cecil	106	X	X	85,951
MD	Harford	104	V	V	218,590
MD	Kent	100	X	X	19,197
MD	Prince Georges	97	X	X	801,515
MI	Benzie	89	X	X	15,998
MI	Macomb	88	X	V	788,149
MI	Mason	91	X	X	28,274
MI	Muskegon	92	X	X	170,200
MI	Oakland	84	X	X	1,194,156
MI	St Clair	85		X	164,235
MO	St Charles	90		X	283,883
MO	St Louis	88		X	1,016,315
MS	Hancock	87	X	X	42,967
MS	Harrison	89	X	X	189,601
MS	Jackson	87	X	X	131,420
NJ	Cumberland	97	X	X	146,438
NJ	Monmouth	94	X	X	615,301
NJ	Morris	97	X	X	470,212
NJ	Passaic	89	X	X	489,049
NY	Bronx	83	X	X	1,332,650
NY	Erie	92	X	X	950,265
NY	Niagara	87	X	X	219,846
NY	Putnam	89	X	X	95,745
NY	Suffolk	91	X	X	1,419,369
OH	Geauga	93	X	X	90,895
OH	Lake	91	X	X	227,511
PA	Allegheny	92	X	X	1,281,666
PA	Delaware	94	X	X	550,864
PA	Lancaster	96	X	X	470,658
PA	Lehigh	96	X	X	312,090
PA	Northampton	97	X	X	267,066
PA	Philadelphia	88	X	X	1,517,550
RI	Kent	94	X	X	167,090
RI	Washington	92	X	X	123,546
TN	Shelby	93	X	X	897,472

State	County	1999 - 2001 Design Value (ppb)	2020	2030	Population in 2000
TX	Brazoria	91	X	X	241,767
TX	Collin	99	X	X	491,675
TX	Dallas	93	X	X	2,218,899
TX	Denton	101	X	X	432,976
TX	Jefferson	85	X	X	252,051
TX	Montgomery	91	X	X	293,768
TX	Tarrant	97	X	X	1,446,219
VA	Alexandria City	88		X	128,283
VA	Arlington	92	X	X	189,453
VA	Fairfax	95	X	X	969,749
WI	Door	93	X	X	27,961
WI	Kewaunee	89	X	X	20,187
WI	Manitowoc	92	X	X	82,887
WI	Milwaukee	89	X	X	940,164
WI	Ozaukee	95	X	X	82,317
WI	Racine	87	X	X	188,831
WI	Sheboygan	95	X	X	112,646
WI	Waukesha	86	X	X	360,767
Number of Counties within 10%			79	82	
Population of Counties within 10%[b]			40,465,492	44,013,587	

[a] Populations are based on 2020 and 2030 estimates from the U.S. Census.
Source: US EPA (2003) Air Quality Data Analysis 1999-2001, Technical Support Document for Regulatory Actions This document is available in Docket A-2001-28, Document No. II-A-196, Appendix A “Base Case.”

This air quality modeling suggests that without emission reductions beyond those already required under promulgated regulations and approved SIPs, ozone nonattainment will likely persist into the future. With reductions from programs already in place, the number of counties violating the ozone 8-hour standard is expected to decrease in 2020 to 30 counties where 43 million people are projected to live. Thereafter, exposure to unhealthy levels of ozone is expected to begin to increase again. In 2030 the number of counties violating the ozone 8-hour NAAQS is projected to increase to 32 counties where 47 million people are projected to live. In addition, in 2030, 82 counties where 44 million people are projected to live will be within 10 percent of violating the ozone 8-hour NAAQS.

Based on our modeling, we are also able to provide a quantitative prediction of the number of people anticipated to reside in counties in which ozone concentrations are predicted for 8-hour periods to be in the range of 0.085 to 0.12 ppm and higher on multiple days. Our analysis relies on projected county-level population from the U.S. Department of Census for the period representing each year analyzed.

For each of the counties analyzed, we determined the number of days for periods on which the highest model-adjusted 8-hour concentration at any monitor in the county was predicted, for example, to be equal to or above 0.085 ppm. We then grouped the counties which had days with ozone in this range according to the number of days this was predicted to happen, and summed their projected populations.

We estimate that in 2020 53 million people are predicted to live in counties with at least 2 days with 8-hour average concentrations of 0.085 ppm or higher. This baseline will increase in 2030 to 56 million people are predicted to live in counties with at least 2 days with 8-hour average concentrations of 0.085 ppm or higher. About 30 million people live in counties with at least 7 days of 8-hour ozone concentrations at or above 0.085 ppm in 2020 and 2030 without additional controls. Approximately 15 million people are predicted to live in counties with at least 20 days of 8-hour ozone concentrations at or above 0.085 ppm in 2020 and 2030 without additional controls.

EPA is still developing the implementation process for bringing the nation's air into attainment with the ozone 8-hour NAAQS. EPA's current plans call for designating ozone 8-hour nonattainment areas in April 2004. EPA is planning to propose that States submit SIPs that address how areas will attain the 8-hour ozone standard within three years after nonattainment designation regardless of their classification. EPA is also planning to propose that certain SIP components, such as those related to reasonably available control technology (RACT) and reasonable further progress (RFP), be submitted within 2 years after designation. We therefore anticipate that States will submit their attainment demonstration SIPs by April 2007. Section 172(a)(2) of the Clean Air Act requires that SIP revisions for areas covered only under subpart 1 of part D, Title I of the Act demonstrate that the nonattainment areas will attain the ozone 8-hour standard as expeditiously as practicable but no later than five years from the date that the area was designated nonattainment. However, based on the severity of the air quality problem and the availability and feasibility of control measures, the Administrator may extend the attainment date "for a period of no greater than 10 years from the date of designation as nonattainment." Based on these provisions, we expect that most or all areas covered under subpart 1 will have to attain the ozone standard in the 2007 to 2014 time frame. For areas covered under subpart 2, the maximum attainment dates will range from 3 to 20 years after designation, depending on an area's classification. Thus, we anticipate that areas covered by subpart 2 will attain in the 2007 to 2024 time period.

The HC and NOx emission reductions expected from the new highway motorcycle standards will assist States in their effort to meet and maintain the 8-hour ozone NAAQS, both for areas that are expected to be in nonattainment and those that are at risk of being in nonattainment in the future.

It should be noted that while reductions in NOx and VOC levels generally and provide significant ozone-related health benefits, this may not always be the case at the local level. Due to the complex photochemistry of ozone production, NOx emissions lead to both the formation and destruction of ozone, depending on the relative quantities of NOx, VOC, and ozone catalysts such as the OH and HO_2 radicals. In areas dominated by fresh emissions of NOx, ozone catalysts are removed via the production of nitric acid which slows the ozone formation rate. Because NOx is generally depleted more rapidly than VOC, this effect is usually short-lived and the emitted NOx can lead to ozone formation later and further downwind. The terms "NOx disbenefits" or "ozone disbenefits" refer to the ozone increases that can result from NOx emissions reductions in these localized areas. According to the NARSTO Ozone Assessment, these disbenefits are generally limited to small regions within specific urban cores and are surrounded by larger regions in which NOx control is beneficial.[62] Historically, NOx reductions have been very successful at reducing regional/national ozone levels.

1.1.5 - Other Ozone Welfare Effects

Ozone at these levels can have other welfare effects, with damage to plants being of most concern. Plant damage affects crop yields, forestry production, and ornamentals. The adverse effect of ozone on forests and other natural vegetation can in turn cause damage to associated ecosystems, with additional resulting economic losses. Prolonged ozone concentrations of 0.10 ppm can be phytotoxic to a large number of plant species, and can produce acute injury and reduced crop yield and biomass production. Ozone concentrations within the range of 0.05 to 0.10 ppm have the potential over a longer duration of creating chronic stress on vegetation that can result in reduced plant growth and yield, shifts in competitive advantages in mixed populations, decreased vigor, and injury. Ozone effects on vegetation are presented in more detail in Chapter 5, Volume II of the 1996 Ozone Criteria Document.

1.2 - Particulate Matter

1.2.1 - General Background

Particulate matter (PM) represents a broad class of chemically and physically diverse substances. It can be principally characterized as discrete particles that exist in the condensed (liquid or solid) phase spanning several orders of magnitude in size. PM_{10} refers to particles with an aerodynamic diameter less than or equal to a nominal 10 micrometers. Fine particles refer to those particles with an aerodynamic diameter less than or equal to a nominal 2.5 micrometers (also known as $PM_{2.5}$), and coarse fraction particles are those particles with an aerodynamic diameter greater than 2.5 microns, but less than or equal to a nominal 10 micrometers. Ultrafine PM refers to particles with diameters of less than 100 nanometers (0.1 micrometers). The health and environmental effects of PM are in some cases related to the size of the particles. Specifically, larger particles (> 10 micrometers) tend to be removed by the respiratory clearance mechanisms whereas smaller particles are deposited deeper in the lungs.

Fine particles are formed in two ways. They can be directly emitted from combustion sources. They can also be formed secondarily from gaseous precursors such as sulfur dioxide, oxides of nitrogen, or organic compounds.[63] These particles are generally composed of sulfate, nitrate, chloride, ammonium compounds, organic carbon, elemental carbon, and metals. Fine particles can remain in the atmosphere for days to weeks and travel through the atmosphere hundreds to thousands of kilometers.

Coarse particles typically result from mechanical crushing or grinding in both natural and anthropogenic sources. They include resuspended dusts, plant material, and crustal material from paved roads, unpaved roads, construction, farming, and mining activities. In contrast to fine particles, coarse particles deposit to the earth within minutes to hours and within tens of kilometers from the emission source.

1.2.2 - Health and Welfare Effects of PM

Scientific studies show ambient PM contributes to a series of adverse health effects. These health effects are discussed in detail in the EPA Air Quality Criteria Document for PM as well as the draft updates of this document released in the past year.[64] In addition, EPA recently released its final "Health Assessment Document for Diesel Engine Exhaust" (the "Diesel HAD"), which also reviews health effects information related to diesel exhaust as a whole including diesel PM, which is one component of ambient PM.[65]

As detailed in these documents, health effects associated with short-term variation in ambient particulate matter (PM) have been indicated by epidemiologic studies showing associations between exposure and increased hospital admissions for ischemic heart disease,[66] heart failure,[67] respiratory disease,[68, 69, 70, 71] including chronic obstructive pulmonary disease (COPD) and pneumonia.[72, 73, 74] Short-term elevations in ambient PM have also been associated with increased cough, lower respiratory symptoms, and decrements in lung function.[75, 76, 77] Short-term variations in ambient PM have also been associated with increases in total and cardiorespiratory daily mortality in individual cities[78, 79, 80, 81] and in multi-city studies.[82, 83, 84]

Studies examining populations exposed to different levels of air pollution over a number of years, including the Harvard Six Cities Study and the American Cancer Society Study suggest an association between exposure to ambient $PM_{2.5}$ and premature mortality.[85, 86] Two studies further analyzing the Harvard Six Cities Study's air quality data have also established a specific influence of mobile source-related $PM_{2.5}$ on daily mortality[87] and a concentration-response function for mobile source-associated $PM_{2.5}$ and daily mortality.[88] Another recent study in 14 U.S. cities examining the effect of PM_{10} on daily hospital admissions for cardiovascular disease found that the effect of PM_{10} was significantly greater in areas with a larger proportion of PM_{10} coming from motor vehicles, indicating that PM_{10} from these sources may have a greater effect on the toxicity of ambient PM_{10} when compared with other sources.[89] Additional studies have associated changes in heart rate and/or heart rhythm in addition to changes in blood characteristics with exposure to ambient PM.[90]

The health effects of PM_{10} are similar to those of $PM_{2.5}$, since PM_{10} includes all of $PM_{2.5}$ plus the coarse fraction from 2.5 to 10 micrometers in size. EPA also evaluated the health effects of PM between 2.5 and 10 micrometers in the draft revised Criteria Document. As discussed in the

Diesel HAD and other studies, most diesel PM is smaller than 2.5 micrometers.[91] Both fine and coarse fraction particles can enter and deposit in the respiratory system.

PM also causes adverse impacts to the environment. Fine PM has been clearly associated with the impairment of visibility over urban areas and large multi-State regions. Other environmental impacts occur when particles deposit onto soils, plants, water or materials. For example, particles containing nitrogen and sulphur that deposit on to land or water bodies may change the nutrient balance and acidity of those environments. Finally, PM causes soiling and erosion damage to materials, including culturally important objects such as carved monuments and statues. It promotes and accelerates the corrosion of metals, degrades paints, and deteriorates building materials such as concrete and limestone. Components of particulate matter (e.g., sulfuric or nitric acid) also contribute to acid deposition, nitrification of surface soils and water eutrophication of surface water.

1.2.3 - PM Nonattainment

1.2.3.1 - Current PM_{10} Nonattainment

The current NAAQS for PM_{10} was first established in 1987. The primary (health-based) and secondary (public welfare based) standards for PM_{10} include both short- and long-term NAAQS. The short-term (24 hour) standard of 150 ug/m^3 is not to be exceeded more than once per year on average over three years. The long-term standard specifies an expected annual arithmetic mean not to exceed 50 ug/m^3 averaged over three years.

Currently, 29 million people live in PM_{10} nonattainment areas, including moderate and serious areas. There are currently 56 moderate PM_{10} nonattainment areas with a total population of 6.6 million.[92] The attainment date for the initial moderate PM_{10} nonattainment areas, designated by law on November 15, 1990, was December 31, 1994. Several additional PM_{10} nonattainment areas were designated on January 21, 1994, and the attainment date for these areas was December 31, 2000.

There are 8 serious PM_{10} nonattainment areas with a total affected population of 22.7 million. According to the Act, serious PM_{10} nonattainment areas must attain the standards no later than 10 years after designation. The initial serious PM_{10} nonattainment areas were designated January 18, 1994 and had an attainment date set by the Act of December 31, 2001. The Act provides that EPA may grant extensions of the serious area attainment dates of up to 5 years, provided that the area requesting the extension meets the requirements of Section 188(e) of the Act. Five serious PM_{10} nonattainment areas (Phoenix, Arizona; Clark County (Las Vegas), NV; Coachella Valley, South Coast (Los Angeles), and Owens Valley, California) have received extensions of the December 31, 2001 attainment date and thus have new attainment dates of December 31, 2006.

Many PM_{10} nonattainment areas continue to experience exceedances. Of the 29 million people living in designated PM_{10} nonattainment areas, approximately 25 million people are living in nonattainment areas with measured air quality violating the PM_{10} NAAQS in 1999-2001. Among these are the seven serious areas listed in Table 1.2-1 and 4 moderate areas: Nogales, AZ, Imperial Valley, CA, Mono Basin, CA, and El Paso, TX.

Table 1.2-1
Serious PM_{10} Nonattainment Areas

Area	Attainment Date	2000 Population	1999-2001 Measured Violation
Owens Valley, CA	December 31, 2006	7,000	Yes
Phoenix, AZ	December 31, 2006	3,111,876	Yes
Clark County, NV (Las Vegas)	December 31, 2006	1,375,765	Yes
Coachella Valley, CA	December 31, 2006	225,000	Yes
Los Angeles South Coast Air Basin, CA	December 31, 2006	14,550,521	Yes
San Joaquin Valley, CA	2001	3,080,064	Yes
Walla Walla, WA	2001	10,000	No
Washoe County, NV (Reno)	2001	339,486	Yes
Total Population	22.7 million		

In addition to these designated nonattainment areas, there are 19 unclassified areas, where 8.7 million live, for which States have reported PM_{10} monitoring data for 1999-2001 period indicating a PM_{10} NAAQS violation. An official designation of PM_{10} nonattainment indicates the existence of a confirmed PM_{10} problem that is more than a result of a one-time monitoring upset or a result of PM_{10} exceedances attributable to natural events. We have not yet excluded the possibility that one or the other of these is responsible for the monitored violations in 1999-2001 in these 19 unclassified areas. We adopted a policy in 1996 that allows areas whose PM_{10} exceedances are attributable to natural events to remain unclassified if the State is taking all reasonable measures to safeguard public health regardless of the sources of PM_{10} emissions. Areas that remain unclassified areas are not required to submit attainment plans, but we work with each of these areas to understand the nature of the PM_{10} problem and to determine what best can be done to reduce it.

1.2.3.2 - Current $PM_{2.5}$ Nonattainment

The NAAQS for $PM_{2.5}$ were established in 1997 (62 Fed. Reg., 38651, July 18, 1997). The short term (24-hour) standard is set at a level of 65 $\mu g/m^3$ based on the 98th percentile concentration averaged over three years. (The air quality statistic compared to the standard is referred to as the "design value.") The long-term standard specifies an expected annual arithmetic mean not to exceed 15 ug/m^3 averaged over three years.

Current $PM_{2.5}$ monitored values for 1999-2001, which cover counties having about 75 percent of the country's population, indicate that at least 65 million people in 129 counties live in areas where annual design values of ambient fine PM violate the $PM_{2.5}$ NAAQS. There are an additional 9 million people in 20 counties where levels above the NAAQS are being measured, but there are insufficient data at this time to calculate a design value in accordance with the standard, and thus determine whether these areas are violating the $PM_{2.5}$ NAAQS. In total, this means that 37 percent of the counties and 64 percent of the national population are in areas with monitored levels above the NAAQS. Furthermore, an additional 11 million people live in 41 counties that have air quality measurements within 10 percent of the level of the standard, with complete data. These areas, although not currently violating the standard, will also benefit from the additional reductions from this rule in order to ensure long term maintenance.

As shown in Table 1.2-2, of the 74 million people currently living in counties with measurements above the NAAQS (15 ug/m^3), 22 million live in counties above 20 ug/m^3. Absent additional controls, our modeling predicts there will continue to be large numbers of people living in counties with PM levels above the standard.

Table 1.2-2
1999/2001 Monitored Population[a] Living in Counties with Annual Average[b] $PM_{2.5}$ Concentrations Shown (70 Percent of Total U.S. Population)

Measured 1999/2000 Annual Average $PM_{2.5}$ Concentration (µg/m3) (A)	Number of Counties Within The Concentration Range	2000 Population Living in Monitored Counties Within The Concentration Range (Millions, 2000 Census Data) (B)	Percent of 2000 Monitored Population Living in Counties Within The Concentration Range[c] (C)
>25	3	12.8	7
>20 <=25	10	9.2	5
>15 <=20	136	52.3	27
<=15	402	115.6	61

[a] Monitored population estimates represent populations living in monitored counties (with community based monitors) based on monitors with at least 10 quarter with at least 11 samples per quarter between 1999 and 2001.
[b] Annual average represents the monitor reading with the highest average in each monitored county.
[c] The monitored population is 189.2 million (as reflected in column C, where C=B/Monitored Population). Total monitored population is 191 million; the Census total county-based 2000 population is 272.7 million.

1.2.3.3 - Risk of Future $PM_{2.5}$ Violations

In conjunction with our Nonroad Diesel proposal, we performed a series of PM air quality modeling simulations for the continental U.S. The model outputs from the 1996, 2020 and 2030 baselines, combined with current air quality data, were used to identify areas expected to exceed the $PM_{2.5}$ NAAQS in 2020 and 2030. These areas became candidates for being determined to be residual exceedance areas which will require additional emission reductions to attain and maintain the $PM_{2.5}$ NAAQS. This modeling supports the conclusion that there is a broad set of areas with predicted $PM_{2.5}$ concentrations at or above 15 ug/m^3 between 1996 and 2030 without additional emission reductions.

The air quality modeling performed for this rule was based upon an improved version of the modeling system used in the HD Engine/Diesel Fuel rule with the addition of updated inventory estimates for 1996, 2020 and 2030. A national-scale version of the REgional Model System for Aerosols and Deposition (REMSAD) was utilized to estimate base and future-year PM concentrations over the contiguous U.S. for the various emissions scenarios. Version 7 of REMSAD was used for this analysis. REMSAD was designed to calculate the concentrations of both inert and chemically reactive pollutants in the atmosphere that affect annual particulate concentrations and deposition over large spatial scales.[3] More detailed information is included in the AQ Modeling TSD for our Nonroad Diesel proposal.[93]

This air quality modeling suggests that the present widespread number of counties with annual averages above 15 ug/m^3 is likely to persist in the future in the absence of additional controls. For example, in 2020 based on emission controls currently adopted or expected to be in place, we project that 66 million people will live in 79 counties with average $PM_{2.5}$ levels at and above 15 ug/m^3. In 2030, the number of people projected to live in areas exceeding the $PM_{2.5}$ standard is expected to increase to 85 million in 107 counties. An additional 24 million people are projected to live in counties within 10 percent of the standard in 2020, which will decrease to 17 million people in 2030.

Table 1.2-3 lists the counties with 2020 and 2030 projected annual $PM_{2.5}$ design values that violate the annual standard. Counties are marked with an "V" in the table if their projected design values are greater than or equal to 15.05 ug/m^3. The current 3-year average design values of these counties are also listed. Recall that we project future design values only for counties that have current design values, so this list is limited to those counties with ambient monitoring data sufficient to calculate current 3-year design values.

Table 1.2-3
Counties with 2020 and 2030 Projected Annual PM2.5
Design Values in Violation of the Annual PM2.5 Standard.[a]

State	County	1999 - 2001 Design Value (ug/m^3)	2020	2030	Population in 2000
AL	De Kalb	16.8		V	64,452

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[3] Given the potential impact of the porposed rule on secondarily formed particles it is important to employ a Eulerian model such as REMSAD. The impact of secondarily formed pollutants typically involves primary precursor emissions from a multitude of widely dispersed sources, and chemical and physical processes of pollutants that are best addressed using an air quality model that employs an Eulerian grid model design.

State	County	1999 - 2001 Design Value (ug/m^3)	2020	2030	Population in 2000
AL	Houston	16.3	V	V	88,787
AL	Jefferson	21.6	V	V	662,047
AL	Mobile	15.3		V	399,843
AL	Montgomery	16.8	V	V	223,510
AL	Morgan	19.1	V	V	111,064
AL	Russell	18.4	V	V	49,756
AL	Shelby	17.2	V	V	143,293
AL	Talladega	17.8	V	V	80,321
CA	Fresno	24	V	V	799,407
CA	Imperial	15.7		V	142,361
CA	Kern	23.7	V	V	661,645
CA	Los Angeles	25.9	V	V	9,519,338
CA	Merced	18.9	V	V	210,554
CA	Orange	22.4	V	V	2,846,289
CA	Riverside	29.8	V	V	1,545,387
CA	San Bernardino	25.8	V	V	1,709,434
CA	San Diego	17.1	V	V	2,813,833
CA	San Joaquin	16.4		V	563,598
CA	Stanislaus	19.7	V	V	446,997
CA	Tulare	24.7	V	V	368,021
CT	New Haven	16.8	V	V	824,008
DE	New Castle	16.6	V	V	500,265
DC	Washington	16.6	V	V	572,059
GA	Bibb	17.6	V	V	153,887
GA	Chatham	16.5	V	V	232,048
GA	Clarke	18.6	V	V	101,489
GA	Clayton	19.2	V	V	236,517
GA	Cobb	18.6	V	V	607,751
GA	De Kalb	19.6	V	V	665,865
GA	Dougherty	16.6	V	V	96,065
GA	Floyd	18.5	V	V	90,565
GA	Fulton	21.2	V	V	816,006
GA	Hall	17.2	V	V	139,277
GA	Muscogee	18	V	V	186,291
GA	Paulding	16.8	V	V	81,678
GA	Richmond	17.4	V	V	199,775
GA	Washington	16.5	V	V	21,176
GA	Wilkinson	18.1	V	V	10,220
IL	Cook	18.8	V	V	5,376,741

State	County	1999 - 2001 Design Value (ug/m^3)	2020	2030	Population in 2000
IL	Du Page	15.4		V	904,161
IL	Madison	17.3	V	V	258,941
IL	St Clair	17.4	V	V	256,082
IL	Will	15.9	V	V	502,266
IN	Clark	17.3	V	V	96,472
IN	Lake	16.3	V	V	484,564
IN	Marion	17	V	V	860,454
IN	Vanderburgh	16.9		V	171,922
KY	Jefferson	17.1	V	V	693,604
KY	Kenton	15.9		V	151,464
LA	East Baton Rouge	14.6		V	412,852
LA	West Baton Rouge	14.1		V	21,601
MD	Baltimore	16		V	754,292
MD	Prince Georges	17.3	V	V	801,515
MD	Baltimore City	17.8	V	V	651,154
MA	Suffolk	16.1	V	V	689,807
MI	Wayne	18.9	V	V	2,061,162
MS	Jones	16.6	V	V	64,958
MO	St Louis City	16.3	V	V	348,189
MT	Lincoln	16.4	V	V	18,837
NJ	Hudson	17.5	V	V	608,975
NJ	Union	16.3		V	522,541
NY	Bronx	16.4	V	V	1,332,650
NY	New York	17.8	V	V	1,537,195
NC	Catawba	17.1	V	V	141,685
NC	Davidson	17.3	V	V	147,246
NC	Durham	15.3		V	223,314
NC	Forsyth	16.2		V	306,067
NC	Gaston	15.3		V	190,365
NC	Guilford	16.3	V	V	421,048
NC	McDowell	16.2		V	42,151
NC	Mecklenburg	16.8	V	V	695,454
NC	Wake	15.3		V	627,846
OH	Butler	17.4	V	V	332,807
OH	Cuyahoga	20.3	V	V	1,393,978
OH	Franklin	18.1	V	V	1,068,978
OH	Hamilton	19.3	V	V	845,303
OH	Jefferson	18.9	V	V	73,894
OH	Lawrence	17.4	V	V	62,319

State	County	1999 - 2001 Design Value (ug/m^3)	2020	2030	Population in 2000
OH	Lucas	16.7	V	V	455,054
OH	Mahoning	16.4		V	257,555
OH	Montgomery	17.6	V	V	559,062
OH	Scioto	20	V	V	79,195
OH	Stark	18.3	V	V	378,098
OH	Summit	17.3	V	V	542,899
OH	Trumbull	16.2		V	225,116
PA	Allegheny	21	V	V	1,281,666
PA	Delaware	15		V	550,864
PA	Philadelphia	16.6	V	V	1,517,550
PA	York	16.3		V	381,751
SC	Greenville	17	V	V	379,616
SC	Lexington	15.6		V	216,014
TN	Davidson	17		V	569,891
TN	Hamilton	18.9	V	V	307,896
TN	Knox	20.4	V	V	382,032
TN	Shelby	15.6		V	897,472
TN	Sullivan	17		V	153,048
TX	Dallas	14.4		V	2,218,899
TX	Harris	15.1	V	V	3,400,578
UT	Salt Lake	13.6		V	898,387
VA	Richmond City	14.9		V	197,790
WV	Brooke	17.4	V	V	25,447
WV	Cabell	17.8	V	V	96,784
WV	Hancock	17.4	V	V	32,667
WV	Kanawha	18.4	V	V	200,073
WV	Wood	17.6	V	V	87,986
WI	Milwaukee	14.5		V	940,164
Number of Violating Counties			79	107	
Population of Violating Counties[b]			65,821,078	85,525,624	

[a] The proposal differs based on updated information; however, we believe that the net results would approximate future emissions, although we anticipate the design value improvements would be slightly smaller.

[b] Populations are based on 2020 and 2030 estimates. See US EPA (2003) Air Quality Data Analysis 1999-2001, Technical Support Document for Regulatory Actions This document is available in Docket A-2001-28, Document No. II-A-196, Appendix A for details, "Base case."

Table 2.1-4 lists the counties with 2020 and 2030 projected annual $PM_{2.5}$ design values that do not violate the annual standard, but are within 10 percent of it. Counties are marked with an "X" in the table if their projected design values are greater than or equal to13.55 ug/m^3, but less than 15.05 ug/m^3. Counties are marked with an “V” in the table if their projected design values are greater than or equal to 15.05 ug/m^3. The current design values of these counties are also listed.

Table 2.1-4
Counties with 2020 and 2030 Projected Annual PM2.5 Design Values within Ten Percent of the Annual PM2.5 Standard.[a]

State	County	1999 - 2001 Design Value (ug/m^3)	2020	2030	Population in 2000
AL	Alabama	15.5	X	X	14,254
AL	De Kalb	16.8	X	V	64,452
AL	Houston	16.3	V	V	88,787
AL	Madison	15.5		X	276,700
AL	Mobile	15.3	X	V	399,843
AR	Crittenden	15.3	X	X	50,866
AR	Pulaski	15.9	X	X	361,474
CA	Butte	15.4		X	203,171
CA	Imperial	15.7	X	V	142,361
CA	Kings	16.6	X	X	129,461
CA	San Joaquin	16.4	X	V	563,598
CA	Ventura	14.5	X	X	753,197
CT	Fairfield	13.6		X	882,567
DE	Sussex	14.5		X	156,638
GA	Hall	17.2	V	V	139,277
IL	Du Page	15.4	X	V	904,161
IL	Macon	15.4	X	X	114,706
IL	Will	15.9	V	V	502,266
IN	Elkhart	15.1	X	X	182,791
IN	Floyd	15.6	X	X	70,823
IN	Howard	15.4	X	X	84,964
IN	Marion	17	V	V	860,454
IN	Porter	13.9		X	146,798
IN	Tippecanoe	15.4	X	X	148,955
IN	Vanderburgh	16.9	X	V	171,922
KY	Bell	16.8	X	X	30,060
KY	Boyd	15.5	X	X	49,752
KY	Bullitt	16		X	61,236
KY	Campbell	15.5	X	X	88,616
KY	Daviess	15.8	X	X	91,545
KY	Fayette	16.8	X	X	260,512
KY	Kenton	15.9	X	V	151,464
KY	Pike	16.1	X	X	68,736
LA	Caddo	13.7		X	252,161
LA	Calcasieu	12.7		X	183,577
LA	East Baton Rouge	14.6	X	V	412,852

State	County	1999 - 2001 Design Value (ug/m^3)	2020	2030	Population in 2000
LA	Iberville	13.9	X	X	33,320
LA	Jefferson	13.6		X	455,466
LA	Orleans	14.1	X	X	484,674
LA	West Baton Rouge	14.1	X	V	21,601
MD	Baltimore	16	X	V	754,292
MA	Hampden	14.1		X	456,228
MA	Suffolk	16.1	V	V	689,807
MI	Kalamazoo	15	X	X	238,603
MS	Forrest	15.2	X	X	72,604
MS	Hinds	15.1	X	X	250,800
MS	Jackson	13.8		X	131,420
MS	Jones	16.6	V	V	64,958
MS	Lauderdale	15.3	X	X	78,161
MO	Jackson	13.9		X	654,880
MO	Jefferson	15	X	X	198,099
MO	St Charles	14.6	X	X	283,883
MO	St Louis	14.1		X	1,016,315
MO	St Louis City	16.3	V	V	348,189
NJ	Mercer	14.3	X	X	350,761
NJ	Union	16.3	X	V	522,541
NY	Bronx	16.4	V	V	1,332,650
NC	Alamance	15.3	X	X	130,800
NC	Cabarrus	15.7	X	X	131,063
NC	Catawba	17.1	V	V	141,685
NC	Cumberland	15.4	X	X	302,963
NC	Durham	15.3	X	V	223,314
NC	Forsyth	16.2	X	V	306,067
NC	Gaston	15.3	X	V	190,365
NC	Guilford	16.3	V	V	421,048
NC	Haywood	15.4	X	X	54,033
NC	McDowell	16.2	X	V	42,151
NC	Mitchell	15.5	X	X	15,687
NC	Orange	14.3		X	118,227
NC	Wake	15.3	X	V	627,846
NC	Wayne	15.3		X	113,329
OH	Butler	17.4	V	V	332,807
OH	Lorain	15.1	X	X	284,664
OH	Mahoning	16.4	X	V	257,555
OH	Portage	15.3	X	X	152,061

State	County	1999 - 2001 Design Value (ug/m^3)	2020	2030	Population in 2000
OH	Trumbull	16.2	X	V	225,116
PA	Berks	15.6	X	X	373,638
PA	Cambria	15.3		X	152,598
PA	Dauphin	15.5	X	X	251,798
PA	Delaware	15	X	V	550,864
PA	Lancaster	16.9	X	X	470,658
PA	Washington	15.5		X	202,897
PA	York	16.3	X	V	381,751
SC	Georgetown	13.9		X	55,797
SC	Lexington	15.6	X	V	216,014
SC	Richland	15.4	X	X	320,677
SC	Spartanburg	15.4	X	X	253,791
TN	Davidson	17	X	V	569,891
TN	Roane	17	X	X	51,910
TN	Shelby	15.6	X	V	897,472
TN	Sullivan	17	X	V	153,048
TN	Sumner	15.7	X	X	130,449
TX	Dallas	14.4	X	V	2,218,899
UT	Salt Lake	13.6	X	V	898,387
VA	Bristol City	16		X	17,367
VA	Richmond City	14.9	X	V	197,790
VA	Roanoke City	15.2		X	94,911
VA	Virginia Beach Cit	13.2		X	425,257
WV	Berkeley	16	X	X	75,905
WV	Marshall	16.5	X	X	35,519
WV	Ohio	15.7	X	X	47,427
WV	Wood	17.6	V	V	87,986
WI	Milwaukee	14.5	X	V	940,164
WI	Waukesha	14.1		X	360,767
Number of Counties within 10%			70	64	
Population of Counties within 10%[b]			23,836,367	16,870,324	

[a] The proposal differs based on updated information; however, we believe that the net results would approximate future emissions, although we anticipate the design value improvements would be slightly smaller.

[b] Populations are based on 2020 and 2030 estimates. See US EPA (2003) Air Quality Data Analysis 1999-2001, Technical Support Document for Regulatory Actions This document is available in Docket A-2001-28, Document No. II-A-196, Appendix A, "Base case" for details.

While the final implementation process for bringing the nation's air into attainment with the $PM_{2.5}$ NAAQS is still being completed in a separate rulemaking action, the basic framework is well defined by the statute. EPA's current plans call for designating $PM_{2.5}$ nonattainment areas in late-2004. Following designation, Section 172(b) of the Clean Air Act allows states up to 3 years to submit a revision to their state implementation plan (SIP) that provides for the attainment of the $PM_{2.5}$ standard. Based on this provision, states could submit these SIPs in late-2007. Section 172(a)(2) of the Clean Air Act requires that these SIP revisions demonstrate that the nonattainment areas will attain the $PM_{2.5}$ standard as expeditiously as practicable but no later than 5 years from the date that the area was designated nonattainment. However, based on the severity of the air quality problem and the availability and feasibility of control measures, the Administrator may extend the attainment date "for a period of no greater than 10 years from the date of designation as nonattainment." Therefore, based on this information, we expect that most or all areas will need to attain the $PM_{2.5}$ NAAQS in the 2009 to 2014 time frame, and then be required to maintain the NAAQS thereafter.

This emission control program for highway motorcycles is another component of the effort by federal, state and local governments to reduce the health related impacts of air pollution and to reach attainment of the NAAQS for and particulate matter as well as to improve other environmental conditions such as atmospheric visibility. The emission reductions associated with these standards will help these areas in maintaining the standards.

1.2.4 - Particulate Matter and Visibility Degradation

Visibility can be defined as the degree to which the atmosphere is transparent to visible light.[94] Visibility impairment has been considered the "best understood and most easily measured effect of air pollution."[95] Visibility degradation is often directly proportional to decreases in light transmittal in the atmosphere. Scattering and absorption by both gases and particles decrease light transmittance. Haze obscures the clarity, color, texture, and form of what we see. Fine particles are the major cause of reduced visibility in parts of the U.S. Visibility is an important effect because it has direct significance to people's enjoyment of daily activities in all parts of the country. Visibility is also highly valued in significant natural areas such as national parks and wilderness areas, because of the special emphasis given to protecting these lands now and for future generations.

The size and chemical composition of particles strongly affect their ability to scatter or absorb light. The same particles (sulfates, nitrates, organic carbon, smoke, and soil dust) comprising $PM_{2.5}$, which are linked to serious health effects and environmental effects can also significantly degrade visual air quality. Sulfates contribute to visibility impairment especially on the haziest days across the U.S., accounting in the rural Eastern U.S. for more than 60 percent of annual average light extinction on the best days and up to 86 percent of average light extinction on the haziest days. Nitrates and elemental carbon each typically contribute 1 to 6 percent of average light extinction on haziest days in rural Eastern U.S. locations.[96]

Visibility effects are manifest in two principal ways: (1) as local impairment (e.g., localized hazes and plumes) and (2) as regional haze. The emissions from engines covered by this rule contribute to both types of visibility impairment.

Local-scale visibility degradation is commonly in the form of either a plume resulting from the emissions of a specific source or small group of sources, or it is in the form of a localized haze such as an urban "brown cloud." Plumes are comprised of smoke, dust, or colored gas that obscure the sky or horizon relatively near sources. Impairment caused by a specific source or small group of sources has been generally termed as "reasonably attributable."

The second type of impairment, regional haze, results from pollutant emissions from a multitude of sources located across a broad geographic region. It impairs visibility in every direction over a large area, in some cases over multi-state regions. Regional haze masks objects on the horizon and reduces the color and contrast of nearby objects.[97]

On an annual average basis, the concentrations of non-anthropogenic fine PM are generally small when compared with concentrations of fine particles from anthropogenic sources.[98] Anthropogenic contributions account for about one-third of the average extinction coefficient in the rural West and more than 80 percent in the rural East.[99] In the Eastern U.S., reduced visibility is mainly attributable to secondarily formed particles, particularly those less than a few micrometers in diameter (e.g., sulfates). While secondarily formed particles still account for a significant amount in the West, primary emissions contribute a larger percentage of the total particulate load than in the East. Furthermore, it is important to note that even in those areas with relatively low concentrations of anthropogenic fine particles, such as the Colorado plateau, small increases in anthropogenic fine particle concentrations can lead to significant decreases in visual range. This is one of the reasons mandatory Federal Class I areas have been given special consideration under the Clean Air Act. The 156 mandatory Federal Class I areas are displayed on the map in Figure 2-1 above.

Without the effects of pollution, a natural visual range is approximately 140 miles (230 kilometers) in the West and 90 miles (150 kilometers) in the East. However, over the years, in many parts of the U.S., fine particles have significantly reduced the range that people can see. In the West, the current range is 33 to 90 miles (53 to 144 kilometers), and in the East, the current range is only 14 to 24 miles (22 to 38 kilometers).[100]

Based upon the light-extinction coefficient, a unitless visibility index or deciview can be calculated.[101, 4] As shown in Table 1.2-5, in 2030 we estimate visibility in the East to be about 20.54 deciviews (or visual range of 50 kilometers) on average, with poorer visibility in urban areas, compared to the visibility conditions without man-made pollution of 9.5 deciviews (or visual range of 150 kilometers). Likewise, we estimate visibility in the West to be about 8.83

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[4] To quantify changes in visibility, the analysis presented in this chapter computes a light-extinction coefficient based on the work of Sisler (1996), which shows the total fraction of light decreased per unit distance. This coefficient accounts for the scattering and absorption of light by both particles and gases, and accounts for the higher extinction efficiency of fine particles compared to coarse particles. Visibility can be described in terms of visual range, light extinction or deciview. Visibility impairment also has a temporal dimension in that impairment might relate to a short-term excursion or to longer periods (e.g., worst 20 percent of days or annual average levels).
[4] cont-d...More detailed discussions of visibility effects are contained in the EPA Criteria Document for PM.

deciviews (or visual range of 162 kilometers) in 2030, compared to the visibility conditions without anthropogenic pollution of 5.3 deciviews (or visual range of 230 kilometers). Thus, in the future, a substantial percent of the population may experience unacceptable visibility impairment in areas where they live, work and recreate.

Table 1.2-5
Summary of Future National (48 state) Baseline Visibility Conditions Absent Additional Controls (Deciviews)

Regions[a]	Predicted 2020 Visibility (annual average)	Predicted 2030 Visibility (annual average)	Natural Background Visibility
Eastern U.S.	20.27	20.54	9.5
Urban	21.61	21.94	
Rural	19.73	19.98	
Western U.S.	8.69	8.83	5.3
Urban	9.55	9.78	
Rural	8.5	8.61	

[a] Eastern and Western Regions are separated by 100 degrees north longitude. Background visibility conditions differ by region.

The emissions from highway motorcycles contribute to this visibility impairment through their direct and indirect PM emissions.

In the 1990 Clean Air Act amendments, Congress provided additional emphasis on regional haze issues (see section 169B). There are 156 Mandatory Federal Class I areas that are in need of additional action to reduce regional haze. These areas include many of our best known and most treasured natural areas, such as the Grand Canyon, Yosemite, Yellowstone, Mount Rainier, Shenandoah, the Great Smokies, Acadia, and the Everglades. More than 280 million visitors come to enjoy the scenic vistas and unique natural features in these and other park and wilderness areas each year.

In 1999 EPA finalized a rule that calls for States to establish goals and emission reduction strategies for improving visibility in the 156 mandatory Class I national parks and wilderness areas. In that rule, EPA established a "natural visibility" goal.[102] EPA also encouraged the States to work together in developing and implementing their air quality plans. The regional haze program is focused on long-term emissions decreases from the entire regional emissions inventory comprised of major and minor stationary sources, area sources and mobile sources. The regional haze program is designed to improve visibility and air quality in our most treasured natural areas so that these areas may be preserved and enjoyed by current and future generations. At the same time, control strategies designed to improve visibility in the national parks and wilderness areas will improve visibility over broad geographic areas, including other recreational sites, our cities and residences. For mobile sources, there may also be a need for a Federal role in reduction of those emissions, in particular, because mobile source engines are regulated primarily at the Federal level.

The regional haze program calls for states to establish goals for improving visibility in national parks and wilderness areas to improve visibility on the haziest 20 percent of days and to ensure that no degradation occurs on the clearest 20 percent of days (64 FR 35722. July 1, 1999). The rule requires states to develop long-term strategies including enforceable measures designed to meet reasonable progress goals toward natural visibility conditions. Under the regional haze program, States can take credit for improvements in air quality achieved as a result of other Clean Air Act programs, including national mobile-source programs.[5] The highway motorcycle standards in this rule will assist states in meeting their goals under the regional haze program.

1.3 - Air Toxics

In addition to the human health and welfare impacts described above, emissions from the engines covered by this rule also contain several other substances that are known or suspected human or animal carcinogens, or have serious noncancer health effects.[103] These include benzene, 1,3-butadiene, formaldehyde, acetaldehyde, and acrolein. This section describes the health effects of these air toxics. Additional information can also be found in the Technical Support Document four our final Mobile Source Air Toxics rule.[104] The HC limits for highway motorcycles will help reduce emissions of these harmful pollutants.

1.3.1 - Benzene

Benzene is an aromatic hydrocarbon which is present as a gas in both exhaust and evaporative emissions from mobile sources. For gasoline-powered highway vehicles, the benzene fraction of TOG varies depending on control technology (e.g., type of catalyst) and the levels of benzene and other aromatics in the fuel, but is generally higher than for diesel engines, about three to five percent. The benzene fraction of evaporative emissions from gasoline vehicles depends on control technology and fuel composition and characteristics (e.g., benzene level and the evaporation rate) and is generally about one percent.[105]

The EPA's IRIS database lists benzene as a known human carcinogen (causing leukemia at

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[5] Although a recent court case, American Corn Growers Association v. EPA, 291F.3d 1(D.C .Cir 2002), vacated the Best Available Retrofit Technology (BART) provisions of the Regional Haze rule, the court denied industry's challenge to EPA's requirement that state's SIPS provide for reasonable progress towards achieving natural visibility conditions in national parks and wilderness areas and the "no degradation" requirement. Industry did not challenge requirements to improve visibility on the haziest 20 percent of days. The court recognized that mobile source emission reductions would need to be a part of a long-term emission strategy for reducing regional haze. A copy of this decision can be found in Docket A-2000-01, Document IV- A-113.

high, prolonged air exposures) by all routes of exposure.[106] It is associated with additional health effects including genetic changes in humans and animals and increased proliferation of bone marrow cells in mice.[107, 108] EPA states in its IRIS database that the data indicate a causal relationship between benzene exposure and acute lymphocytic leukemia and suggest a relationship between benzene exposure and chronic non-lymphocytic leukemia and chronic lymphocytic leukemia. Respiration is the major source of human exposure and at least half of this exposure is attributable to gasoline vapors and automotive emissions. A number of adverse noncancer health effects including blood disorders, such as preleukemia and aplastic anemia, have also been associated with low-dose, long-term exposure to benzene.

Respiration is the major source of human exposure to benzene. Long-term respiratory exposure to high levels of ambient benzene concentrations has been shown to cause cancer of the tissues that form white blood cells. Among these are acute nonlymphocytic leukemia,[6] chronic lymphocytic leukemia and possibly multiple myeloma (primary malignant tumors in the bone marrow), although the evidence for the latter has decreased with more recent studies.[109,110] Leukemias, lymphomas, and other tumor types have been observed in experimental animals exposed to benzene by inhalation or oral administration. Exposure to benzene and/or its metabolites has also been linked with genetic changes in humans and animals[111] and increased proliferation of mouse bone marrow cells.[112] The occurrence of certain chromosomal changes in individuals with known exposure to benzene may serve as a marker for those at risk for contracting leukemia.[113]

The latest assessment by EPA places the excess risk of developing acute nonlymphocytic leukemia at 2.2×10^{-6} to $7.7 \times 10^{-6}/\mu g/m^3$. In other words, there is a risk of about two to eight excess acute nonlymphocytic leukemia cases in one million people exposed to 1 $\mu g/m^3$ over a lifetime (70 years).[114] This range of unit risk represents the maximum likelihood estimate of risk. Upper bound cancer risk is above 10 in a million across the entire U.S. EPA projects a median nationwide reduction in ambient concentrations of benzene from mobile sources of about 46 percent between 1996 and 2007, as a result of current and planned control programs based on the analysis referenced earlier examining these pollutants in the 1996 to 2007 time frame based on the analysis of hazardous air pollutants in the 1996 to 2007 time frame referenced earlier.

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[6] Leukemia is a blood disease in which the white blood cells are abnormal in type or number. Leukemia may be divided into nonlymphocytic (granulocytic) leukemias and lymphocytic leukemias. Nonlymphocytic leukemia generally involves the types of white blood cells (leukocytes) that are involved in engulfing, killing, and digesting bacteria and other parasites (phagocytosis) as well as releasing chemicals involved in allergic and immune responses. This type of leukemia may also involve erythroblastic cell types (immature red blood cells). Lymphocytic leukemia involves the lymphocyte type of white bloods cell that are responsible for the immune responses. Both nonlymphocytic and lymphocytic leukemia may, in turn, be separated into acute (rapid and fatal) and chronic (lingering, lasting) forms. For example; in acute myeloid leukemia (AML) there is diminished production of normal red blood cells (erythrocytes), granulocytes, and platelets (control clotting) which leads to death by anemia, infection, or hemorrhage. These events can be rapid. In chronic myeloid leukemia (CML) the leukemic cells retain the ability to differentiate (i.e., be responsive to stimulatory factors) and perform function; later there is a loss of the ability to respond.

A number of adverse noncancer health effects, blood disorders such as preleukemia and aplastic anemia, have also been associated with low-dose, long-term exposure to benzene.[115, 116] People with long-term exposure to benzene may experience harmful effects on the blood-forming tissues, especially the bone marrow. These effects can disrupt normal blood production and cause a decrease in important blood components, such as red blood cells and blood platelets, leading to anemia (a reduction in the number of red blood cells), leukopenia (a reduction in the number of white blood cells), or thrombocytopenia (a reduction in the number of blood platelets, thus reducing the ability for blood to clot). Chronic inhalation exposure to benzene in humans and animals results in pancytopenia,[7] a condition characterized by decreased numbers of circulating erythrocytes (red blood cells), leukocytes (white blood cells), and thrombocytes (blood platelets).[117,118] Individuals that develop pancytopenia and have continued exposure to benzene may develop aplastic anemia,[8] whereas others exhibit both pancytopenia and bone marrow hyperplasia (excessive cell formation), a condition that may indicate a preleukemic state.[119] [120] The most sensitive noncancer effect observed in humans is the depression of absolute lymphocyte counts in the circulating blood.[121]

1.3.2 - 1,3-Butadiene

1,3-Butadiene is formed in engine exhaust by the incomplete combustion of fuel. It is not present in engine evaporative emissions because it is not present in any appreciable amount in fuel. 1,3-Butadiene accounts for less than one percent of total organic gas exhaust from mobile sources.

EPA earlier identified 1,3-butadiene as a probable human carcinogen in its IRIS database.[122] Recently EPA redesignated 1,3-butadiene as a known human carcinogen.[123,124,125] The specific mechanisms of 1,3-butadiene-induced carcinogenesis are unknown. However, it is virtually certain that the carcinogenic effects are mediated by genotoxic metabolites of 1,3-butadiene. Animal data suggest that females may be more sensitive than males for cancer effects; but more data are needed before reaching definitive conclusions on potentially sensitive subpopulations.

The unit cancer risk estimate is 0.08/ppm or 3x10-5 per µg/m3 (based primarily on linear

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[7] Pancytopenia is the reduction in the number of all three major types of blood cells (erythrocytes, or red blood cells, thrombocytes, or platelets, and leukocytes, or white blood cells). In adults, all three major types of blood cells are produced in the bone marrow of the vertebra, sternum, ribs, and pelvis. The bone marrow contains immature cells, known as multipotent myeloid stem cells, that later differentiate into the various mature blood cells. Pancytopenia results from a reduction in the ability of the red bone marrow to produce adequate numbers of these mature blood cells.

[8] Aplastic anemia is a more severe blood disease and occurs when the bone marrow ceases to function, i.e.,these stem cells never reach maturity. The depression in bone marrow function occurs in two stages - hyperplasia, or increased synthesis of blood cell elements, followed by hypoplasia, or decreased synthesis. As the disease progresses, the bone marrow decreases functioning. This myeloplastic dysplasia (formation of abnormal tissue) without acute leukemias known as preleukemia. The aplastic anemia can progress to AML (acute mylogenous leukemia).

modeling and extrapolation of human data). In other words, it is estimated that approximately 30 persons in one million exposed to 1 μg/m^3 1,3-butadiene continuously for their lifetime (70 years) would develop cancer as a result of this exposure. The human incremental lifetime unit cancer risk (incidence) estimate is based on extrapolation from leukemias observed in an occupational epidemiologic study.[126] A twofold adjustment to the epidemiologic-based unit cancer risk was applied to reflect evidence from the rodent bioassays suggesting that the epidemiologic-based estimate may underestimate total cancer risk from 1,3-butadiene exposure in the general population. Upper bound cancer risk is above 10 in a million across the entire U.S. EPA projects a median nationwide reduction in ambient concentrations of benzene from mobile sources of about 46 percent between 1996 and 2007, as a result of current and planned control programs.

1,3-Butadiene also causes a variety of reproductive and developmental effects in mice; no human data on these effects are available. The most sensitive effect was ovarian atrophy observed in a lifetime bioassay of female mice.[127] Based on this critical effect and the benchmark concentration methodology, an RfC (i.e., a chronic exposure level presumed to be "without appreciable risk" for noncancer effects) was calculated. This RfC for chronic health effects was 0.9 ppb.

1.3.3 - Formaldehyde

Formaldehyde is the most prevalent aldehyde in engine exhaust. It is formed from incomplete combustion of both gasoline and diesel fuel. In a recent test program which measured toxic emissions from several nonroad diesel engines, ranging from 50 to 480 horsepower, formaldehyde consistently accounted for well over 10 percent of total exhaust hydrocarbon emissions.[128] Formaldehyde accounts for far less of total exhaust hydrocarbon emissions from gasoline engines, although the amount can vary substantially by duty cycle, emission control system, and fuel composition. It is not found in evaporative emissions.

EPA has classified formaldehyde as a probable human carcinogen based on limited evidence for carcinogenicity in humans and sufficient evidence of carcinogenicity in animal studies, rats, mice, hamsters, and monkeys.[129, 130] Epidemiological studies in occupationally exposed workers suggest that long-term inhalation of formaldehyde may be associated with tumors of the nasopharyngeal cavity (generally the area at the back of the mouth near the nose), nasal cavity, and sinus.[131] Studies in experimental animals provide sufficient evidence that long-term inhalation exposure to formaldehyde causes an increase in the incidence of squamous (epithelial) cell carcinomas (tumors) of the nasal cavity.[132, 133, 134] The distribution of nasal tumors in rats suggests that not only regional exposure but also local tissue susceptibility may be important for the distribution of formaldehyde-induced tumors.[135] Research has demonstrated that formaldehyde produces mutagenic activity in cell cultures.[136]

The upper confidence limit estimate of a lifetime extra cancer risk from continuous formaldehyde exposure is about 1.3×10^{-5}/μg/m^3. In other words, it is estimated that approximately 10 persons in one million exposed to 1 μg/m^3 formaldehyde continuously for their lifetime (70 years) would develop cancer as a result of this exposure. The agency is currently conducting a reassessment of risk from inhalation exposure to formaldehyde based on new information including a study by the Chemistry Industry Institute of Toxicology.[137, 138] Upper bound cancer risk is above 10 in a million for more than one hundred million Americans. EPA projects a median nationwide reduction in ambient concentrations of benzene from mobile sources of about 43 percent between 1996 and 2007, as a result of current and planned control programs (Cook et al., 2002).

Formaldehyde exposure also causes a range of noncancer health effects. At low concentrations (e.g. 0.05-2.0 ppm), irritation of the eyes (tearing of the eyes and increased blinking) and mucous membranes is the principal effect observed in humans. At exposure to 1-11 ppm, other human upper respiratory effects associated with acute formaldehyde exposure include a dry or sore throat, and a tingling sensation of the nose. Sensitive individuals may experience these effects at lower concentrations. Forty percent of formaldehyde-producing factory workers reported nasal symptoms such as rhinitis (inflammation of the nasal membrane), nasal obstruction, and nasal discharge following chronic exposure.[139] In persons with bronchial asthma, the upper respiratory irritation caused by formaldehyde can precipitate an acute asthmatic attack, sometimes at concentrations below 5 ppm.[140] Formaldehyde exposure may also cause bronchial asthma-like symptoms in non-asthmatics.[141] [142]

Immune stimulation may occur following formaldehyde exposure, although conclusive evidence is not available. Also, little is known about formaldehyde's effect on the central nervous system. Several animal inhalation studies have been conducted to assess the developmental toxicity of formaldehyde: The only exposure-related effect noted in these studies was decreased maternal body weight gain at the high-exposure level. No adverse effects on reproductive outcome of the fetuses that could be attributed to treatment were noted. An inhalation reference concentration (RfC), below which long-term exposures would not pose appreciable noncancer health risks, is not available for formaldehyde at this time. The Agency is currently conducting a reassessment of risk from inhalation exposure to formaldehyde.

1.3.4 - Acetaldehyde

Acetaldehyde is a saturated aldehyde that is found in engine exhaust and is formed as a result of incomplete combustion of both gasoline and diesel fuel. In a recent test program which measured toxic emissions from several nonroad diesel engines, ranging from 50 to 480 horsepower, acetaldehyde consistently accounted for over 5 percent of total exhaust hydrocarbon emissions.[143] Acetaldehyde accounts for far less of total exhaust hydrocarbon emissions from gasoline engines, although the amount can vary substantially by duty cycle, emission control system, and fuel composition. It is not a component of evaporative emissions.

Acetaldehyde is classified as a probable human carcinogen. Studies in experimental animals provide sufficient evidence that long-term inhalation exposure to acetaldehyde causes an increase in the incidence of nasal squamous cell carcinomas (epithelial tissue) and adenocarcinomas (glandular tissue).[144, 145, 146, 147, 148] The upper confidence limit estimate of a lifetime extra cancer risk from continuous acetaldehyde exposure is about 2.2×10^{-6} /µg/m^3. In other words, it is estimated that about 2 persons in one million exposed to 1 µg/m^3 acetaldehyde continuously for their lifetime (70 years) would develop cancer as a result of their exposure. The Agency is currently conducting a reassessment of risk from inhalation exposure to acetaldehyde. Upper bound cancer risk is above one in a million for more than one hundred million Americans. EPA projects a median nationwide reduction in ambient concentrations of benzene from mobile sources of about 36 percent between 1996 and 2007, as a result of current and planned control programs

EPA's IRIS database states that noncancer effects in studies with rats and mice showed acetaldehyde to be moderately toxic by the inhalation, oral, and intravenous routes (EPA, 1988). Similar conclusions have been made by the California Air Resources Board.[149] The primary acute effect of exposure to acetaldehyde vapors is irritation of the eyes, skin, and respiratory tract. At high concentrations, irritation and pulmonary effects can occur, which could facilitate the uptake of other contaminants. Little research exists that addresses the effects of inhalation of acetaldehyde on reproductive and developmental effects. The in vitro and in vivo studies provide evidence to suggest that acetaldehyde may be the causative factor in birth defects observed in fetal alcohol syndrome, though evidence is very limited linking these effects to inhalation exposure. Long-term exposures should be kept below the reference concentration of 9 µg/m^3 to avoid appreciable risk of these noncancer health effects (EPA, 1988).

Acetaldehyde has been associated with lung function decrements in asthmatics. In one study, aerosolized acetaldehyde caused reductions in lung function and bronchoconstriction in asthmatic subjects.[150]

1.3.5 - Acrolein

In a recent test program which measured toxic emissions from several nonroad diesel engines, ranging from 50 to 480 horsepower, acrolein accounted for about 0.5 to 2 percent of total exhaust hydrocarbon emissions.[151] Acrolein accounts for far less of total exhaust hydrocarbon emissions from gasoline engines, although the amount can vary substantially by duty cycle, emission control system, and fuel composition. It is not a component of evaporative emissions.

Acrolein is extremely toxic to humans from the inhalation route of exposure, with acute exposure resulting in upper respiratory tract irritation and congestion. The Agency developed a reference concentration for inhalation (RfC) of acrolein of 0.02 µg/m^3 in 1993. The hazard quotient is greater than one for most of the U.S. population, indicating a potential for adverse noncancer health effects.

Although no information is available on its carcinogenic effects in humans, based on laboratory animal data, EPA considers acrolein a possible human carcinogen.[152]

1.4 - Inventory Contributions

1.4.1 - Inventory Contribution

The contribution of emissions from highway motorcycles to the national inventories of pollutants associated with the health and public welfare effects described in this chapter are considerable. Emission estimates for highway motorcycles were developed using information on the emission levels of current motorcycles and updated information on motorcycle use provided by the motorcycle industry. A more detailed description of the modeling and our estimation methodology can be found in the Chapter 6 of this document.

Baseline emission inventory estimates for the years 1996 and 2020 for highway motorcycles are summarized in Tables 1.4-1 through 1.4-3 for VOC, NOx, and PM, respectively.[9] The estimates shown for highway motorcycles are baseline estimates and do not account for the impact of the standards adopted today. These tables show the relative contributions of the different mobile-source categories to the overall national mobile-source inventory. Highway motorcycles contribute about 0.6 percent, 0.1 percent, and less than 0.1 percent of mobile source VOC, NOx, and PM emissions, respectively, in the year 1996. Our inventory projections for 2020 for highway motorcycles show that emissions are expected to increase over time if left uncontrolled. The projections for 2020 indicate that motorcycles are expected to contribute 2.3 percent, 0.3 percent, and 0.1 percent of mobile source VOC, NOx, and PM emissions, respectively, in the year 2020. Population growth and the effects of other regulatory control programs are factored into these projections.

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[9] The inventories cited in Tables 1.4-1 through 1.4-4 were developed for the Nonroad Diesel Rulemaking. (See 68 FR 28328, published May 23, 2003.) The inventories for recreational marine engines greater than 50 horsepower, nonroad spark-ignition engines greater than 25 horsepower, and recreations spark-ignition engines have been updated using the latest version of EPA's NONROAD model to account for the new standards adopted by EPA in late 2002. (See 67 FR 68242, published November 8, 2002.)

Table 1.4-1
Annual VOC Baseline Emission Levels for Mobile and Other Source Categories [a,b]

Category	1996			2020		
	VOC short tons	% of mobile source	% of total	VOC short tons	% of mobile source	% of total
Highway Motorcycles	47,368	0.6%	0.3%	86,520	2.2%	0.6%
Highway Light-duty	4,635,410	55.8%	25.0%	1,755,119	45.4%	13.0%
Highway Heavy-duty	608,607	7.3%	3.3%	226,641	5.9%	1.7%
Land-based Nonroad Diesel	221,403	2.7%	1.2%	96,855	2.5%	0.7%
Recreational Marine Diesel ≤50 hp	128	0.0%	0.0%	108	0.0%	0.0%
Recreational Marine Diesel >50 hp	1,199	0.0%	0.0%	1,531	0.0%	0.0%
Recreational Marine SI	804,488	9.7%	4.3%	380,891	9.9%	2.8%
Nonroad SI ≤25 hp	1,330,229	16.0%	7.2%	650,158	16.8%	4.8%
Nonroad SI >25hp	85,701	1.0%	0.5%	12,265	0.3%	0.1%
Recreational SI	308,285	3.7%	1.7%	339,098	8.8%	2.5%
Commercial Marine Diesel	31,545	0.4%	0.2%	37,290	1.0%	0.3%
Commercial Marine SI	960	0.0%	0.0%	998	0.0%	0.0%
Locomotive	48,381	0.6%	0.3%	36,546	0.9%	0.3%
Aircraft	176,394	2.1%	1.0%	239,654	6.2%	1.8%
Total Nonroad	3,008,713	36%	16%	1,795,394	46%	13%
Total Highway	5,291,385	64%	29%	2,068,280	54%	15%
Total Mobile Sources	8,300,098	100%	45%	3,863,674	100%	29%
Stationary Point and Area Sources	10,249,136	—	55%	9,648,376	—	71%
Total Man-Made Sources	18,549,234	—		13,512,050	—	
Mobile Source Percent of Total	45%	—		29%	—	

[a] These are 48-state inventories. They do not include Alaska and Hawaii.

[b] The mobile source estimates include both exhaust and evaporative emissions.

Table 1.4-2
Annual NO_x Baseline Emission Levels for Mobile and Other Source Categories [a]

Category	1996			2020		
	NOx short tons	% of mobile source	% of total	NOx short tons	% of mobile source	% of total
Highway Motorcycles	7,284	0.1%	0.0%	14,059	0.3%	0.1%
Highway Light-duty	4,427,634	33.8%	18.0%	1,264,342	25.0%	8.4%
Highway Heavy-duty	4,626,004	35.3%	18.8%	696,911	13.8%	4.6%
Land-based Nonroad Diesel	1,583,664	12.1%	6.4%	1,140,727	22.6%	7.6%
Recreational Marine Diesel ≤50 hp	523	0.0%	0.0%	682	0.0%	0.0%
Recreational Marine Diesel >50 hp	33,468	0.3%	0.1%	47,675	0.9%	0.3%
Recreational Marine SI	33,304	0.3%	0.1%	61,749	1.2%	0.4%
Nonroad SI ≤25 hp	63,584	0.5%	0.3%	100,119	2.0%	0.7%
Nonroad SI >25hp	273,099	2.1%	1.1%	43,322	0.9%	0.3%
Recreational SI	4,297	0.0%	0.0%	17,129	0.3%	0.1%
Commercial Marine Diesel	959,704	7.3%	3.9%	819,201	16.2%	5.4%
Commercial Marine SI	6,428	0.0%	0.0%	4,551	0.1%	0.0%
Locomotive	921,556	7.0%	3.8%	612,722	12.1%	4.1%
Aircraft	165,018	1.3%	0.7%	228,851	4.5%	1.5%
Total Nonroad	4,044,645	31%	16%	3,076,728	61%	20%
Total Highway	9,060,922	69%	37%	1,975,312	39%	13%
Total Mobile Sources	13,105,567	100%	53%	5,052,040	100%	33%
Stationary Point and Area Sources	11,449,752	—	47%	10,050,213	—	67%
Total Man-Made Sources	24,555,319	—		15,102,253	—	
Mobile Source Percent of Total	53%	—		33%	—	

[a] These are 48-state inventories. They do not include Alaska and Hawaii.

Table 1.4-3
Annual PM-2.5 Baseline Emission Levels for Mobile and Other Source Categories [a,b]

Category	1996			2020		
	PM-2.5 short tons	% of mobile source	% of total	PM-2.5 short tons	% of mobile source	% of total
Highway Motorcycles	184	0.0%	0.0%	434	0.1%	0.0%
Highway Light-duty	57,534	10.2%	2.6%	47,136	13.2%	2.3%
Highway Heavy-duty	172,965	30.7%	7.8%	24,806	7.0%	1.2%
Land-based Nonroad Diesel	176,510	31.3%	8.0%	124,334	34.9%	6.0%
Recreational Marine Diesel ≤50 hp	62	0.0%	0.0%	70	0.0%	0.0%
Recreational Marine Diesel >50 hp	815	0.1%	0.0%	1,162	0.3%	0.1%
Recreational Marine SI	35,147	6.2%	1.6%	26,110	7.3%	1.3%
Nonroad SI ≤25 hp	24,130	4.3%	1.1%	29,998	8.4%	1.5%
Nonroad SI >25hp	1,374	0.2%	0.1%	2,302	0.6%	0.1%
Recreational SI	7,968	1.4%	0.4%	9,963	2.8%	0.5%
Commercial Marine Diesel	36,367	6.5%	1.6%	41,365	11.6%	2.0%
Commercial Marine SI	1,370	0.2%	0.1%	1,326	0.4%	0.1%
Locomotive	20,937	3.7%	0.9%	16,727	4.7%	0.8%
Aircraft	27,891	5.0%	1.3%	30,024	8.4%	1.5%
Total Nonroad	332,571	59%	15%	283,381	80%	14%
Total Highway	230,683	41%	10%	72,376	20%	4%
Total Mobile Sources	563,254	100%	25%	355,757	100%	17%
Stationary Point and Area Sources	1,653,392	—	75%	1,712,004	—	83%
Total Man-Made Sources	2,216,646	—		2,067,761	—	
Mobile Source Percent of Total	25%	—		17%	—	

[a] These are 48-state inventories. They do not include Alaska and Hawaii.
[b] Excludes natural and miscellaneous sources.

1.4.2 - Inventory Impacts on a Per Vehicle Basis

In addition to the general inventory contributions described above, motorcycles have much higher emissions than cars on a per vehicle basis. A highway motorcycle driven 10 miles emits as many hydrocarbon emissions as a current passenger car driven for 210 miles. The per engine emissions are important because they mean that operators of these engines and vehicles, as well as those who work in their vicinity, are exposed to high levels of emissions, many of which are air toxics. These effects are described in more detail in the next section.

1.5 - Other Health and Environmental Effects

1.5.1 - Acid Deposition

Acid deposition, or acid rain as it is commonly known, occurs when SO_2 and NOx react in the atmosphere with water, oxygen, and oxidants to form various acidic compounds that later fall to earth in the form of precipitation or dry deposition of acidic particles.[153] It contributes to damage of trees at high elevations and in extreme cases may cause lakes and streams to become so acidic that they cannot support aquatic life. In addition, acid deposition accelerates the decay of building materials and paints, including irreplaceable buildings, statues, and sculptures that are part of our nation's cultural heritage. To reduce damage to automotive paint caused by acid rain and acidic dry deposition, some manufacturers use acid-resistant paints, at an average cost of $5 per vehicle--a total of $61 million per year if applied to all new cars and trucks sold in the U.S.

Acid deposition primarily affects bodies of water that rest atop soil with a limited ability to neutralize acidic compounds. The National Surface Water Survey (NSWS) investigated the effects of acidic deposition in over 1,000 lakes larger than 10 acres and in thousands of miles of streams. It found that acid deposition was the primary cause of acidity in 75 percent of the acidic lakes and about 50 percent of the acidic streams, and that the areas most sensitive to acid rain were the Adirondacks, the mid-Appalachian highlands, the upper Midwest and the high elevation West. The NSWS found that approximately 580 streams in the Mid-Atlantic Coastal Plain are acidic primarily due to acidic deposition. Hundreds of the lakes in the Adirondacks surveyed in the NSWS have acidity levels incompatible with the survival of sensitive fish species. Many of the over 1,350 acidic streams in the Mid-Atlantic Highlands (mid-Appalachia) region have already experienced trout losses due to increased stream acidity. Emissions from U.S. sources contribute to acidic deposition in eastern Canada, where the Canadian government has estimated that 14,000 lakes are acidic. Acid deposition also has been implicated in contributing to degradation of high-elevation spruce forests that populate the ridges of the Appalachian Mountains from Maine to Georgia. This area includes national parks such as the Shenandoah and Great Smoky Mountain National Parks.

1.5.2 - Eutrophication and Nitrification

Nitrogen deposition into bodies of water can cause problems beyond those associated with acid rain. The Ecological Society of America has included discussion of the contribution of air emissions to increasing nitrogen levels in surface waters in a recent major review of causes and consequences of human alteration of the global nitrogen cycle in its *Issues in Ecology* series.[154] Long-term monitoring in the United States, Europe, and other developed regions of the world shows a substantial rise of nitrogen levels in surface waters, which are highly correlated with human-generated inputs of nitrogen to their watersheds. These nitrogen inputs are dominated by fertilizers and atmospheric deposition.

Human activity can increase the flow of nutrients into those waters and result in excess algae and plant growth. This increased growth can cause numerous adverse ecological effects and economic impacts, including nuisance algal blooms, dieback of underwater plants due to reduced light penetration, and toxic plankton blooms. Algal and plankton blooms can also reduce the level of dissolved oxygen, which can also adversely affect fish and shellfish populations. This problem is of particular concern in coastal areas with poor or stratified circulation patterns, such as the Chesapeake Bay, Long Island Sound, or the Gulf of Mexico. In such areas, the "overproduced" algae tends to sink to the bottom and decay, using all or most of the available oxygen and thereby reducing or eliminating populations of bottom-feeder fish and shellfish, distorting the normal population balance between different aquatic organisms, and in extreme cases causing dramatic fish kills.

Collectively, these effects are referred to as eutrophication, which the National Research Council recently identified as the most serious pollution problem facing the estuarine waters of the United States.[155] Nitrogen is the primary cause of eutrophication in most coastal waters and estuaries.[156] On the New England coast, for example, the number of red and browntides and shellfish problems from nuisance and toxic plankton blooms have increased over the past two decades, a development thought to be linked to increased nitrogen loadings in coastal waters. We believe that airborne NOx contributes from 12 to 44 percent of the total nitrogen loadings to United States coastal water bodies. For example, some estimates assert that approximately one-quarter of the nitrogen in the Chesapeake Bay comes from atmospheric deposition.

Excessive fertilization with nitrogen-containing compounds can also affect terrestrial ecosystems.[10] Research suggests that nitrogen fertilization can alter growth patterns and change the balance of species in an ecosystem, providing beneficial nutrients to plant growth in areas that do not suffer from nitrogen over-saturation. In extreme cases, this process can result in nitrogen saturation when additions of nitrogen to soil over time exceed the capacity of the plants and microorganisms to utilize and retain the nitrogen. This phenomenon has already occurred in some areas of the U.S.

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[10] Terrestrial nitrogen deposition can act as a fertilizer. In some agricultural areas, this effect can be beneficial.

Notes to Chapter 1

1. The air quality modeling data presented in this chapter was developed for our proposed rulemaking proposing standards for nonroad diesel engines and their fuels. See 68 FR 28328, May 23, 2003. Additional information about the air quality modeling and other aspects of the health and welfare impacts of the pollutants described in this chapter can be found in the Draft Regulatory Impact Analysis prepared for that proposal. A copy of that document can be found in Docket A-2001-28, Document III-B-01. It is also available on EPA's web-based electronic docket as OAR-2003-0012-0025.

2. For more information about VOC and HC, see U.S. EPA (1997), Conversion Factors for Hydrocarbon Emission Components, Report No. NR-002. This document is available in Docket A-2000-02, Document IV-A-26.

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CHAPTER 2: Industry Characterization

To accurately assess the potential impact of this emission control program, it is important to understand the nature of the affected industries. This chapter describes relevant background information related to highway motorcycles. Portions of this industry characterization were developed in part under contract with RTI International[1] as well as independent analyses conducted by EPA through interaction with the industry and other sources. The complete report from RTI International is available in the public docket.

Motorcycles come in a variety of two- and three-wheeled configurations and styles. For the most part, however, they are two-wheeled self-powered vehicles designed for operation on paved roadway surfaces. Federal regulations currently define a motorcycle as “any motor vehicle with a headlight, taillight, and stoplight and having: two wheels, or three wheels and a curb mass less than or equal to 793 kilograms (1749 pounds).” (See 40 CFR 86.402-98). By using the term “motor vehicle,” this definition includes only those vehicles that can achieve speeds of 25mph or greater. Thus, most small scooters are considered to be highway motorcycles, but mopeds and motorized bicycles are not. Vehicles that can be used both on and off-highway, called dual-purpose or dual-sport motorcycles, are also covered by the current regulation.

Both EPA and California regulations sub-divide highway motorcycles into classes based on engine displacement. Table 2.1-1 below shows how these classes are defined by EPA.

Table 2.1-1
Motorcycle Classes

Motorcycle Class	Engine Displacement (cubic centimeters)
Class I	0[a] - 169
Class II	170 - 279
Class III	280 and greater

[a] This rule extends Class I to include <50cc.

2.1 - Manufacturers

Six companies account for about 95 percent of all motorcycles sold (Honda, Harley-Davidson/Buell, Yamaha, Kawasaki, Suzuki, and BMW). All of these companies except Harley-Davidson and BMW also manufacture off-road motorcycles and ATVs for the U.S. market. From 1996 to 2000, Harley-Davidson produced more on-road motorcycles than any other manufacturer and accounted for nearly 30 percent of total production by the six largest firms. Honda accounted for 23.2 percent of total production by the six largest firms and Yamaha accounted for 18.4 percent. Kawasaki and Suzuki each accounted for approximately 13 percent of production by the six largest firms, while BMW accounted for 2.7 percent. As a whole, these firms increased production steadily in 1997, 1998, 1999, and 2000. In 2001, these firms are continued producing over 90 percent of all highway motorcycles manufactured for the US market.

Many other companies make up the remaining few percent of sales. Many of these are small U.S. companies manufacturing anywhere from a couple dozen to a couple thousand motorcycles, although importers and U.S. affiliates of larger international companies also contribute to the remaining few percent. Excluding the six large manufacturers noted above, the manufacturers with certified 2003 model year motorcycles are shown in Table 2.1-2. Aprilia, Ducati, Piaggio, and Triumph are large international companies that, with the exception of Triumph, have large market shares in Europe. Victory Motorcycle is a division of Polaris Industries, a large U.S. leisure craft producer. The remainder are small U.S.-based manufacturers or importers.

Table 2.1-2
2003 Motorcycle Manufacturers Excluding the Largest Six[A]

American Ironhorse	Minneapolis Custom Cycles
Aprilia	Moto America
Big Dog Motorcycles	Muz Motorrad
Big Mike's Choppers	Panzer
Carafree Custom Cycles	Piaggio
Classic Motorcycles & Sidecars	Pro-One Performance
Classic Motorcycles, Inc.	Ridley Motorcycle Co.
DC Imports	Roadstertec
Ducati	Swift Motor Sports
Focus Inc.	Triumph
Force Chopper Design	Vengeance Motorcycles
Indian	Victory Motorcycle
Iron Eagle Motorcycles	Westward Ind.,Ltd.
KTM	

[A] BMW, Kawasaki, Harley-Davidson, Honda, Suzuki, Yamaha.

With the exception of Harley-Davidson/Buell, all the major manufacturers produce at least a portion of their on-road motorcycles for the U.S. market outside of the U.S. BMW, Suzuki, and Yamaha manufacture all on-road motorcycles destined for the U.S. market outside of the U.S. Sixty-five percent of Honda's on-road motorcycles produced for the U.S. market are manufactured outside the U.S., in either Italy or Japan. Sixty-one percent of Kawasaki's on-road motorcycles destined for the U.S. market are produced in Japan.

2.2 - Sales and Fleet Size

Motorcycle sales are sensitive to economic cycles due to the recreational nature of motorcycle ownership. While certainly some are used as basic transportation, in general they are purchased by consumers who already own one or more cars, and the motorcycle is used for recreation on evenings or weekends. All available data suggest that recreational uses dominate. Data from the Federal Highway Administration's last two Nationwide Personal Transportation surveys indicate that motorcycles were used for only 0.2 percent of the total number of journey-to-work vehicle trips. RTI International concludes that motorcycle owners are only one-fifth as likely to use their vehicle for commuting as owners of passenger cars or light trucks.[2] In much of the nation the motorcycle is not a practical means of transportation for one third of the year or more. Sales were high in the late 1970's and early 1980's, but as the economy neared its downturn that started around 1987-1988 sales clearly began to drop. Sales bottomed out with that downturn in 1992, then as the economy boomed in the 1990's sales once again began to take off, with retail dollars in 1998 approaching triple the retail dollars of ten years before. Historical sales and retail dollars are shown in Table 2.2-1. Data for 2000 indicate that the trend continued, with the retail sales of highway motorcycles up by more than 20 percent relative to 1999. The unit sales of highway motorcycles in calendar year 2000 was approximately 437,000 (including dual-sport motorcycles).[11] The current fleet of highway motorcycles is approximately 4.3 million units.

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[11] Dealernews. Vol. 37, No. 2, Feb. 2001, p. 158. Available in Docket A-2000-02 for review.

Table 2.2-1
On-Highway Motorcycle Retail Sales: 1982-2002[a]

Year	*Units (thousands)*	*Dollars (millions)*
2001	577	5758
2000	490	4789
1999	394	3935
1998	311	3132
1997	260	2556
1996	242	2213
1995	230	1931
1994	228	1773
1993	217	1563
1992	203	1333
1991	206	1157
1990	226	1148
1989	245	1072
1988	335	1304
1987	465	1401
1986	470	1375
1985	565	1580
1984	605	1777
1983	605	1542
1982	605	1463

[a] Source: Motorcycle Industry Council, 2002 Motorcycle Statistical Annual.

2.3 - Usage

Highway motorcycles are primarily for use on public roads and typically fall into one of four categories: cruiser, touring, sport bike, or standard. A cruiser motorcycle is designed for relatively short distances and is the most commonly purchased on-road motorcycle in the U.S. A touring motorcycle is designed for long distance travel and extra load capacity. A sport bike is designed for performance and uses racing technology, and finally a standard motorcycle is a basic model. Each of these categories of motorcycles also differs in appearance and styling. For instance, a cruiser motorcycle has a heavier appearance, a custom paint job, full-view engines, and swept-back handlebars. A touring bike is built for rider comfort and includes saddlebags. In contrast, a sportbike is more aerodynamic in appearance, and has low handle bars and high performance tires.

The highway motorcycle category also includes motorcycles termed "dual-use" or "dual-sport," meaning that their designs incorporate features that enable them to be competent both on and off road. Dual-sport motorcycles generally can be described as street-legal dirt bikes, because they often bear a closer resemblance in terms of design features and engines to true off-road motorcycles than to highway cruisers, touring, or sport bikes.

2.4 - Current Trends

Analyzing production and sales numbers based on type of motorcycle and engine displacement reveals that heavyweight motorcycles have become particularly popular in recent years. In 2000, 72 percent of all on-road motorcycles produced for the U.S. market were heavyweight motorcycles (651 cc or greater displacement). Just five years prior, heavyweight motorcycles made up 67 percent of total production for the U.S. market. Until relatively recently, Harley-Davidson was the only significant manufacturer of American heavyweight cruiser and touring motorcycles. In 2000, Harley-Davidson/Buell was still the largest producer of heavyweight on-road motorcycles (it produced 34 percent of all heavyweight motorcycles).

Of the 190 engine families certified in 2002 by manufacturers for sale in the U.S., 162 fall in the Class III category (above 279cc), representing more than 90 percent of projected sales. More than three-quarters of projected 2003 highway motorcycle sales are above 700cc. The average displacement of all 2003 certified engine families is about 940cc, and the average displacement of certified Class III engine families is above 1000cc. The sales-weighted average displacement of 2003 highway motorcycles is about 1100cc. Class I and II motorcycles, which make up about five percent of projected 2003 sales and only 29 out of 190 certified 2003 engine families, consist mostly of scooters, with a few dual-sport bikes and entry-level sportbikes and cruisers.

According to the Motorcycle Industry Council (MIC), in 1998 there were about 5.4 million highway motorcycles in use in the United States (565,000 of these were dual-sport).[3] Total sales in 1998 of highway motorcycles was estimated to be about 411,000, or about 72 percent of motorcycle sales. About 13,000 of these were dual-sport motorcycles. Recent figures for the

2000 calendar year show that retail sales approached 438,000 highway motorcycles, about 19,000 of which were dual-sport bikes.[4]

In the second half of the 1990's, motorcycle production at Harley-Davidson fell short of meeting the rapidly growing demand for their motorcycles. The result has been the entry of at least ten new companies into the heavyweight motorcycle market in the last several years. These companies include two that ceased producing on-road motorcycles more than 50 years ago, Excelsior Henderson Motorcycles and Indian Motorcycles. Polaris began manufacturing Victory motorcycles in 1998. American Eagle Motorcycle Company began commercial production in 1996. Other competitors include companies that custom-build heavyweight motorcycles from mostly non-proprietary components, including Titan, Big Dog, Pure Steel, American Ironhorse, and Ultra.

A number of these companies have not been successful in the heavyweight motorcycle market. American Quantum, Excelsior-Henderson, and Titan have filed for bankruptcy. One possible explanation for the difficulty that smaller companies have had in profiting from insufficient production of heavyweight motorcycle is that Harley increased its production by more than expected. Harley-Davidson reports a 17.5 percent increase in production from 1998 to 1999. MIC projects that Harley-Davidson increased production by 15.4 percent between 1999 and 2000.

2.5 - Customer Concerns

2.5.1 - Performance

Adequate performance is clearly an important attribute for highway motorcycles. In particular, buyers of sport or super-sport motorcycles are generally seeking performance that is high or even extreme, sometimes rivaling the performance of exclusive racing motorcycles. In the touring and cruiser segments of the market this kind of outrageous performance is generally not sought after; these bikes have attributes (such as riding style and position) that make high performance a less important design factor. For example, touring motorcycles are designed for long-term riding comfort and luggage carrying capacity, and cruisers are often more focused on a retro look, sound, and feel that allows them to be noticed cruising down Main Street, not sprinting down the freeway.

2.5.2 - Cost

Motorcycles can range in price from around $1500 - $2000 for inexpensive entry-level or dual-sport machines and mopeds and scooters to over $50,000 for elite custom machines. According to Motorcycle Industry Council data the average amount spent by consumers on a new motorcycle in 2001 can be estimated at just over $10,100.[5] As with other recreational vehicles, highway motorcycles are generally discretionary purchases. Significant cost increases could therefore result in decreased sales of these motorcycles if the increased costs cause consumers to take their discretionary income elsewhere and into other recreational opportunities.

2.5.3 - Consumer Modifications

Many motorcycle owners personalize their motorcycles in a variety of ways. This is one of the aspects of motorcycle ownership that is appealing to a large number of motorcycle owners, and they take their freedom to customize their bikes very seriously. However, there are some forms of customization that are not legal under the provisions of Clean Air Act section 203(a), which states that it is illegal:

> "for any person to remove or render inoperative any device or element of design installed on or in a motor vehicle or motor vehicle engine in compliance with regulations under this title ... after such sale and delivery to the ultimate purchaser..."

In other words, owners of motor vehicles cannot legally make modifications that cause the emissions to exceed the applicable emissions standards, and they cannot remove or disable emission-control devices installed by the manufacturer.

We use the term "tampering" to refer specifically to actions that are illegal under Clean Air Act section 203; the term, and the prohibition, do not apply generally to the wide range of actions that a motorcycle enthusiast can do to personalize their vehicle, but only to actions that remove or disable emission control devices or cause the emissions to exceed the standards. We know, from anecdotal reports and from some data collected from in-use motorcycles, that a portion of the motorcycle riding population has removed, replaced, or modified the original equipment on their motorcycles. This customization can include changes that can be detrimental (or, in some cases, possibly beneficial) to the motorcycle's emission levels. The NPRM sought comments and data that could better help us understand the nature of the issue, such that our proposal could be made with the best understanding possible of current consumer practices. We did not intend to suggest that we would be revising the existing tampering restrictions to prohibit many of the things that motorcycle owners are now doing legally.

The emissions standards do not change this "tampering" prohibition, which has been in place for more than 20 years. Owners would still be free generally to customize their motorcycles in any way, as long as they do not disable emission controls or cause the motorcycle to exceed the emission standards. They would also be free, as they are now, to perform routine maintenance on their motorcycles to restore or maintain the motorcycle engine and related components in their original condition and configuration.

2.5.4 - Safety

The nature of motorcycling makes riders particularly aware of the many safety issues that confront them. Many riders that submitted comments to us following the publication of the NPRM in August of 2002 questioned whether catalytic converters could be implemented on motorcycles without increasing the risk of harm to the rider and/or passenger. The primary concern is regarding the close proximity of the riders to hot exhaust pipes and the catalytic converter. Protecting the rider from the excessive heat is a concern for both riders and manufacturers. The current use of catalytic converters on a number of motorcycles (accounting for tens of thousands in the current fleet) already indicates that these issues are not insurmountable on a variety of motorcycle styles and engine sizes. A number of approaches to shielding the rider from the heat of the catalytic converter are possible, such as exterior pipe covers, shielded foot rests, and similar components. Some manufacturers have found that placing the converter on the underside of the engine can keep it adequately distant from the rider. Others may use double-pipe systems that reduce overall heat loss while remaining cooler on the exterior. Based on the significant lead time that would be allowed for meeting these standards, as well as on the two years of prior experience in California before meeting the requirements federally, we believe that these issues can be satisfactorily resolved for the proportion of motorcycles for which catalytic converters will be required.

Chapter 2 References

1. "Industry Profile: Highway Motorcycles," RTI International, Contract No. 68-D-99-024, June, 2003. Available in Docket A-2000-02.

2. "Industry Profile: Highway Motorcycles," RTI International, Contract No. 68-D-99-024, June, 2003. Available in Docket A-2000-02.

3. Motorcycle Industry Council, "2000 Motorcycle Statistical Annual." Available in Docket A-2000-02.

4. DealerNews, volume 37, no. 2, February 2001. Available in Docket A-2000-02.

5. Motorcycle Industry Council, "2002 Motorcycle Statistical Annual." Available in Docket A-2000-02.

CHAPTER 3: Technology

This chapter describes the current state of spark-ignition technology for engines and permeation evaporative emission technology as well as the emission control technologies expected to be available for motorcycle manufacturers. Chapter 4 presents the technical analysis of the feasibility of the standards.

3.1 - Introduction to Spark-Ignition Engine Technology

The two most common types of engines are gasoline-fueled engines and diesel-fueled engines. These engines have very different combustion mechanisms. Gasoline-fueled engines initiate combustion using spark plugs, while diesel fueled engines initiate combustion by compressing the fuel and air to high pressures. Thus these two types of engines are often more generally referred to as "spark-ignition" and "compression-ignition" (or SI and CI) engines, and include similar engines that used other fuels. SI engines include engines fueled with LPG and CNG. SI engines may also be four-stroke or two-stroke which refers to the number of piston strokes per combustion cycle. Motorcycle engines are primarily spark-ignition, four-stroke engines. As of today EPA is aware of one CI motorcycle family; there are no SI motorcycle families certified on alternative fuels,

3.1.1 - Basics of Spark-Ignition Four-Stroke Engines

Four-stroke engines are used in many different applications. Virtually all highway motorcycles, automobiles, and many trucks are powered by four-stroke SI engines. Four-stroke engines are also common in off-road motorcycles, all-terrain vehicles (ATVs), boats, airplanes, and numerous nonroad applications such as lawn mowers, lawn and garden tractors, and generators, to name just a few.

A “four-stroke” engine gets it’s name from the fact that the piston makes four passes or strokes in the cylinder to complete an entire cycle. The strokes are intake, compression, power, and exhaust. Two of the strokes are downward (intake & power) and two of the strokes are upward (compression & exhaust). Valves in the combustion chamber open and close to route gases into and out of the combustion chamber or create compression.

The first step of the cycle is for an intake valve in the combustion chamber to open during the “intake” stroke allowing a mixture of air and fuel to be drawn into the cylinder while an exhaust valve is closed and the piston moves down the cylinder. The piston moves from top dead center (TDC) or the highest piston position to bottom dead center (BDC) or lowest piston position. This creates a vacuum or suction in the cylinder, which draws air and fuel past the open intake valve into the combustion chamber.

The intake valve then closes and the momentum of the crankshaft causes the piston to move back up the cylinder from BDC to TDC, compressing the air and fuel mixture. This is the "compression" stroke. As the piston nears TDC, at the very end of the compression stroke, the air and fuel mixture is ignited by a spark from a spark plug and begins to burn. As the air and fuel mixture burns, increasing temperature and pressure cause the piston to move back down the cylinder, transmitting power to the crankshaft. This is referred to as the "power" stroke. The last stroke in the four-stroke cycle is the "exhaust" stroke. At the bottom of the power stroke, an exhaust valve opens in the combustion chamber and as the piston moves back up the cylinder, the burnt gases are pushed out through the exhaust valve to the exhaust manifold, and the cycle is complete.

3.1.2 - Basics of Spark-ignition Two-stroke Engines

Two-stroke SI engines are not generally used for highway motorcycles above 50 cc, but are used in many highway motorcycles below 50 cc. They have been more widely used in nonroad applications, especially for recreational vehicles, such as snowmobiles, off-highway motorcycles and ATVs. The basic operating principle of the charge scavenged two-stroke engine (traditional two-stroke) is well understood; in two-strokes the engine performs the operations of intake, compression, expansion and exhaust, which the four-stroke engine requires four strokes to accomplish. Two-stroke engines have much higher emission rates than four-stroke engines. We expect that as a result of this rule, almost all new highway motorcycles will use four-stroke engines. However, the emission control systems discussed below are generally applicable to both two-stroke and four-stroke engines, if any manufacturers choose to continue to use two-stroke engines.

Another difference between two- and four-stroke engines is how the engines are lubricated. Four-stroke engines use the crankcase as a sump for lubricating oil. Oil is distributed throughout the engine by a pump through a series of small channels. Because the crankcase in a two-stroke engine serves as the pump for the scavenging process, it is not possible to use it as an oil sump as is the case for four-stroke engines. Otherwise, gasoline would mix with the oil and dilute it. Instead, lubrication for two-stroke engines is provided by mixing specially-formulated two-stroke oil with the incoming charge of air and fuel mixture. The oil is either mixed with the gasoline in the fuel tank, or metered into the gasoline as it is consumed, using a small metering pump. As the gasoline/oil mixture passes through the carburetor, it is atomized into fine droplets and mixed with air. The gasoline quickly vaporizes, while the less volatile oil forms a fine mist of fine droplets. Some of these droplets contact the crankshaft, piston pin, and cylinder walls, providing lubrication. Most of the oil droplets, however, pass out of the crankcase and into the cylinder with the rest of the incoming charge.

In a two-stroke engine, combustion occurs in every revolution of the crankshaft. Two-stroke engines eliminate the intake and exhaust strokes, leaving only compression and power strokes. This is due to the fact that two-stroke engines do not use intake and exhaust valves. Instead, they have openings, referred to as "ports," in the sides of the cylinder walls. There are typically three ports in the cylinder; an intake port that brings the air-fuel mixture into the crankcase; a transfer port that channels the air and fuel mixture from the crankcase to the combustion chamber; and an exhaust port that allows burned gases to leave the cylinder and flow into the exhaust manifold. Two-stroke engines route incoming air and fuel mixture first into the crankcase, then into the cylinder via the transfer port. This is fundamentally different from a four-stroke engine which delivers the air and fuel mixture directly to the combustion chamber.

With a two-stroke engine, as the piston approaches the bottom of the power stroke, it uncovers exhaust ports in the wall of the cylinder. The high pressure burned combustion gases blow into the exhaust manifold. At the same time, downward piston movement compresses the fresh air and fuel mixture charge in the crankcase. As the piston gets closer to the bottom of the power stroke, the transfer ports are uncovered, and fresh mixture of air and fuel are forced into the cylinder while the exhaust ports are still open. Exhaust gas is “scavenged” or forced into the exhaust by the pressure of the incoming charge of fresh air and fuel. In the process, however, some mixing between the exhaust gas and the fresh charge of air and fuel takes place, so that some of the fresh charge is also emitted in the exhaust. Losing part of the fuel out of the exhaust during scavenging causes the very high hydrocarbon emission characteristics of two-stroke engines.

At this point, the power, exhaust, and transfer events have been completed. When the piston begins to move up, its bottom edge uncovers the intake port. Vacuum draws fresh air and fuel into the crankcase. As the piston continues upward, the transfer port and exhaust ports are closed. Compression begins as soon as the exhaust port is blocked. When the piston nears TDC, the spark plug fires and the cycle begins again.

3.1.3 - Engine Calibration

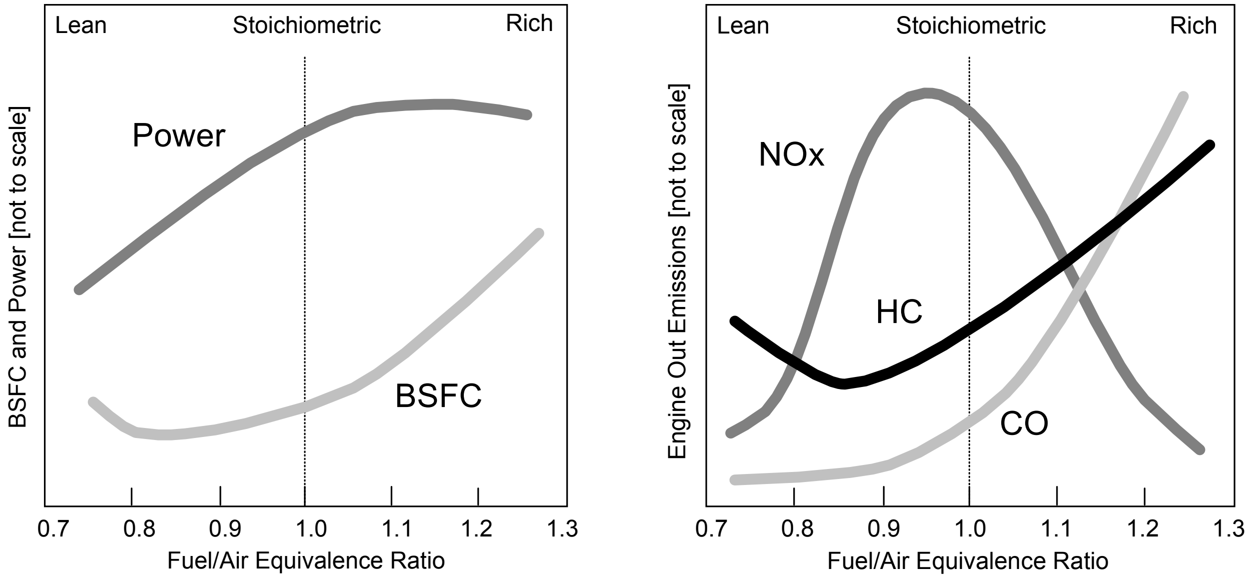
For most current SI engines, after moving from two-stroke to four-stroke technology, the two primary variables that manufacturers can control to reduce emissions are the air and fuel mixture (henceforth referred to as air-fuel ratio) and the spark timing. For highway motorcycles, these two variables are currently the most common methods for controlling exhaust emissions.

3.1.3.1 - Air-fuel ratio

The calibration of the air-fuel mixture affects power, fuel consumption (referred to as Brake Specific Fuel Consumption (BSFC)), and emissions for SI engines. The effects of changing the air-fuel mixture are shown in Figure 3-1.[1] Traditionally, in most SI applications, manufacturers have calibrated their fuel systems for rich operation for two main advantages. First, by running the engine rich, manufacturers can reduce the risk of lean misfire due to imperfect mixing of the fuel and air and variations in the air-fuel mixture from cylinder to cylinder. Second, by making extra fuel available for combustion, it is possible to get more power from the engine. At the same time, since a rich mixture lacks sufficient oxygen for full combustion, it results in increased fuel consumption rates and higher HC and CO emissions. As can be seen from the figure, the best fuel consumption rates occur when the engine is running lean.

With the use of more advanced fuel systems, manufacturers would be able to improve control of the air-fuel mixture in the cylinder. This improved control allows for leaner operation without increasing the risk of lean misfire. This reduces HC and CO emissions and fuel consumption. Leaner air-fuel mixtures, however, increase NOx emissions due to the higher temperatures and increased supply of oxygen.

Figure 3-1: Effects of Air-fuel Ratio on Power, Fuel Consumption, and Emissions



3.1.3.2 - Spark-timing:

For each engine speed and air-fuel mixture, there is an optimum spark-timing that results in peak torque. If the spark is advanced to an earlier point in the cycle, more combustion occurs during the compression stroke. If the spark is retarded to a later point in the cycle, peak cylinder pressure is decreased because too much combustion occurs later in the expansion stroke when it generates little torque on the crankshaft. Timing retard may be used as a strategy for reducing NOx emissions, because it suppresses peak cylinder temperatures that lead to high NOx levels. Timing retard also results in higher exhaust gas temperatures, because less mechanical work is extracted from the available energy. This may have the benefit of warming catalyst material to more quickly reach the temperatures needed to operate effectively during light-load operation.[2] Some automotive engine designs rely on timing retard at start-up to reduce cold-start emissions.

Advancing the spark-timing at higher speeds gives the fuel more time to burn. Retarding the spark timing at lower speeds and loads avoids misfire. With a mechanically controlled engine, a fly-weight or manifold vacuum system adjusts the timing. Mechanical controls, however, limit the manufacturer to a single timing curve when calibrating the engine. This means that the timing is not completely optimized for most modes of operation.

3.1.3.3 - Fuel Metering

Fuel injection has proven to be an effective and durable strategy for improving performance, controlling emissions and reducing fuel consumption from highway gasoline engines. Comparable upgrades are also available for gaseous fuels. This section describes a variety of technologies available to improve fuel metering.

Throttle-body gasoline injection: A throttle-body system uses the same intake manifold as a carbureted engine. However, the throttle body replaces the carburetor. By injecting the fuel into the intake air stream, the fuel is better atomized than if it were drawn through with a venturi. This results in better mixing and more efficient combustion. In addition, the fuel can be more precisely metered to achieve benefits for fuel economy, performance, and emission control.

Throttle-body designs have the drawback of potentially large cylinder-to-cylinder variations. Like a carburetor, TBI injects the fuel into the intake air at a single location upstream of all the cylinders. Because the air-fuel mixture travels different routes to each cylinder, the amount of fuel that reaches each cylinder will vary. Manufacturers account for this variation in their design and may make compromises such as injecting extra fuel to ensure that the cylinder with the leanest mixture will not misfire. These compromises affect emissions and fuel consumption.

Multi-port gasoline injection: As the name suggests, multi-port fuel injection means that a fuel injector is placed at each of the intake ports. A quantity of fuel is injected each time the intake valve opens for each cylinder. This allows manufacturers to more precisely control the amount of fuel injected for each combustion event. This control increases the manufacturer's ability to optimize the air-fuel ratio for emissions, performance, and fuel consumption. Because of these benefits, multi-port injection is has been widely used in automotive applications for over 15 years.

Sequential injection has further improved these systems by more carefully timing the injection event with the intake valve opening. This improves fuel atomization and air-fuel mixing, which further improves performance and control of emissions.

Direct injection: Direct Injection (DI) systems are very similar to multi-port injection systems, since both are electronically controlled systems that inject fuel directly into the cylinder. The main difference is that DI systems more fully atomize (i.e., break-down into very small droplets) the fuel, which can greatly improve combustion efficiency resulting in improved power and reduced emissions. For 2-stroke engines, only air is pumped into the cylinder, rather than air and fuel. Finely atomized fuel is then injected into the combustion chamber once all of the ports are closed. This eliminates the short-circuiting of fresh air and fuel into the exhaust port. The biggest problem with DI is that there is very little time for air to be pumped into the cylinder and fuel then injected after all of the ports have closed. This is overcome by the use of numerous engines sensors, a high-speed electronic control module, and software which uses sophisticated control algorithms.

DI systems have been in use for the past several years in some small motorcycle, scooter and marine applications, primarily for personal watercraft (PWC) and outboard engines. There are numerous variations of DI systems, but two primary approaches that are commercially available today: high pressure injection and air-assisted injection. There are a number of companies who have developed high pressure DI systems, but the most successful systems currently belong to FICHT and Yamaha. The FICHT system uses a special fuel injector that is able to inject fuel at very high pressure (e.g., over 250 psi). The fuel injector itself is essentially a piston that is operated by an electromagnet. Fuel enters the injector at low pressure from an electric fuel pump and is forced out of the injector nozzle at high pressure when the piston hammers down on the fuel. The Yamaha system uses a high pressure fuel pump to generate the high fuel pressure. The other DI approach that is most common in various engine applications is the air-assisted injection system which has been developed by Orbital. The Orbital system uses pressurized air to help inject the fuel into the combustion chamber. The system uses a small single cylinder reciprocating air compressor to assist in the injection of the fuel. All three systems are currently used in some marine applications by companies such as Kawasaki, Polaris, Sea-Doo, and Yamaha. The Orbital system is also currently used on some small motorcycle and scooter applications by Aprilla.

3.1.4 - Gaseous Fuels

Engines operating on LPG or natural gas carry compressed fuel that is gaseous at atmospheric pressure. The technical challenges for gasoline related to an extended time to vaporize the fuel don’t apply to gaseous-fuel engines. Typically, a mixer introduces the fuel into the intake system. Manufacturers are pursuing new designs to inject the fuel directly into the intake manifold. This improves control of the air-fuel ratio and the combustion event, similar to the improvements in gasoline injection technology.

3.2 - Exhaust Emissions and Control Technologies

HC and CO emissions from four-stroke engines are primarily the result of poor in-cylinder combustion. Higher levels of NOx emissions are the result of leaner air-fuel ratios and the resulting higher combustion temperatures. Combustion chamber modifications can help reduce HC emission levels, while using improved air-fuel ratio and spark timing calibrations, as discussed in sections 3.1.2.1 and 3.1.2.2, can further reduce HC emissions and lower CO emissions. The conversion from carburetor to EFI will also help reduce HC and CO emissions. The use of exhaust gas recirculation on can reduce NOx emissions, but is not necessarily needed for highway motorcycles, due to their relatively low NOx emission levels related to engine calibrations. The addition of secondary air into the exhaust can significantly reduce HC and CO emissions. Finally, the use catalytic converters can further reduce all three emissions.

3.2.1 - Combustion chamber design

Unburned fuel can be trapped momentarily in crevice volumes (especially the space between the piston and cylinder wall) before being released into the exhaust. Reducing crevice volumes decreases this amount of unburned fuel, which reduces HC emissions. One way to reduce crevice volumes is to design pistons with piston rings closer to the top of the piston. HC may be reduced by 3 to 10 percent by reducing crevice volumes, with negligible effects on NOx emissions.[3]

HC emissions also come from lubricating oil that leaks into the combustion chamber. The heavier hydrocarbons in the oil generally don't burn completely. Oil in the combustion chamber can also trap gaseous HC from the fuel and prevent it from burning. For engines using catalytic control, some components in lubricating oil can poison the catalyst and reduce its effectiveness, which would further increase emissions over time. To reduce oil consumption, manufacturers can tighten tolerances and improve surface finishes for cylinders and pistons, improve piston ring design and material, and improve exhaust valve stem seals to prevent excessive leakage of lubricating oil into the combustion chamber.

3.2.2 - Exhaust gas recirculation

Exhaust gas recirculation (EGR) has been in use in cars and trucks for many years. The recirculated gas acts as a diluent in the air-fuel mixture, slowing reaction rates and absorbing heat to reduce combustion temperatures. These lower temperatures can reduce the engine-out NOx formation rate by as much as 50 percent.[4] HC is increased slightly due to lower temperatures for HC burn-up during the late expansion and exhaust strokes.

Depending on the burn rate of the engine and the amount of recirculated gases, EGR can reduce fuel consumption. Although EGR slows the burn rate, it can offset this effect with some benefits for engine efficiency. EGR reduces pumping work since the addition of recirculated gas increases intake pressure. Because the burned gas temperature is decreased, there is less heat loss to the exhaust and cylinder walls. In effect, EGR allows more of the chemical energy in the fuel to be converted to useable work.[5]

For catalyst systems with high conversion efficiencies, the benefit of using EGR becomes proportionally smaller. Also, including EGR as a design variable for optimizing the engine adds significantly to the development time needed to fully calibrate engine models.

The use of EGR may not necessarily be needed for highway motorcycles, due to their relatively low NOx emission levels related to engine calibrations and packaging constraints.

3.2.3 - Secondary air

Secondary injection of air into exhaust ports or pipes after cold start (e.g., the first 40-60 seconds) when the engine is operating rich, coupled with spark retard, can promote combustion of unburned HC and CO in the exhaust manifold and increase the warm-up rate of the catalyst. By means of an electrical or mechanical pump, secondary air is injected into the exhaust system, preferably in close proximity to the exhaust valve. Together with the oxygen of the secondary air and the hot exhaust components of HC and CO, oxidation ahead of the catalyst can bring about an efficient increase in the exhaust temperature which helps the catalyst to heat up quicker and also reduces the emissions load into the catalyst. The exothermic reaction that occurs is dependent on several parameters (secondary air mass, location of secondary air injection, engine A/F ratio, engine air mass, ignition timing, manifold and headpipe construction, etc.), and ensuring reproducibility demands detailed individual application for each vehicle or engine design.

Secondary air injection was first used as an emission control technique in itself without a catalyst, and still is used for this purpose in many highway motorcycles and some off-highway motorcycles to meet federal and California emission standards. For motorcycles, air is usually provided or injected by a system of check valves which uses the normal pressure pulsations in the exhaust manifold to draw in air from outside, rather than by a pump.

3.2.4 - Catalytic Aftertreatment

Over the last several years, there have been tremendous advances in exhaust aftertreatment systems. Catalyst manufacturers are progressively moving to palladium (Pd) as the main precious metal in automotive catalyst applications. Improvements to catalyst thermal stability and washcoat technologies, the design of higher cell densities, and the use of two-layer washcoat applications are just some of the advances made in catalyst technology. There are two types of catalytic converters commonly used: oxidation and three-way. Oxidation catalysts use platinum and/or palladium to increase the rate of reaction between oxygen in the exhaust and unburned HC and CO. Ordinarily, this reaction would proceed very slowly at temperatures typical of engine exhaust. The effectiveness of the catalyst depends on its temperature, on the air-fuel ratio of the mixture, and on the mix of HC present. Highly reactive species such as formaldehyde and olefins are oxidized more effectively than less-reactive species. Short-chain paraffins such as methane, ethane, and propane are among the least reactive HC species, and are difficult to oxidize. Because they are less reactive, they are also less of a concern as ozone precursors.

Three-way catalysts use a combination of platinum and/or palladium and rhodium. In addition to promoting oxidation of HC and CO, these metals also promote the reduction of NO to nitrogen and oxygen. In order for the NO reduction to occur efficiently, an overall rich or stoichiometric air-fuel ratio is required. The NOx disassociation efficiency drops rapidly as the ai-fuel ratio becomes leaner than stoichiometric. If the air-fuel ratio can be maintained precisely at or just rich of stoichiometic, a three-way catalyst can simultaneously oxidize HC and CO and reduce NOx. The window of air-fuel ratios within which this is possible is very narrow and there is a trade-off between NOx and HC/CO control even within this window.

There are several issues involved in designing catalytic control systems for the four-stroke engines covered by this rule. The primary issues are the cost of the system, packaging constraints, and the durability of the catalyst. This section addresses these issues.

3.2.4.1 - System cost

Sales volumes of motorcycles are small compared to automotive sales. Manufacturers therefore have a limited ability to recoup large R&D expenditures for highway motorcycle engines. For this reason, we believe it is not appropriate to consider highly refined catalyst systems that are tailored specifically to these applications. The cost of these systems will decrease substantially when catalysts become commonplace. Chapter 5 describes the estimated costs for a motorcycle catalyst system.

3.2.4.2 - Packaging constraints

Many motorcycles have space constraints for adding a catalyst because they have been finely designed over many years with a very compact fit. Automotive catalyst designs typically have one or two catalyst units upstream of the muffler. This is a viable option for some motorcycles. However, if there is no available space to add a separate catalyst, it is possible to build a full catalyst/muffler combination that fits in the same space as the conventional muffler. With this packaging option, even compact applications should have little or no trouble integrating a catalyst into the equipment design. The catalyst designs already used on highway motorcycles clearly demonstrate the viability of this approach. However, unlike automobiles, there is an active aftermarket for motorcycle accessories which includes exhaust system components. If an integrated muffler/catalyst approach is used, manufacturers will have to design them in such a way that removal of the exhaust system for replacement with an aftermarket component does not inherently result in removal of the catalyst as well. Otherwise, aftermarket parts will need to include a catalyst.

3.2.4.3 - Two-Stroke Aftertreatment

There are two exhaust aftertreatment technologies that can provide additional emission reductions from two-stroke engines: thermal oxidation (e.g., secondary air) and oxidation catalyst. Thermal oxidation reduces HC and CO by promoting further oxidation of these species in the exhaust. The oxidation usually takes place in the exhaust port or pipe, and may require the injection of additional air to supply the needed oxygen. If the exhaust temperature can be maintained at a high enough temperature (e.g., 600 to 700°C) for a long enough period, substantial reductions in HC and CO can occur. Air injection at low rates into the exhaust system has been shown to reduce emissions by as much as 77 percent for HC and 64 percent for CO.[12]

Like thermal oxidation, the oxidation catalyst is used to promote further oxidation of HC and CO emissions in the exhaust stream, and it also requires sufficient oxygen for the reaction to take place. Some of the requirements for a catalytic converter to be used in two-stroke engines

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[12] White, J.J., Carroll,J.N., Hare, C.T., and Lourenco, J.G. (1991), "Emission Control Strategies for Small Utility Engines," SAE Paper No. 911807, Society of Automotive Engineers, Warrendale, PA, 1991.

include high HC conversion efficiency, resistance to thermal damage, resistance to poisoning from sulfur and phosphorus compounds in lubricating oil, and low light-off temperature.

Application of catalytic converters to two-stroke engines presents a problem, because of the high concentrations of HC and CO in their exhaust. If combined with sufficient air, these high pollutant concentrations result in catalyst temperatures that can easily exceed the temperature limits of the catalyst. Therefore, the application of oxidation catalysts to two-stroke engines may first require engine modifications to reduce HC and CO and may also require secondary air be supplied to the exhaust in front of the catalyst.

Researchers of Graz University of Technology and the Industrial Technology Research Institute (ITRI) in Taiwan have published data on the application of catalytic converters in small two-stroke moped and motorcycle engines using catalytic converters. The Graz researchers focused on reducing emissions using catalysts, as well as by improving the thermodynamic characteristics of the engines, such as gas exchange and fuel handling systems, cylinder and piston geometry and configurations, and exhaust cooling systems. For HC and CO emissions, they found that an oxidation catalyst could reduce emissions by 88 to 96 percent. Researchers at ITRI successfully retrofitted a catalytic converter to a 125 cc two-stroke motorcycle engine, and demonstrated both effective emissions control and durability.[13] The Manufacturers of Emission Controls Association (MECA)in their publication titled "Emission Control of Two-and Three-wheel Vehicles," published May 7, 1999, state that catalyst technology has clearly demonstrated the ability to achieve significant emissions reductions from two-stroke engines. MECA points to the success of two-stroke moped and motorcycle engines equipped with catalysts that have been operating for several years in Taiwan, Thailand, Austria, and Switzerland.

3.2.5 - Multiple valves and variable valve timing

Four-stroke engines generally have two valves for each cylinder, one for intake of the air-fuel mixture and the other for exhaust of the combusted mixture. The duration and lift (distance the valve head is pushed away from its seat) of valve openings is constant regardless of engine speed. As engine speed increases, the aerodynamic resistance to pumping air in and out of the cylinder for intake and exhaust also increases. Automotive engines have started to use two intake and two exhaust valves to reduce pumping losses and improve their volumetric efficiency and useful power output. Some highway motorcycles have used multiple valves for years, especially the high-performance sport motorcycles.

In addition to gains in breathing, 4-valve designs allow the spark plug to be positioned closer to the center of the combustion chamber, which decreases the distance the flame must travel inside the chamber. This decreases the likelihood of flame-out conditions in the areas of the combustion chamber farthest from the spark plug. In addition, the two streams of incoming

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[13] Hsien, P.H., Hwang, L.K., and Wang, H.W (1992), "Emission Reduction by Retrofitting a 125 cc Two-Stroke Motorcycle with Catalytic Converter," SAE Paper No. 922175, Society of Automotive Engineers, Warrendale, PA, 1992.

gas can be used to achieve greater mixing of air and fuel, further increasing combustion efficiency and lowering engine-out emissions.

Control of valve timing and lift take full advantage of the 4-valve configuration for even greater improvement in combustion efficiency. Engines normally use fixed-valve timing and lift across all engine speeds. If the valve timing is optimized for low-speed torque, it may offer compromised performance under higher-speed operation. At light engine loads, for example, it is desirable to close the intake valve early to reduce pumping losses. Variable-valve timing can enhance both low-speed and high-speed performance with compromise. Variable-valve timing can allow for increased swirl and intake charge velocity, especially during low-load operating conditions where this is most problematic. By providing a strong swirl formation in the combustion chamber, the air-fuel mixture can mix sufficiently, resulting in a faster, more complete combustion, even under lean air-fuel conditions, thereby reducing emissions.

Variable-valve technology by itself may have somewhat limited effect on reducing emissions, but combining it with optimized spark plug location and exhaust gas recirculation can lead to substantial emission reductions.

3.2.6 - Advanced Emission Controls

On February 10, 2000, EPA published new "Tier 2" emission standards for all passenger vehicles, including sport utility vehicles (SUVs), minivans, vans and pick-up trucks. The new standards will ensure that exhaust VOC emissions be reduced to less than 0.1 g/mi on average over the fleet, and that evaporative emissions be reduced by at least 50 percent. Onboard refueling vapor recovery requirements were also extended to medium-duty passenger vehicles. By 2020, these standards will reduce VOC emissions from light-duty vehicles by more than 25 percent of the projected baseline inventory. To achieve these reductions, manufacturers will need to incorporate advanced emission controls, including: larger and improved close-coupled catalysts, optimized spark timing and fuel control, improved exhaust systems.

To reduce emissions, gasoline-fueled automobile and truck manufacturers have designed their engines to achieve virtually complete combustion and have installed advanced catalytic converter systems in the exhaust system. In order for these controls to work well for gasoline-fueled vehicles, it is necessary to maintain the mixture of air and fuel at a nearly stoichiometric ratio (that is, just enough air to completely burn the fuel). Poor air-fuel mixture can result in significantly higher emissions of uncombusted fuel. Current generation automobiles and trucks are able to maintain stoichiometry by using closed-loop electronic feedback control of the fuel systems. As part of these systems, technologies have been developed to closely meter the amount of fuel entering the combustion chamber to promote complete combustion. Sequential multi-point fuel injection delivers a more precise amount of fuel to each cylinder independently and at the appropriate time increasing engine efficiency and fuel economy. Electronic throttle control offers a faster response to engine operational changes than mechanical throttle control can achieve, but it is currently considered expensive and only used on some higher-price vehicles. The greatest gains in fuel control can be made through engine calibrations -- the algorithms contained in the powertrain control module (PCM) software that control the operation of various engine and emission control components/systems. As microprocessor speed becomes faster, it is possible to perform quicker calculations and to increase response times for controlling engine parameters such as fuel rate and spark timing. Other advances in engine design have also been used to reduce engine-out emissions, including: the reduction of crevice volumes in the combustion chamber to prevent trapping of unburned fuel; "fast burn" combustion chamber designs that promote swirl and flame propagation; and multiple valves with variable-valve timing to reduce pumping losses and improve efficiency. These technologies are discussed in more detail in the RIA for the Tier 2 FRM.[6]

As noted above, manufacturers are also using aftertreatment control devices to control emissions. New three-way catalysts for highway vehicles are so effective that once a TWC reaches its operating temperature, emissions are virtually undetectable.[7] Manufacturers are now working to improve the durability of the TWC and to reduce light-off time (that is, the amount of time necessary after starting the engine before the catalyst reaches its operating temperature and is effectively controlling VOCs, NOx and other pollutants). EPA expects that manufacturers will be able to design their catalyst systems so that they light off within less than thirty seconds of engine starting. Other potential exhaust aftertreatment systems that could further reduce cold-start emissions are thermally insulated catalysts, electrically heated catalysts, and HC adsorbers (or traps). Each of these technologies, which are discussed below, offer the potential for VOC reductions in the future. However, there are technological, implementation, and cost issues that still need to be addressed to incorporate these technologies into automobiles, and these issues are further magnified when considering their use in lower cost applications such as motorcycles. For example, the electrical power demands of an electrically heated catalyst system far exceed the limits of current battery and alternator systems in automobiles, and it may be impractical or even impossible to add the extra weight and equipment needed for such systems to the limited space available on a motorcycle. As noted below, it may be necessary in some cases to pair an electrically heated catalyst with an HC absorber in order to improve emissions, further complicating the use of these technologies on motorcycles. At this time these advanced technologies are only used on a limited number of automobiles, in part due to their high cost and relatively early stage of development. Therefore, at this time it appears that these technologies would not be a cost-effective means of reducing motorcycle emissions on a nationwide basis.

Thermally insulated catalysts maintain sufficiently high catalyst temperatures by surrounding the catalyst with an insulating vacuum. Prototypes of this technology have demonstrated the ability to store heat for more than 12 hours.[8] Since ordinary catalysts typically cool down below their light-off temperature in less than one hour, this technology could reduce in-use emissions for vehicles that have multiple cold-starts in a single day. However, this technology would have less impact on emissions from vehicles that have only one or two cold-starts per day.

Electrically-heated catalysts reduce cold-start emissions by applying an electric current to the catalyst before the engine is started to get the catalyst up to its operating temperature more quickly.[9] These systems require a modified catalyst, as well as an upgraded battery and charging system. These can greatly reduce cold-start emissions, but could require the driver to wait until the catalyst is heated before the engine would start to achieve optimum performance.

Hydrocarbon adsorbers are designed to trap VOCs while the catalyst is cold and unable to sufficiently convert them. They accomplish this by utilizing an adsorbing material which holds onto the VOC molecules. Once the catalyst is warmed up, the trapped VOCs are automatically released from the adsorption material and are converted by the fully functioning downstream three-way catalyst. There are three principal methods for incorporating an adsorber into the exhaust system. The first is to coat the adsorber directly on the catalyst substrate. The advantage is that there are no changes to the exhaust system required, but the desorption process cannot be easily controlled and usually occurs before the catalyst has reached light-off temperature. The second method locates the adsorber in another exhaust pipe parallel with the main exhaust pipe, but in front of the catalyst and includes a series of valves that route the exhaust through the adsorber in the first few seconds after cold start, switching exhaust flow through the catalyst thereafter. Under this system, mechanisms to purge the adsorber are also required. The third method places the trap at the end of the exhaust system, in another exhaust pipe parallel to the muffler, because of the low thermal tolerance of adsorber material. Again a purging mechanism is required to purge the adsorbed VOCs back into the catalyst, but adsorber overheating is avoided. One manufacturer who incorporates a zeolite hydrocarbon adsorber in its California SULEV vehicle found that an electrically heated catalyst was necessary after the adsorber because the zeolite acts as a heat sink and nearly negates the cold start advantage of the adsorber. This approach has been demonstrated to effectively reduce cold start emissions.

3.3 - Evaporative Emissions

3.3.1 Sources of Evaporative Emissions

Evaporative emissions from motorcycles represents a small but not insignificant part of their HC emissions. The magnitude of the emissions varies widely depending on the engine design and application. Evaporative emissions can be grouped into five categories:

DIURNAL: Gasoline evaporation increases as the temperature rises during the day, heating the fuel tank and venting gasoline vapors.

RUNNING LOSSES: The hot engine and exhaust system can vaporize gasoline when the engine is running.

HOT SOAK: The engine remains hot for a period of time after the engine is turned off and gasoline evaporation continues. This problem is most pronounced for carbureted motorcycles.

REFUELING: Gasoline vapors are always present in typical fuel tanks. These vapors are forced out when the tank is filled with liquid fuel.

PERMEATION: Gasoline molecules can saturate plastic fuel tanks and rubber hoses, resulting in a relatively constant rate of emissions as the fuel continues to permeate through these components.

Among the factors that affect emission rates are: (1) fuel metering (fuel injection or carburetor); (2) fuel permeation is affected by the material used to construct the fuel lines and fuel tanks; (3) the proximity of the fuel tank to the exhaust system or other heat sources; (4) whether the fuel system is sealed and the pressure at which fuel vapors are vented;(5) fuel tank volume; and (6) where the vehicle is stored when not in-use. Fuel fill level and fuel vapor pressure are also important, but these are not vehicle design parameters.

3.3.1.1 - Diurnal and Running Loss Emissions

In an open fuel tank, the vapor space is at atmospheric pressure (typically about 14.7 psi), and contains a mixture of fuel vapor and air. At all temperatures below the fuel's boiling point, the vapor pressure of the fuel is less than atmospheric pressure. This is also called the partial pressure of the fuel vapor. The partial pressure of the air is equal to the difference between atmospheric pressure and the fuel vapor pressure. For example, in an open-vented fuel tank at 60˚F, the vapor pressure of typical gasoline would be about 4.5 psi. In this example, the partial pressure of the air would be about 10.2 psi. Assuming that the vapor mixture behaves as an ideal gas, then the mole fractions (or volumetric fractions) of fuel vapor and air would be equal to their respective partial pressures divided by the total pressure; thus, the fuel would be 31 percent of the mixture (4.5/14.7) and the air would be 69 percent of the mixture (10.2/14.7).

Diurnal emissions occur when the fuel temperature increases, which increases the equilibrium vapor pressure of the fuel. For example, assume that the fuel in the previous example was heated to 90˚F, where the vapor pressure of that same typical fuel would be about 8.0 psi. To maintain the vapor space at atmospheric pressure, the partial pressure of the air would need to decrease to 6.7 psi, which means that the vapor mixture must expand in volume. This forces some of the fuel-air mixture to be vented out of the tank. When the fuel later cools, the vapor pressure of the fuel decreases, contracting the mixture, and drawing fresh air in through the vent. When the fuel is heated again, another cycle of diurnal emissions occurs. It is important to note that this is generally not a rate-limited process. Although the evaporation of the fuel can be slow, it is generally fast enough to maintain the fuel tank in an essentially equilibrium state.

Consider a typical fuel use cycle beginning with a full tank. As fuel is used by the engine, and the liquid fuel volume decreases, air is drawn into the tank to replace the volume of the fuel. (Note: the decrease in the liquid fuel level could be offset to some degree by increasing fuel vapor pressure caused by increasing fuel temperature. However, this would be offset by the decrease in fuel vapor pressure due to weathering.) This would continue while the engine was running. If the engine was shut off and the tank was left overnight, the vapor pressure of the fuel would drop as the temperature of the fuel dropped. This would cause a small negative pressure within the tank that would cause it to fill with more air until the pressure equilibrated. The next day, the vapor pressure of the fuel would increase as the temperature of the fuel increased. This would cause a small positive pressure within the tank that would force a mixture of fuel vapor and air out. The daily emission rate varies as a function of the diurnal temperature swing the tank sees, the fuel vapor pressure, the tank volume, and the fuel fill level.

3.3.1.2 - Hot Soak Emissions

Hot soak emissions occur after the engine is turned off, especially during the resulting temperature rise. For motorcycle engines, the primary source of hot soak emissions is the evaporation of the fuel left in the carburetor bowl. Other sources can include increased evaporation of fuel from plastic or rubber fuel lines in the engine compartment.

3.3.1.3 - Refueling Emissions

Refueling emissions occur when the fuel vapors are forced out when the tank is filled with liquid fuel. At a given temperature, refueling emissions are proportional to the volume of the fuel dispensed into the tank. Every gallon of fuel put into the tank forces out one-gallon of the mixture of air and fuel vapors. Thus, refueling emissions are highest when the tank is near empty. Refueling emissions are also affected by the temperature of the liquid and dispensed fuels. Vapor shrinkage or vapor growth can occur depending on the temperature difference between the two fuels involved. Fuel vapor pressure differences are also important.

3.3.1.4 - Permeation

The polymeric material (plastic or rubber) of which many gasoline fuel tanks and fuel hoses generally are constructed have a chemical composition much like that of gasoline. As a result, constant exposure of gasoline liquid and vapor to these surfaces allows the material to continually absorb fuel. The outer surfaces of these materials are exposed to ambient air, so the gradient drives gasoline molecules to permeate through these fuel-system components and are emitted directly into the air. Permeation rates are relatively low, but emissions continue at a nearly constant rate, regardless of how much the vehicle or equipment is used or where it is stored. Permeation-related emissions can therefore add up to a significant fraction of the total emissions from gasoline powered vehicles.

3.3.2 Evaporative Emission Controls

This section focuses on emission-control technologies that can be used to reduce permeation emissions from motorcycle fuel tanks and hoses. Chapter 4 presents more detail on how we expect manufacturers to use these technologies to meet the emission standards for this rule.

3.3.2.1 Fuel Tanks

Blow molding is widely used for the manufacture of plastic motorcycle fuel tanks. Typically, blow molding is performed by creating a hollow tube, known as a parison, by pushing high-density polyethylene (HDPE) through an extruder with a screw. The parison is then pinched in a mold and inflated with an inert gas. In automotive applications, non-permeable plastic fuel tanks are produced by blow molding a layer of ethylene vinyl alcohol (EVOH) or nylon between two layers of polyethylene. This process is called coextrusion and requires at least five layers: the barrier layer, adhesive layers on either side of the barrier layer, and HDPE as the outside layers which make up most of the thickness of the fuel tank walls. However, multi-layer construction requires additional extruder screws which significantly increases the cost of the blow molding process.

Multi-layer fuel tanks can also be formed using injection molding. In this method, a low viscosity polymer is forced into a thin mold to create each side of the fuel tank. The two sides are then welded together. In typical fuel tank construction, the sides are welded together by using a hot plate for localized melting and then pressing the sides together. The sides may also be connected using vibration or sonic welding. To add a barrier layer, a thin sheet of the barrier material is placed inside the mold prior to injection of the poleythylene. The polyethylene, which generally has a much lower melting point than the barrier material, bonds with the barrier material to create a shell with an inner liner. As an alternative, an additional extruder can be added to inject the barrier layer prior to injecting the HDPE; however, this substantially increases the cost of the process.

A less expensive alternative to coextrusion is to blend a low permeable resin with the HDPE and extrude it with a single screw. The trade name typically used for this permeation control strategy is Selar®. The low permeability resin, typically EVOH or nylon, creates non-continuous platelets in the HDPE fuel tank which reduce permeation by creating long, tortuous pathways that the hydrocarbon molecules must navigate to pass through the fuel tank walls. Although the barrier is not continuous, this strategy can still achieve greater than a 90 percent reduction in permeation of gasoline. EVOH has much higher permeation resistance to alcohol than nylon; therefore, it would be the preferred material to use for meeting our standard which is based on testing with a 10 percent ethanol fuel.

Another type of low permeation technology for fuel tanks would be to treat the surfaces of a plastic fuel tanks with a barrier layer. Two ways of achieving this are known as fluorination and sulfonation. The fluorination process causes a chemical reaction where exposed hydrogen atoms are replaced by larger fluorine atoms which a barrier on surface of the fuel tank. In this process, fuel tanks are generally processed post production by stacking them in a steel container. The container is then voided of air and flooded with fluorine gas. By pulling a vacuum in the container, the fluorine gas is forced into every crevice in the fuel tanks. As a result of this process, both the inside and outside surfaces of the fuel tank would be treated. As an alternative, fuel tanks can be fluorinated on-line by exposing the inside surface of the fuel tank to fluorine during the blow molding process. However, this method may not prove as effective as off-line fluorination which treats the inside and outside surfaces.

The sulfonation process uses sulfur trioxide to create the barrier by reacting with the exposed polyethylene to form sulfonic acid groups on the surface. Current practices for sulfonation are to place fuel tanks on a small assembly line and expose the inner surfaces to sulfur trioxide, then rinse with a neutralizing agent. However, this can also be performed off-line. Either of these processes can be used to reduce gasoline permeation by more than 95 percent.

Fuel tank permeation can also be reduced through the use of alternative materials. For instance, the majority of motorcycle fuel tanks are made from metal which does not permeate. Chapter 4 discusses alternative low-permeation polymers which manufacturers may be able to use to mold plastic tanks.

3.3.2.2 Fuel Hoses

Fuel hoses produced for use in motorcycles are generally extruded nitrile rubber with a cover for abrasion resistance. Lower permeability fuel hoses produced today for other applications are generally constructed in one of two ways: either with a low permeability layer or by using a low permeability rubber blend. By using hose with a low permeation thermoplastic layer, permeation emissions can be reduced by more than 95 percent. Because the thermoplastic layer is very thin, on the order of 0.1 to 0.2 mm, the rubber hose retains its flexibility. Three thermoplastics which have excellent permeation resistance, even with an alcohol-blend fuel, are ethylene-tetrafluoro-ethylene (ETFE), tetra-fluoro-ethylene, hexa-fluoro-propylene, and vinyledene fluoride (THV), and Teflon®.

In automotive applications, multilayer plastic tubing, made of fluoropolymers is generally used. An added benefit of these low permeability lines is that some fluoropolymers can be made to be conductive and therefore can prevent the buildup of static charges. Although this technology can achieve more than an order of magnitude lower permeation than barrier hoses, it is relatively inflexible and may need to be molded in specific shapes for each motorcycle design. Manufacturers have commented that they would need flexible hose to fit their many designs, resist vibration, and to simplify the hose connections and fittings.

Chapter 3 References

1. Heywood, J., “Internal Combustion Engine Fundamentals,” McGraw-Hill, Inc., New York, 1988, pp.829-836.

2. Heywood, pp.827-829.

3. Energy and Environmental Analysis, “Benefits and Cost of Potential Tier 2 Emission Reduction Technologies”, Final Report, November 1997, Docket A-2000-01, Document II-A-01.

4. Southwest Research Institute, “Three-Way Catalyst Technology for Off-Road Equipment Powered by Gasoline and LPG Engines,” prepared for CARB, CEPA, and SCAQMD, (SwRI 8778), April 1999, Docket A-2000-01, Document II-A-08.

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7. McDonald, J., L. Jones, Demonstration of Tier 2 Emission Levels for Heavy Light-Duty Trucks, SAE 2000-01-1957.

8. Burch, S.D., and J.P. Biel, SULEV and "Off-Cycle" Emissions Benefits of a Vacuum-Insulated Catalytic Convert, SAE 1999-01-0461.

9. Laing, P.M., Development of an Alternator-Powered Electrically-Heated Catalyst System, SAE 941042.

CHAPTER 4: Technological Feasibility

We are finalizing new motorcycle standards under the authority of section 202 of the Clean Air Act. Sections 202(a) and (b) of the Act provide EPA with the general authority to prescribe vehicle standards, subject to any specific limitations otherwise included in the Act. Section 202(a)(1) of the Act directs us to establish standards regulating the emission of any air pollutant from an class or classes of new motor vehicles or engines that, in the Administrator's judgement, cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare. Section 202(a)(2) directs the Administrator to provide lead time sufficient to "permit the development and application of the requisite technology, giving appropriate consideration to the cost of compliance within such period." Section 202(a)(3)(E) directs the Administrator, in establishing emission standards for highway motorcycles, to "consider the need to achieve equivalency of emission reductions between motorcycles and other motor vehicles to the maximum extent practicable."

This chapter presents the technical analyses and information that form the basis of EPA's belief that the new emission standards are technically achievable accounting for all the above factors.

4.1 - Exhaust Emission Control from Motorcycles

The emission standards for highway motorcycles are summarized in the Executive Summary. As discussed in Chapter 3, we believe there are several technologies that can be used to reduce exhaust emissions from highway motorcycles. This section presents certification emissions data on a range of emissions levels achieved using different technology options. The following sections summarize the data and rationale supporting the emission standards for highway motorcycles.

In the development of the proposal, we considered several regulatory alternatives. These included: no revision to the standards, harmonization with one of the "tiers" of California standards (current, 2004 Tier-1, 2008 Tier-2), more stringent standards than those in place in California, or possibly different implementation timing. We also considered various alternatives designed to reduce the burden on small manufacturers (these are presented in Chapter 8 on the Small Business Flexibility Analysis). As required by section 202(a)(3)(E) of the Clean Air Act (CAA, or "the Act"), we also considered "the need to achieve equivalency of emission reductions between motorcycles and other motor vehicles to the maximum extent practicable."

After considering comments on the NPRM, we believe the existing standards should be revised. The existing federal standards were established more than twenty years ago, and it is clear that emission control technology has advanced a great deal in that time. California has continued to revise their standards to maintain some contact with current technology, and manufacturers have generally (but not uniformly) responded by producing motorcycles for sale nationwide that meet the more stringent California standards. Thus, in large part the existing federal standards have been superseded because of the preponderance of manufacturers that have responded in this way. Those arguing against new emission standards often cite the fact that motorcycles are typically far cleaner than the existing federal standards require. Although we agree, we see this fact as a reason <u>for</u> improving emission standards and as evidence that the current federal standards are out of touch with the reality of today's technology.

We believe it is most appropriate at this time to harmonize with the California exhaust emission standards, as opposed to other options. For example, the dissimilarities between on- and off-highway motorcycles do not encourage a one-size-fits-all approach for all motorcycles (this opinion is supported by a significant number of those who commented on the NPRM). Off-highway motorcycles are powered predominantly by two-stroke engines, whereas highway motorcycles are all powered by four-stroke engines as of the 2002 model year. On- and off-highway motorcycle engines also lie at vastly different ends of the size spectrum. The average highway motorcycle sold today has a displacement of nearly 1000cc, whereas almost 90 percent of off-highway motorcycle engines have an engine displacement of less than 350cc. In addition, on- and off-highway motorcycles are used in very different ways; finding a set of standards and a test procedure that adequately represents the typical range of operation for both types would therefore be extremely challenging. The fact that manufacturers claim that many off-highway bikes are used solely for competition would create an additional obstacle to technological harmonization. On-highway motorcycle manufacturers have commented that, to the extent the standards are revised, harmonization with California, rather than a distinctly different set of standards, is preferable because it eliminates the possibility of needing two distinct product lines for California and Federal regulations.[1]

Delaying implementation of the California standards on a nationwide basis by two years will provide an opportunity for manufacturers to gain some experience with the technology needed to meet the new standards. Two years provides time for technology optimization and cost reduction. Providing a longer delay could potentially provide the option of a further decrease in the level of the emission standards, given that the technological feasibility of the California standards has been adequately demonstrated (there are already several motorcycle models available today that meet the 2008 California standards). However, this would be a tradeoff against a more timely introduction of the new standards.

We also evaluated whether the federal motorcycle program should incorporate averaging provisions, as the California program does. Given the desire of most manufacturers to manufacture a motorcycle for nationwide sale, such a program without averaging would not be desirable because it would not provide the flexibility needed to meet the California and federal requirements together and could have at least potentially led to a somewhat less stringent Federal standard. Therefore, we are providing an averaging program comparable to California's.

In promulgating these standards, EPA has considered the need to achieve equivalency in emission reduction between motorcycles and other motor vehicles. In most cases the benchmark technology for spark-ignition engines is found in automobiles. As we have consistently indicated, the differences between motorcycles and cars justify different levels of emission standards. First, motorcycles are typically far less expensive than cars, and we do not believe it would be appropriate to burden a low-cost transportation alternative with the higher costs of emission controls that can be justified on more expensive, heavily used motor vehicles. In addition, cars and light trucks make up a vastly larger proportion of highway vehicles than motorcycles, which allows for greater economies of scale in the manufacturing process. Cars and light trucks also represent a far greater percentage of total emissions than highway motorcycles. The average useful life of a car or light truck is 5 or more times greater than that of a motorcycle. Emission benefits for the investment are therefore proportionally greater. Achieving low emission levels on today's cars requires a vast amount of technology, including high-efficiency catalytic converters (sometimes in multiples) and sophisticated computer controls. High-efficiency catalytic converters on cars require additional precious metals relative to the motorcycle catalysts that will be required on some future motorcycles. Additional precious metals means additional cost, weight, and increased catalyst volume, none of which we believe are justified for lower cost machines where weight and space limitations can be obstacles to integrating vehicle emission control technologies. Motorcycles do not have the abundance of space under the vehicle or under the hood, in locations isolated from the drivers, passengers, and the elements, that cars and trucks do. Achieving lower average HC+NOx standards would require more efficient catalysts. This would put upward pressure on CO emission levels and this could potentially raise heat rejection concerns for the exhaust system. Our final rule carefully considered these limitations by not requiring large and ultra-sophisticated catalyst technologies, on-board diagnostic systems, sophisticated evaporative emission controls, and other technologies that are routinely found on passenger cars today. We believe the standards we are promulgating are consistent with statutory intent and are appropriate considering factors such as cost, safety, lead time, noise, and energy. As part of the 2006 technology review and our assessment of the World Motorcycle Test Cycle, we will review and assess the need for and viability of potential changes or additions to the exhaust and evaporative emission standards and related provisions as technology progresses and more information becomes available.

4.1.1 - Class I and II Motorcycles

4.1.1.1 - Class I Motorcycles Above 50cc and Class II Motorcycles

As noted above, we are adopting the current California standards for Class I and Class II motorcycles. These standards have been in place in California since 1982. The question of whether or not these standards are technically feasible has been answered in the affirmative, since 21 of the 22 EPA-certified 2001 model year motorcycle engine families in these classes are already certified to these standards, all 24 of the 2002 model year engine families meet these standards, and 22 of 29 2003 model year engine families meet these standards. These 29 model year 2003 engine families are all powered by four-stroke engines, with a variety of emission controls applied, including basic engine modifications on almost all engine families, secondary air injection on three engine families, and catalysts on four engine families.

Up to one half of the motorcycles in these classes are scooters from European and Asian manufacturers which tend to be offered at prices significantly lower than the larger Class III motorcycles, while the remainder is a mix of standard motorcycles, introductory cruisers and sportbikes, and dual sport motorcycles. The market for these motorcycles is about one-tenth the size of the Class III market. While it may be technologically feasible for many of these motorcycles to meet more stringent emission standards, we do not believe it is appropriate at this time to require additional emission reductions from this segment of the market. Like the case described below in section 4.1.1.2 for motorcycles under 50cc, manufacturers tend to bring Class I and II motorcycles to the U.S. that have been designed for the large European and Asian markets. Standards that are ultimately more stringent than those in Europe and/or Asia could cause manufacturers to withdraw from the very small U.S. market for these types of motorcycles. Although a direct comparison is not possible due to differing test procedures, the European HC standard for motorcycles up to 150cc will be 0.8 g/km starting in 2006. We are adopting an HC standard of 1.0 g/km.

4.1.1.2 - Class I Motorcycles Under 50cc

As we have described earlier we are applying the current California standard for Class I motorcycles to motorcycles with displacements of less than 50cc (e.g., most motor scooters). These motorcycles are currently not subject to regulation by the U.S. EPA or by the State of California. They are, however, subject to emission standards in Europe and much of the rest of the world. Historically these motorcycles have been powered by 2-stroke engines, but a trend appears to be developing that would result in most of these being replaced by 4-stroke engines or possibly by advanced technology 2-stroke engines, in some cases with catalysts. This trend is largely due to emission requirements in the European and Asian nations where these types of two-wheelers are popular forms of transportation.

The 4-stroke engine is capable of meeting our standards. Class I motorcycles above 50cc are already meeting it, and most of them employ nothing more than a 4-stroke engine. For example, the existing Class I scooters certify at levels ranging from 0.4 to 0.8 grams per kilometer HC. All of these achieve the standards with 4-stroke engine designs, and only one incorporates additional technology (a catalyst). These current engines range from 80 to 151cc in displacement, which provides an indication that small 4-stroke scooter engines are capable of meeting the standards. In a test program conducted by the Japan Automobile Research Institute, a 49cc 4-stroke achieved average HC emissions of 0.71 g/km, a level that falls well under the 1.0 g/km standard we are adopting.[2] The technological feasibility of meeting a 1.0 g/km HC standard was also supported by MIC if EPA made appropriate revisions to the test cycle and the useful life, both of which we have adopted in this final rule. The Association of European Motorcycle Manufacturers (ACEM) confirmed that European manufactures will seek to export to the U.S. the same motorcycles under 50cc that they develop for the European market, and that standards in the E.U. are forcing the transition to 2-stroke direct injection and 4-stroke EFI technologies in 2002 and 2003.[14] ACEM also confirmed the feasibility of meeting the new U.S. standard and aligned with MIC comments regarding the test cycle and useful life.

In order to meet more stringent standards being implemented worldwide, manufacturers are developing and implementing a variety of options. Honda, perhaps the largest seller of scooters in the U.S., has entirely eliminated 2-stroke engines from their scooter product lines as of the 2002 model year. They continue to offer a 50cc model, but with a 4-stroke engine. Both of Aprilia's 2-stroke 49cc scooters available in the U.S. have incorporated electronic direct injection technology, which, in the case of one model, enables it to meet the "Euro-2" standards of 1.2 grams per kilometer HC and 0.3 grams per kilometer NOx, without use of a catalytic converter.[3] Piaggio, while currently selling a 49cc basic 2-stroke scooter in the U.S., expects to begin production of a direct injection version in 2002, and a 4-stroke 50cc scooter is also in development. Numerous 49cc models marketed by Piaggio in Europe are available either as a 4-stroke or a 2-stroke with a catalyst. Piaggio, also an engine manufacturer and seller, is already offering a 50cc 4-stroke engine to its customers for incorporation into scooters.[4]

The U.S. represents a very small portion of the market for small motorcycles and scooters. There are few, if any, manufacturers that develop a small-displacement motorcycle exclusively for the U.S. market; the domestic sales volumes do not appear large enough at this time to support an industry of this kind. The Italian company Piaggio (maker of the Vespa scooters), for example, sold about as many scooters worldwide in 2000 (about 480,000) as the entire volume of highway motorcycles of all sizes sold in the U.S. in that year. U.S. sales of Vespas in 2000 amounted to about 4800. The largest scooter markets today are in South Asia and Europe, where millions are sold annually. In Taiwan alone almost 800,000 motorcycles were sold domestically. More than one third of these were powered by 2-stroke engines. Two- and three-wheelers constitute a large portion of the transportation sector in Asia, and in some urban areas these vehicles - many of them powered by 2-stroke engines - can approach 75 percent of the vehicle population. According to a World Bank report, two-stroke gasoline engine vehicles are estimated to account for about 60 percent of the total vehicle fleet in South Asia.[15]

Many nations are now realizing that the popularity of these vehicles and the high density of these vehicles in urban areas are contributing to severe air quality problems. As a consequence, some of the larger small motorcycle markets in Asia and India are now placing these vehicles under fairly strict regulation. It is clear that actions in these nations will move the emission control technology on small motorcycles, including those under 50cc, in a positive direction. For example, according to the World Bank report, beginning in 2000 catalytic converters will be

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[14] ACEM members are: Aprilia, Benelli, BMW, Derbi, Ducati, Honda, Kawasaki, KTM, Malaguti, MV Augusta, Peugeot, Piaggio, Suzuki, Triumph, Yamaha.

[15] Improving Urban Air Quality in South Asia by Reducing Emissions from Two-Stroke Engine Vehicles. Masami Kojima, Carter Brandon, and Jitendra Shah. December 2000. Prepared for the World Bank. Available in the public docket for review, or on the internet at: http://www.worldbank.org/html/fpd/esmap/publication/airquality.html.

installed in all new two-stroke engine motorcycles in India, and 2003 standards in Taiwan will effectively ban new two-strokes with emission standards so stringent that only a four-stroke engine is capable of meeting them.

Given the emerging international picture regarding emission standards for scooters, we believe that scooter manufacturers will be producing scooters of less than 50cc displacement that meet our standards well in advance of the 2006 model year, the first year we will subject this category of motorcycle to U.S. emission standards.

There are other numerous factors in the international arena that may affect the product offerings in the less than 50cc market segment. For example, Europe recently changed the laws regarding insurance and helmet use for under 50cc scooters and mopeds. Previously, the insurance discounts and lack of helmet requirements in Europe provided two relatively strong incentives to purchasers to consider a 49cc scooter. Recently, however, the provisions were changed such that helmets are now required and the insurance costs are comparable to larger motorcycles. The result was a drop of about 30% in European sales of 49cc scooters in 2001 due to customers perceiving little benefit from a 49cc scooter relative to a larger displacement engine.

4.1.2 - Class III Motorcycles

4.1.2.1 - Tier-1 Standards

In the short term, the Tier-1 HC+NOx standard of 1.4 g/km HC+NOx reflects the goal of achieving emission reductions that could be met with reasonably available control technologies, primarily involving technologies less costly and complex, and more easily adaptable to the vast majority of motorcycles, than catalytic converters. As noted earlier, we are adopting this standard effective with the 2006 model year. Based on current certification data, a number of existing engine families would already comply with this standard or would need relatively simple modifications to comply. In other cases, the manufacturers will need to use control technologies that are available but are not yet used on their particular vehicles (e.g., electronic fuel injection to replace carburetors, changes to cam lobes/timing, etc.). For the most part, manufacturers will not need to use advanced technologies such as close-coupled, closed-loop three way catalysts.

While manufacturers will use various means to meet the Tier-1 standard, there are four basic types of existing, non-catalyst-based, emission control systems available to manufacturers. The most important of these is the use of secondary pulse-air injection. Other engine modifications and systems include more precise fuel control, better fuel atomization and delivery, and reduced engine-out emission levels from engine changes. These technologies are used in varying degrees today and are not expected to result in a loss of performance. The combinations of low-emission technologies ultimately chosen by motorcycle manufacturers are dependent on the engine-out emission levels of the vehicle, the effectiveness of the prior emission control system, and individual manufacturer preferences.

Secondary pulse-air injection, as demonstrated on current motorcycles, is applied using a passive system (i.e., no air pump involved) that takes advantage of the flow of gases ("pulse") in the exhaust pipes to draw in fresh air that further combusts unburned hydrocarbons in the exhaust. Engine modifications include a variety of techniques designed to improve fuel delivery or atomization; promote "swirl" (horizontal currents) and "tumble" (vertical currents); maintain tight control on air-to-fuel (A/F) ratios; stabilize combustion (especially in lean A/F mixtures); optimize valve timing; and retard ignition timing.

4.1.2.1.1 - *Secondary Air Injection*

Secondary pulse air injection involves the introduction of fresh air into the exhaust pipe immediately after the gases exist the engine. Secondary pulse-air injection, as demonstrated on current motorcycles, is applied using a passive system (i.e., no air pump involved) that takes advantage of the flow of gases ("pulse") in the exhaust pipes to draw in fresh air that further combusts unburned hydrocarbons in the exhaust. The extra air causes further combustion to occur, thereby controlling more of the hydrocarbons that escape the combustion chamber. This type of system is relatively inexpensive and uncomplicated because it does not require an air pump; air is drawn into the exhaust through a one-way reed valve due to the pulses of negative pressure inside the exhaust pipe. Secondary pulse-air injection is one of the most effective non-catalytic emission-control technologies; compared to engines without the system, reductions of 10 to 40 percent for HC are possible with pulse-air injection. Eighty - or about half - of the 162 2003 model year Class III engine families certified for sale in the U.S. employ secondary pulse-air injection to help meet the current standards. We anticipate that most of the remaining engine families will use this technique to help meet the Tier 1 and Tier 2 standards. There are 47 2003 engine families that are certified using only engine management techniques (e.g., no use of catalysts, fuel injection, secondary air injection, or oxygen sensors). The average certification HC level of these families is 1.17 g/km. By comparing this to the certification results of engine families that employ secondary air injection as the only means of emission control beyond engine modifications, we can gain some measure of the effectiveness of secondary air injection. We find that the currently certified 2003 models which employ secondary air injection have an average certification level of 0.91 g/km, a reduction of 0.26 g/km (or 22%) relative to those using only engine modification techniques.

4.1.2.1.2 - *Improving Fuel Delivery and Atomization*

Improving fuel delivery and atomization primarily involves the replacement of carburetors, currently used on most motorcycles, with more precise fuel injection systems. There are several types of fuel injection systems and components manufacturers can choose. The most likely type of fuel injection manufacturers will choose to help meet the Tier-1 standard is sequential multi-point fuel injection (SFI).

Unlike conventional multi-point fuel injection systems that deliver fuel continuously or to paired injectors at the same time, sequential fuel injection can deliver fuel precisely when needed by each cylinder. With less than optimum fuel injection timing, fuel puddling and intake-manifold wall wetting can occur, both of which hinder complete combustion. Use of sequential-fuel- injection systems help especially in reducing cold start emissions when fuel puddling and wall wetting are more likely to occur and emissions are highest.

Motorcycle manufacturers are already beginning to use sequential fuel injection (SFI). Improved emission levels are one benefit of a fuel injection system relative to carburetion, but other advantages include improved reliability and fuel economy. Of the 151 Class III motorcycle engine families certified for sale this year, 27 employ SFI systems. These 27 engine families account for about 30 percent of projected 2001 sales, indicating that these engine families represent some popular motorcycle models. Indeed, three models that are among the highest-selling - two from Harley-Davidson and one from Honda - are equipped with SFI. We anticipate increased applications of this or similar fuel injection systems to achieve the more precise fuel delivery needed to help meet the Tier-1 and Tier-2 standards. Of the 162 2003 model year Class III motorcycle engine families certified to emission standards, at least 29 employ SFI systems.[16] We anticipate increased application of this or similar fuel injection systems to achieve the more precise fuel delivery needed to help meet the Tier 1 and Tier 2 standards. We analyzed the EPA certification data in the same way as done above with secondary air injection to estimate the effect of using SFI vehicle on emissions. Again, we identified the baseline of 47 engine families using the limited technologies and with an average certification level of 1.17 g/km HC, and compared the emissions of these engines with the emissions of engines using SFI. What we find is that use of all types of fuel injection can significantly reduce emissions. If we analyze those engine families that use some form of fuel injection other than SFI we see an average HC certification level of 1.09 g/km, a modest reduction of about 7 percent. However, the engines using SFI had significantly lower HC emissions on average of 0.72 g/km, a reduction of almost 40 percent. While this provides some indication of what can be achieved with fuel injection techniques (including SFI), it does not necessarily demonstrate the full potential of this technology. At this point in time it appears that SFI can get motorcycle certification levels down to about 0.4 - 0.6 g/km HC (certification at levels in this range can be seen in several current motorcycles that employ no other emission controls), but in the context of more stringent standards the manufacturers are likely to be able to accomplish even more with SFI, and further reductions by teaming SFI with additional emission reduction techniques.

4.1.2.1.3 - Engine Modifications

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[16] When manufacturers certify to EPA emission standards, they report the fuel delivery system used by each certified model as carbureted or fuel injected. They also report the emission control technologies used on each model to meet the emission standards. When reporting the fuel delivery system, they only indicate whether the system is carbureted or fuel injected, but not the specific type of fuel injection that is installed. When reporting the control technologies 29 models indicated the use of sequential fuel injection. However, there may be some inconsistencies in how these technologies are reported, and we believe that there may be models that employ sequential fuel injection that are shown in our database as being fuel injected, but the manufacturer may not have also specifically listed sequential fuel injection as a control technology on the motorcycle model. This is why we say “at least” 29 models are currently using sequential fuel injection.

In addition to the techniques mentioned above, various engine modifications can be made to improve emission levels. Emission performance can be improved, for example, by reducing crevice volumes in the combustion chamber. Unburned fuel can be trapped momentarily in crevice volumes before being subsequently released. Since trapped and re-released fuel can increase engine-out emissions, the elimination of crevice volumes would be beneficial to emission performance. To reduce crevice volumes, manufacturers can evaluate the feasibility of designing engines with pistons that have reduced, top "land heights" (the distance between the top of the piston and the first ring).

Lubrication oil which leaks into the combustion chamber also has a detrimental effect on emission performance since the heavier hydrocarbons in oil do not oxidize as readily as those in gasoline and some components in lubricating oil may tend to foul the catalyst and reduce its effectiveness. Also, oil in the combustion chamber may trap HC and later release the HC unburned. To reduce oil consumption, manufacturers can tighten the tolerances and improve the surface finish on cylinders and pistons, piston ring design and materials, and exhaust valve stem seals to prevent excessive leakage of lubricating oil into the combustion chamber.

Increasing valve overlap is another engine modification that can help reduce emissions. This technique helps reduce NOx generation in the combustion chamber by essentially providing passive exhaust gas recirculation (EGR). When the engine is undergoing its pumping cycle, small amounts of combusted gases flow past the intake valve at the start of the intake cycle. This creates what is essentially a passive EGR flow, which is then either drawn back into the cylinder or into another cylinder through the intake manifold during the intake stroke. These combusted gases, when combined with the fresh air/fuel mixture in the cylinder, help reduce peak combustion temperatures and NOx levels. This technique can be effected by making changes to cam timing and intake manifold design to optimize NOx reduction while minimizing impacts to HC emissions.

4.1.2.2 - Analysis of EPA Certification Data

Secondary pulse-air injection and engine modifications already play important parts in reducing emission levels; we expect increased uses of these techniques to help meet the Tier-1 standard. Direct evidence of the extent these technologies can help manufacturers meet the Tier-1 standard can be found in the EPA on-road motorcycle certification database. This database is comprised of publicly-available certification emission levels and confidential data (e.g., projected sales of each certified engine family) reported by the manufacturers pursuant to existing requirements. If one thing is clear from the EPA certification data, it is that the vast majority of motorcycles are certifying at emission levels well below the existing federal HC standard. The average certification HC level for 2003 Class III motorcycles is 0.93 g/km (the existing EPA standard is 5.0 g/km). This is due in large part to the fact that manufacturers are designing one engine family to market in all 50 states; therefore, it is the California requirements (including the upcoming requirements not yet in effect) that are driving the emission levels down nationwide. In addition, European nations and others around the world are pursuing lower motorcycle emission levels, contributing further to the trend of lower overall emissions from companies that want to market a worldwide product.

The California ARB reports and discussions with manufacturers revealed that typical NOx levels range from about 0.5 to 0.7 g/km. Some in-use data collected by the California ARB indicates an average NOx level for the 109 motorcycles tested of 0.53 g/km. Restricting the data to 44 1988 and later non-tampered Class III motorcycles results in an average NOx level of 0.5 g/km. Only seven out of these 44 motorcycles had NOx levels that exceeded 0.7 g/km. In addition, some recent data from 16 1997-1999 Class III motorcycles tested by Environment Canada found an average NOx level of 0.3 g/km, with a maximum of 0.5 g/km. For the purposes of our analysis we will use the middle of the range reported by the California ARB, or 0.6 g/km, which appears somewhat higher than the average based on the additional data. The only exception is for motorcycles currently equipped with three-way catalysts. In these cases we assume that the catalyst (or catalysts) are operating at 50 percent efficiency, resulting in estimated tailpipe NOx emissions of 0.3 g/km.

Of the 162 Class III motorcycle engine families certified for the 2003 model year, 109, or 67 percent, could be certified to HC+NOx levels up to 1.6 g/km today. Although 1.6 g/km would be in excess of the Tier 1 standard, we believe that the reduction required to get below the standard of 1.4 g/km HC+NOx is minimal enough such that advanced technologies like high-efficiency two- or three-way catalysts would not be required. Table 4.1-1 shows the breakdown of the emission control technologies used by these 109 engine families that could potentially certify to the Tier-1 standards today. Twenty-six of these, or 24 percent, use 3-way catalysts. The remaining 84 could be able to certify near the Tier-1 HC+NOx level by using simpler and less costly engine modifications and secondary air injection. Only 6 of these 84 use a two-way catalyst.

Table 4.1-1
Breakdown of HC+NOx Estimated Certification Levels by Technology Use

		No. of Engine Families Using Specified Technology			
Estimated HC+NOx Certification Level	No. of Engine Families	Engine Modifications [A]	Pulse Air Injection	2-way Ox-Cat.	3-way Catalyst
0.5 - 0.7	7	7	4	0	7
0.8 - 1.0	23	21	14	1	9
1.1 - 1.3	45	35	19	1	8
1.4 - 1.6	34	27	22	4	2
Total	109	90	59	6	26

[A] Includes all forms of fuel injection, electronic control modules, etc. Source: 2001 U.S. EPA Certification Database

We also reviewed the limited available model year 2004 California certification data, where manufacturers are beginning to certify to the Tier 1 standards. Of the 4 engine families certified with three-way catalysts, 3 had NOx+HC certification levels in the range of 0.32-0.43 g/km, with an average of 0.54 g/km. The remaining engine families not equipped with three-way catalysts were in the range of 0.6 - 1.4 g/km, with an average NOx+HC levels of 1.1 g/km.

In addition, we are confident that the two years of experience gained by manufacturers in meeting the new standard in California prior to having to extend compliance nationwide will help ensure that the new emission control systems are fully developed and fully capable of meeting the new standards on a nationwide basis.

4.1.2.3 - Tier-2 Standards

In the long term, the Tier-2 HC+NOx standard of 0.8 g/km will ensure that manufacturers will continue to advance the status of control technologies. The Tier-2 standard will become effective with the 2010 model year. This standard will present some challenges for manufacturers; however, several manufacturers are already using some of the technologies that will be needed to meet this standard. In addition, our implementation time frame gives manufacturers two years of experience in meeting this standard in California before having to meet it on a nationwide basis. Several manufacturers already use closed-loop, three-way catalysts on a number of product lines, and at least two manufacturers are already marketing a motorcycles that meet this standard. Depending upon assumptions regarding NOx levels, other manufacturers have products on the market today with emission levels that could meet or almost meet the Tier-2 standards using two-way catalysts, fuel injection, secondary pulse-air injection, and other engine modifications. We expect that the significant lead time prior to meeting these standards on a nationwide basis will allow manufacturers to optimize these and other technologies to meet the Tier-2 standard.

In addition, the Tier-2 standard is an averaging standard, allowing manufacturers to balance some motorcycles certified at levels above the standard with others certified to levels below the standard. Thus, under the program, not every motorcycle must be designed to meet the 0.8 g/km HC+NOx standard.

To meet the Tier-2 standard for HC+NOx, manufacturers will likely use more advanced engine modifications and secondary air injection. Specifically, we believe manufacturers will use computer-controlled secondary pulse-air injection (i.e., the injection valve would be connected to a computer-controlled solenoid). In addition to these systems, we estimate that approximately 50 percent of motorcycles will need to use catalytic converter technology to meet the Tier-2 standards. There are two types of catalytic converters currently in use: two-way catalysts (which control only HC and CO) and three-way catalysts (which control HC, CO, and NOx). Under the Tier-2 standard, manufacturers will need to minimize levels of both HC and NOx. Therefore, to the extent catalysts are used, manufacturers will likely use a three-way catalyst in addition to engine modifications and computer-controlled, secondary pulse-air injection. These types of technologies are used in varying degrees on current models and are not expected to result in a loss of performance or fuel economy.

4.1.2.4.1 **-** *Improving Fuel Control and Delivery*

As discussed previously, improving fuel control and delivery provides emission benefits by helping to reduce engine-out emissions and minimizing the exhaust variability which the catalytic converter experiences. One method for improving fuel control is to provide enhanced feedback to the computer-controlled fuel injection system through the use of heated oxygen sensors. Heated oxygen sensors (HO2S) are located in the exhaust manifold to monitor the amount of oxygen in the exhaust stream and provide feedback to the electronic control module (ECM). These sensors allow the fuel control system to maintain a tighter band around the stoichiometric A/F ratio than conventional O2 sensors. In this way, HO2S assist vehicles in achieving precise control of the A/F ratio and thereby enhance the overall emissions performance of the engine. At least one manufacturer is currently using this technology on several 2001 - 2003 engine families.

In order to further improve fuel control, some motorcycles with electronic controls may utilize software algorithms to perform individual cylinder fuel control. While dual oxygen sensor systems are capable of maintaining A/F ratios within a narrow range, some manufacturers may desire even more precise control to meet their performance needs. On typical applications, fuel control is modified whenever the O2S determines that the combined A/F of all cylinders in the engine or engine bank is "too far" from stoichiometric. The needed fuel modifications (i.e., inject more or less fuel) are then applied to all cylinders simultaneously. Although this fuel control method will maintain the "bulk" A/F for the entire engine or engine bank around stoichiometric, it would not be capable of correcting for individual cylinder A/F deviations that can result from differences in manufacturing tolerances, wear of injectors, or other factors.

With individual cylinder fuel control, A/F variation among cylinders will be diminished, thereby further improving the effectiveness of the emission controls. By modeling the behavior of the exhaust gases in the exhaust manifold and using software algorithms to predict individual cylinder A/F, a feedback fuel control system for individual cylinders can be developed. Except for the replacement of the conventional front O2S with an HO2S sensor and a more powerful engine control computer, no additional hardware is needed in order to achieve individual cylinder fuel control. Software changes and the use of mathematical models of exhaust gas mixing behavior are required to perform this operation.

In order to maintain good driveability, responsive performance, and optimum emission control, fluctuations of the A/F must remain small under all driving conditions, including transient operation. Virtually all current fuel systems in automobiles incorporate an adaptive fuel control system that automatically adjusts the system for component wear, varying environmental conditions, varying fuel composition, etc., to more closely maintain proper fuel control under various operating conditions. For some fuel control systems today, this adaptation process affects only steady-state operating conditions (i.e., constant or slowly changing throttle conditions). However, most vehicles are now being introduced with adaptation during "transient" conditions (e.g., rapidly changing throttle, purging of the evaporative system).

Accurate fuel control during transient driving conditions has traditionally been difficult because of the inaccuracies in predicting the air and fuel flow under rapidly changing throttle conditions. Because of air and fuel dynamics (fuel evaporation in the intake manifold and air flow behavior) and the time delay between the air flow measurement and the injection of the calculated fuel mass, temporarily lean A/F ratios can occur during transient driving conditions that can cause engine hesitation, poor driveability and primarily an increase in NOx emissions. However, by utilizing fuel and air mass modeling, vehicles with adaptive transient fuel control are more capable of maintaining accurate, precise fuel control under all operating conditions. Virtually all cars sold in California will incorporate adaptive transient fuel control software; motorcycles with computer controlled fuel injection can also benefit from this technique at a relatively low cost.

4.1.2.4.2 - *Three-way Catalytic Converters*

Three-way catalytic converters traditionally utilize rhodium and platinum as the catalytic material to control the emissions of all three major pollutants (hydrocarbons (HC), CO, NOx). Although this type of catalyst is very effective at converting exhaust pollutants, rhodium, which is primarily used to convert NOx, tends to thermally deteriorate at temperatures significantly lower than platinum. Recent advances in palladium and tri-metal (i.e., palladium-platinum-rhodium) catalyst technology, however, have improved both the light-off performance (light-off is defined as the catalyst bed temperature where pollutant conversion reaches 50% efficiency) and high temperature durability over previous catalysts. In addition, other refinements to catalyst technology, such as higher cell density substrates and adding a second layer of catalyst washcoat to the substrate (dual-layered washcoats), have further improved catalyst performance from just a few years ago.

Typical cell densities for conventional catalysts used in motorcycles are less than 300 cells per square inch (cpsi). To meet the Tier-2 standard, we expect manufacturers to use catalysts with cell densities of 300 to 400 cpsi. If catalyst volume is maintained at the same level (we assume volumes of up to 60% of engine displacement), using a higher density catalyst effectively increases the amount of surface area available for reacting with pollutants. Catalyst manufacturers have been able to increase cell density by using thinner walls between each cell without increasing thermal mass (and detrimentally affecting catalyst light-off) or sacrificing durability and performance.

In addition to increasing catalyst volume and cell density, we believe that increased catalyst loading and improved catalyst washcoats will help manufacturers meet the Tier-2 standard. In general, increased precious metal loading (up to a certain point) will reduce exhaust emissions because it increases the opportunities for pollutants to be converted to harmless constituents. The extent to which precious metal loading is increased will be dependent upon the precious metals used and other catalyst design parameters. We believe recent developments in palladium/rhodium catalysts are very promising since rhodium is very efficient at converting NOx, and catalyst suppliers have been investigating methods to increase the amount of rhodium in catalysts for improved NOx conversion.

Double layer technologies allow optimization of each individual precious metal used in the washcoat. This technology can provide reduction of undesired metal-metal or metal-base oxide interactions while allowing desirable interactions. Industry studies have shown that durability and pollutant conversion efficiencies are enhanced with double layer washcoats. These recent improvements in catalysts can help manufacturers meet the Tier-2 standard at reduced cost relative to older three-way catalysts.

New washcoat formulations are now thermally stable up to 1050 °C. This is a significant improvement from conventional washcoats, which are stable only up to about 900 °C. With the improvements in light-off capability, catalysts may not need to be placed as close to the engine as previously thought. However, if placement closer to the engine is required for better emission performance, improved catalysts based on the enhancements described above would be more capable of surviving the higher temperature environment without deteriorating. The improved resistance to thermal degradation will allow closer placement to the engines where feasible, thereby providing more heat to the catalyst and allowing them to become effective quickly.

It is well established that a warmed-up catalyst is very effective at converting exhaust pollutants. Recent tests on advanced catalyst systems in automobiles have shown that over 90% of emissions during the Federal Test Procedure (FTP) are now emitted during the first two minutes of testing after engine start up. Similarly, the highest emissions from a motorcycle occur shortly after start up. Although improvements in catalyst technology have helped reduce catalyst light-off times, there are several methods to provide additional heat to the catalyst. Retarding the ignition spark timing and computer-controlled, secondary air injection have been shown to increase the heat provided to the catalyst, thereby improving its cold-start effectiveness.

In addition to using computer-controlled secondary air injection and retarded spark timing to increase the heat provided to the catalyst, some vehicles may employ warm-up, pre-catalysts to reduce the size of their main catalytic converters. Palladium-only warm-up catalysts (also known as “pipe catalysts” or “Hot Tubes”) using ceramic or metallic substrates may be added to further decrease warm-up times and improve emission performance. Although metallic substrates are usually more expensive than ceramic substrates, some manufacturers and suppliers believe metallic substrates may require less precious metal loading than ceramic substrates due to the reduced light-off times they provide.

Improving insulation of the exhaust system is another method of furnishing heat to the catalyst. Similar to close-coupled catalysts, the principle behind insulating the exhaust system is to conserve the heat generated in the engine for aiding catalyst warm-up. Through the use of laminated thin-wall exhaust pipes, less heat will be lost in the exhaust system, enabling quicker catalyst light-off. As an added benefit, the use of insulated exhaust pipes will also reduce exhaust noise. Increasing numbers of manufacturers are expected to utilize air-gap exhaust manifolds (i.e., manifolds with metal inner and outer walls and an insulating layer of air sandwiched between them) for further heat conservation.

4.1.2.4.3 - *Automotive Technologies*

Besides the hardware modifications described above, motorcycle manufacturers may borrow from other current automobile techniques. These include using engine calibration changes such as a brief period of substantial ignition retard, increased cold idling speed, and leaner air-fuel mixtures to quickly provide heat to a catalyst after cold-starts. Only software modifications are required for an engine which already uses a computer to control the fuel delivery and other engine systems. For these engines, calibration modifications provide manufacturers with an inexpensive method to quickly achieve light-off of catalytic converters. When combined with pre-catalysts, computer-controlled secondary air injection, and the other heat conservation techniques described above, engine calibration techniques may be very effective at providing the required heat to the catalyst for achieving the Tier-2 standard. These techniques are currently in use on most low emission vehicle (LEV) automobiles and may have applications in on-road motorcycles.

4.1.2.5 - Conclusion

4.1.2.5.1 - Tier-1 Standards

We expect that the Tier-1 standard will be met with reasonably available control technologies. A number of existing engine families would already comply with this standard or would need relatively simple modifications to comply. In other cases, the manufacturers will need to use control technologies that are available but are not yet used on their particular vehicles (e.g., electronic fuel injection to replace carburetors, secondary pulse air injection, changes to cam lobes/timing, etc.). For the most part, manufacturers will not need to use advanced technologies such as close-coupled, closed-loop three way catalysts. The ultimate combinations of low-emission technologies ultimately chosen by motorcycle manufacturers are dependent on the engine-out emission levels of the vehicle, the effectiveness of the prior emission control system, and individual manufacturer preferences.

4.1.2.5.2 - Tier-2 Standards

We expect that the Tier-2 standard will likely require the use of more advanced engine modifications and secondary air injection. Depending upon assumptions regarding NOx levels, some manufacturers have products on the market today with emission levels that could meet or almost meet the Tier-2 standard using two-way catalysts, fuel injection, secondary pulse-air injection, and other engine modifications. We believe that manufacturers will use computer-controlled secondary pulse-air injection, in addition to using catalytic converters on some motorcycles to meet the Tier-2 standards. To the extent catalysts are used, manufacturers will likely use a three-way catalyst in addition to engine modifications and computer-controlled, secondary pulse-air injection. We expect that the significant lead time prior to meeting these standards on a nationwide basis will allow manufacturers to optimize these and other technologies to meet the Tier-2 standard.

4.1.3 - Impacts on Noise, Energy, and Safety

As automotive technology demonstrates, achieving low emissions from spark-ignition engines can correspond with greatly reduced noise levels. Virtually all highway motorcycles are equipped with sound suppression systems or mufflers. The four-stroke engines used in highway motorcycles above 50cc are considerably more quiet than the two-stroke engines used by many of their off-road counterparts. In addition, highway motorcycles are required to meet existing noise emission standards. The increased use of four-stroke engines in motorcycles below 50cc, which is expected as a result of this rule, would have the effect of reducing their noise levels.

Adopting new technologies for controlling fuel metering and air-fuel mixing, particularly the conversion of some carbureted highway motorcycles to advanced fuel injection technologies, will lead to improvements in fuel consumption.

Many riders have expressed some concerns regarding the close proximity of the riders to hot exhaust pipes and the catalytic converter. Protecting the rider from the excessive heat is a concern for both riders and manufacturers. We appreciate and understand the concerns raised by many motorcyclists regarding the potential safety issues of catalytic converters due to the heat that the devices can generate. In the NPRM we suggested that current experience with the installation of catalytic converters on motorcycles - both in the U.S. and worldwide - has demonstrated that catalytic converters are a safe emission control technology option for manufacturers. Due to the serious nature of the concerns expressed by riders we have expanded and improved our assessment of the potential risks of using catalytic converters as an emission control device on motorcycles. We continue to believe that catalysts can safely be used as a motorcycle emissions control device.

The additional weight of a catalyst (or even two) does not present a potential safety issue. Perhaps this would be the case if motorcycle catalysts were comparable to automotive catalysts in size, weight, and volume, but this is not the case. Motorcycle catalysts do not and will not have to reach the high efficiency levels of current and projected automotive catalysts, and consequently their size relative to the displacement of the engine is often smaller. Current motorcycle catalysts are typically smaller than a 12 ounce can of carbonated drink - perhaps even half this size or smaller - and weigh no more. Thus, the weight addition caused by a catalyst will have hardly any effect on the weight of these vehicles. All other things held equal, the addition of a catalyst to a motorcycle does add some small additional weight to the motorcycle. But all other things are rarely kept static and without evolution. As demonstrated by the 2003 Yamaha YZF-R6, it is possible, with the use of advanced materials and technologies, to add a catalyst and minimize the impact on the overall weight of the exhaust system. (Yamaha added a catalyst to the 2003 YZF-R6 while at the same time reducing the total weight of the exhaust system by more than two pounds.)

There are currently thousands of motorcycles with catalytic converters being ridden in the U.S. today. These catalyst-equipped motorcycles span the motorcycle categories of cruisers, touring, sport, standard, and even scooters. In particular, BMW has been using 3-way catalytic converters on all of their motorcycles since 1991. In recent years the sales of BMW motorcycles in the U.S. has exceeded 10,000 units per year, and their worldwide sales since 1997 are near 450,000 units. Harley-Davidson has been producing a number of different models with catalytic converters for the California market since 1995, and company estimates put the total number sold with catalytic converters since 1995 at around 45,000.[17]

In addition to BMW and Harley-Davidson, in the last 5 years motorcycle models with catalytic converters have been sold by Aprilia, Cushman, Ducati, Genuine Scooter, Honda, Kawasaki, Kwang Yang Motor Co., Malaguti, Milwaukee Motorcycle, Roadstertec, Russian American Motorbike, Suzuki, Triumph, and Yamaha. Honda models with catalytic converters include the VTX-1800 and VTX-1300 (cruisers), the Gold Wing GL-1800 (touring), the ST-1300 (sport touring), and the Interceptor VFR-800 (sport). Kawasaki models include the Ninja ZX-9R (sport), the ZR-1000 (sport), the Ninja ZX-12R (sport), the ZR-1200 (touring), the VN-1500 Vulcan (cruiser), and the VN-1600 Vulcan (cruiser). Suzuki models with catalytic converters include the Burgmaster AN-650 (large scooter). Yamaha motorcycles currently equipped with catalytic converters include the YZF-R6 (super-sport), the YZF-R1 (sport), and the FJR-1300 (sport touring).

A conservative estimate based on confidential sales projections made by manufacturers when they certify their motorcycles to EPA standards, indicates that 80,000 to 100,000 2003 model year motorcycles equipped with catalytic converters could be sold in the U.S. If we estimate conservatively that there are 150,000 motorcycles on the road today in the U.S. with catalytic converters,[18] and each is driven 2,000-3,000 miles per year, then we can state that over 300 million miles have been ridden on catalyst-equipped motorcycles in the last year. We believe that twenty percent of the motorcycles sold in the last two years, or 100,000 (or likely more) currently on the road, ridden for hundreds of millions of miles, can be reasonably argued to be a significant and substantial in-use demonstration. This total would be far greater if we included the numerous motorcycles with catalysts being ridden in the several countries that already have emission standards for motorcycles that manufacturers are meeting by using catalysts. In these terms it is abundantly clear that there is no shortage of experience with catalytic converters - both in terms of manufacturers and riders - in the U.S. Worldwide the

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[17] Jerry Steffy, Harley-Davidson Motor Company, Regulatory Affairs Department. Docket A-2000-2.

[18] Sales of catalyst-equipped BMW and Harley-Davidson motorcycles alone since 1995 approach 100,000. According to BMW Annual Reports their U.S. sales in the last three years have exceeded 13,000 per year. Include Honda, which has some high-volume products with catalysts such as the Goldwing, and it becomes clear that 150,000 is a conservative estimate.

experience is several orders of magnitude greater. In fact, substantial factual evidence indicates that the safety concerns regarding heat generation from catalytic converters are surmountable (i.e., capable of being overcome). This evidence is not just theoretical or based on engineering principles and judgement - it is the real-world experience today.

Given the U.S. manufacturer and rider experience with catalytic converters, we believe that there has been ample opportunity to assess the issue of catalyst safety, not just on a hypothetical basis but on the basis of actual manufacturing and on-road riding experience. We have already established that a significant number of manufacturers have engineered, produced, and sold a large number of motorcycles with catalytic converters. To assess the rider experience and any potential issues that may have arisen during the hundreds of millions of miles ridden with catalytic converters in the U.S., we analyzed the database of consumer complaints maintained by the National Highway Traffic Safety Administration's Office of Defects Investigation. This database contains all consumer complaints filed since 1995 related to motor vehicles, child safety devices, and other equipment such as tires. The database is used by NHTSA to assist them in targeting investigations and potential vehicle recalls.

When the database was obtained by the EPA in February, 2003, it contained over 370,000 entries. About 2,000 records were specific to motorcycles, and 28 of these contained complaints specifically regarding the exhaust system. Five of these complaints (representing four different manufacturers) specifically regarded the catalytic converter. Two of these five complaints were regarding converters that had failed, another two complaints were regarding unusual or strong odors, and the remaining complaint was regarding a heat shield that fell off. None of the complaints suggested that heat from the catalytic converter was excessive, improperly managed, or unsafe. We then expanded our assessment of the database by reviewing the remaining 23 complaints related to exhaust system components. This was done to be sure that we did not overlook any catalytic converter concerns that may have been improperly categorized or diagnosed by the consumer filing the complaint. Of these 23, five were regarding issues with the fuel petcock or fuel check valve, or the oxygen sensors. Seven complaints were regarding a tailpipe that fell off, was broken, was dented, or somehow failed. An additional four of these complaints were regarding the following issues: an oil leak; a muffler bracket recall; handling issues with installation of long aftermarket pipes; and peeling paint.

The remaining seven complaints, which we describe here in greater detail, were specifically regarding excess heat coming from the exhaust system.

No.	Make	Model & Year	Complaint
1	Kawasaki	1988 Z Series	Passenger on motorcycle received burns on leg from hot mufflers.
2	Suzuki	1995	Muffler not designed with heat shield, causing burn injury to driver when motorcycle turned over.
3	Harley-Davidson	2000 FLHPI	Exhaust manifold reaches temperatures so high that it has an orange glow. Manufacturer knows of problem, and there isn't a solution. Consumer will add additional information
4	Harley-Davidson	2002	Consumer states that when at a stop the exhaust pipe will glow red and this can cause injuries to the consumer. Dealer notified.
5	Harley-Davidson	2003 Electraglide	Exhaust system cross over pipe is located too close to seat, causing driver to be burned while driving, even if properly dressed.
6	BMW	2000 R1200C	Consumer states exhaust pipes are positioned below foot pegs so that when you come to a stop and put feet down, it's very likely that pant leg will at least brush up against pipe. Consumer has ruined clothes because of this. BMW does not feel this is a problem, they suggested to consumer that he buy after market exhaust guards, which are expensive.
7	BMW	2001 K1200RS	Exhaust pipes are positioned below foot pegs so that when you come to a stop and put your foot down you will brush up against hot pipe.

1. Two of these were regarding burns sustained by riders from a hot muffler (one of which was sustained in a crash of the motorcycle and not during normal riding conditions). Both of these complaints were regarding motorcycles known not to be equipped with catalytic converters; one was produced before catalytic converters were used on motorcycles (a 1988 Kawasaki) and the other by a manufacturer that, to our knowledge, did not utilize catalytic converters on their motorcycles until the 2003 model year (a 1995 Suzuki). These complaints demonstrate that the catalytic converter does not introduce a new hazard to motorcycle riders; the very nature of a motorcycle is that the rider is always in close proximity to the engine and exhaust system, both of which can generate significant heat and can cause burns whether or not there is a catalytic converter present.

2. Another complaint was regarding an exhaust pipe that glowed red at idle (a 2002 Harley-Davidson). We do not have enough information to determine whether this is a catalyst-equipped vehicle, but the fact that the complaint originated from an Ohio owner points to the likelihood of it being a non-catalyst model, because the catalyst-equipped Harley-Davidsons are in the minority and are generally destined for sale in California. We also do not know to what extent this motorcycle may have been modified and in what ways components or tuning characteristics may have been altered or replaced, which could potentially introduce an operating problem like this one. Clearly a pipe that glows red is not something that was intentionally engineered by the manufacturer and does not represent a normal situation, and is more likely due to a defect in the operation of the motorcycle. With

respect to this complaint and the following ones regarding Harley-Davidson motorcycles, Harley-Davidson notes in the Harley-Davidson 2003 Genuine Motor Accessories and Genuine Motor Parts that tuning characteristics, cam timing, carburetor jetting, overheating, and other factors can cause discoloration of exhaust pipes. It is entirely possible that these complaints are a result of some of these factors. In fact, since it occurred at idle when exhaust gas flow is at its lowest and catalyst efficiency is high this seems even more likely.

3. A 2003 Harley-Davidson generated a complaint regarding cross-over pipes that were reported to be too close to the seat, burning the rider. This complaint came from a New York owner, thus, like the Ohio report, may in fact be a motorcycle without a catalytic converter. In addition, this is the only complaint of this type for this model of motorcycle, and can not be considered to be indicative of a widespread problem. Again, we do not know to what extent the owner may have modified the exhaust system or the engine of the motorcycle, and there are potential modifications and defects unrelated to a catalytic converter that could increase the heat of the exhaust pipes, particularly near the engine as is the case with this complaint. Indeed, even if this motorcycle does have a catalytic converter it would be rearward of the seat concealed in the muffler or elsewhere and would not result in a complaint of this nature at this location on the motorcycle.

4. A similar complaint came from a 2000 Harley-Davidson owner, who noted that the exhaust manifold would get so hot that it gave off an orange glow. Like the previous complaint of hot cross-over pipes, it is highly unlikely that this phenomenon could be explained by the presence of a catalytic converter, which, if present, would be far rearward of the location where the exhaust exits the engine. Again, this is more likely the result of a defect or of some engine changes introduced by the user or mechanic, and not likely related to the presence of a catalytic converter. Clearly this is not a normal operating characteristic of Harley-Davidson motorcycles. Exhaust pipe heat is generated when unburned fuel from the engine is oxidized in the exhaust system in the presence of excess air. This happens frequently in to a minor degree in all exhaust pipes, but is only significantly if relatively large amounts of unburned fuel and air are present.

5. Finally, there were two complaints regarding 1200cc BMW motorcycles, one complaint each regarding the R1200C and the K1200RS. These complaints stated that the exhaust pipes positioned below the foot pegs can come into contact with the rider's lower leg, thus potentially burning the lower leg or pants near the foot pegs. Based on the configuration of the R1200C, it is possible that the catalytic converter is located in the exhaust pipe below the foot peg, and this is also possibly the configuration of the K1200RS as well. This of course is a design issue which must be considered in the system, but is not an unresolvable concern as demonstrated by BMW's suggestion to the user.

We contacted Harley-Davidson and BMW and asked if they were aware of the complaints filed with NHTSA. We also asked for their own assessment of these complaints. Both manufacturers responded that they consider these to be isolated cases and not indicative of a widespread problem or safety issue. BMW noted that the complaints do not appear to be directly related to the catalytic converter, although they are aware of the fact that catalysts can contribute to overall heat generation. They also stated that a shorter than average person would be more likely to come into contact with the exhaust pipes, and BMW sells aftermarket protective guards for customers who might desire some additional protection. Obviously, it is difficult if not impossible to design a "one-size-fits-all" motorcycle that comfortably and adequately fits people of all sizes and stature. Harley-Davidson examined their own records and reported only two instances that might bear some relation to excess heat from catalysts, and neither record indicated the reporting of any health or safety concerns. They were not able to determine whether or not the NHTSA complaints involved catalyst-equipped motorcycles. They also added that they "educate our customers, through warnings in the Owner's Manual, about being careful not to contact any portion of the motorcycle's exhaust system."

In summary, we do not believe that the data available from NHTSA and described above demonstrates that a catalytic converter constitutes a significant safety risk. In fact, of the complaints identified above where heat from the exhaust pipe was reported to be a problem, there appear to be more involving non-catalyzed systems than there were regarding systems with catalytic converters. In either case, the complaints represent a tiny minority of the complaints brought to NHTSA's attention; this would not be the case if there was a generalized problem with excessive heat from catalyst-equipped motorcycles. The data, however, does demonstrate that heat management from the exhaust system in general is a packaging and design issue for manufacturers, and the manufacturers are certainly aware of this need.

We are confident that manufacturers can design and produce motorcycles that respond to these safety concerns, and information submitted by the manufacturers supports our assessment that catalytic converters can be safely integrated into motorcycle designs. Every motorcycle manufacturer who either testified at the public hearing or provided written comments on the proposed rule has unequivocally stated that they can build motorcycles that will meet the proposed standards with no negative impact on safety or performance relative to motorcycles manufactured today. MIC stated in its oral testimony at the public hearing that "With the lead time that you're providing and with this level of stringency of the standards, there isn't any technological reason why motorcycles can't be produced that are safe and that have driveability and performance that is excellent...." Harley-Davidson echoed this view at the hearing as well, stating that "...the use of cats does raise safety issues for our engineers as they design motorcycles. However, we have been using cats on many of our motorcycles in California for several years now and have been able to address any major personal safety issues arising from the use of cats on bikes." Finally, MECA addressed this issue at the public hearing by noting that catalyst technology has been applied to over 15 million two- and three-wheelers worldwide and that, while the safe integration of catalysts is an engineering issue, it has been addressed in a variety of different ways. There are a number of approaches that manufacturers are using today to protect the rider from excessive heat. Some motorcycle designs permit the catalyst to be placed on the underside of the motorcycle where it is unable to contact the rider. Other manufacturers will use a double-pipe exhaust system to reduce heat loss, allowing the exhaust gases to remain hot before reaching the catalyst while maintaining lower exterior temperatures. Some manufacturers are placing the catalyst inside the muffler or close to the manifold in areas where it is unlikely to be contacted by the rider or passenger. Footrests can be shielded and pipes can be insulated to reduce the exterior transmission of heat. The fact that these approaches are already being successfully employed, combined with the significant lead time provided for the Tier 2 standard, leads us to conclude that catalysts can be safely integrated into both current and future motorcycle designs. It is clearly an engineering issue, but one that can be addressed in any number of ways to protect the user from the additional heat of the device. There is no indication from any nation worldwide - some of which are far more dependent on motorcycles as daily transportation than we are in the U.S. - that the use of catalysts on motorcycles presents a significant risk to the rider.

4.2 - Permeation Evaporative Emission Control from Motorcycles

The following paragraphs summarize the data and rationale supporting the permeation emission standards for motorcycles, which are listed in the Executive Summary. As discussed in Chapter 3, we believe there are several technologies that can be used to reduce permeation emissions from fuel tanks and hoses to levels below the final standards. This section presents available emissions data on baseline emissions and on emission reductions achieved through the application of emission control technology. In addition, this section provides a description of the test procedures for evaporative emission determination.

4.2.1 Baseline Technology and Emissions

4.2.1.1 Fuel Tanks

Motorcycle fuel tanks are either made of metal or plastic. Because fuel does not permeate through metal, this discussion focuses on plastic fuel tanks. Plastic fuel tanks are generally blow-molded or injection-molded using high density polyethylene (HDPE). Data on the permeation rates of fuel through the walls of polyethylene fuel tanks shows that baseline HDPE fuel tanks have very high permeation rates compared to those used in automotive applications. We tested four ATV fuel tanks in our lab for permeation. We also tested three portable marine fuel tanks and two portable gas cans which are of similar construction. This testing was performed at 29°C (85°F) with gasoline. Prior to testing, the fuel tanks had been stored with fuel in them for more than a month to stabilize the permeation rate. The permeation rates are presented in Table 4.2-1. The average for these ten fuel tanks is 1.32 grams per gallon (of tank volume) per day. Although these fuel tanks were not specifically produced for use in highway motorcycles, the same materials and processes are used. Therefore, we believe that this data is representative of highway motorcycle plastic fuel tanks as well.

Table 4.2-1
Permeation Rates for Plastic Fuel Tanks Tested by EPA at 29°C

Tank Capacity [gallons]	Permeation Loss [g/gal/day]	Tank Type
1.3	1.66	all terrain vehicle
1.3	2.90	all terrain vehicle
1.8	1.29	all terrain vehicle
2.1	2.28	all terrain vehicle
5.3	1.00	all terrain vehicle
6.0	0.61	portable marine
6.0	1.19	portable marine
6.0	0.78	portable marine
6.6	0.77	portable fuel container
6.6	0.75	portable fuel container

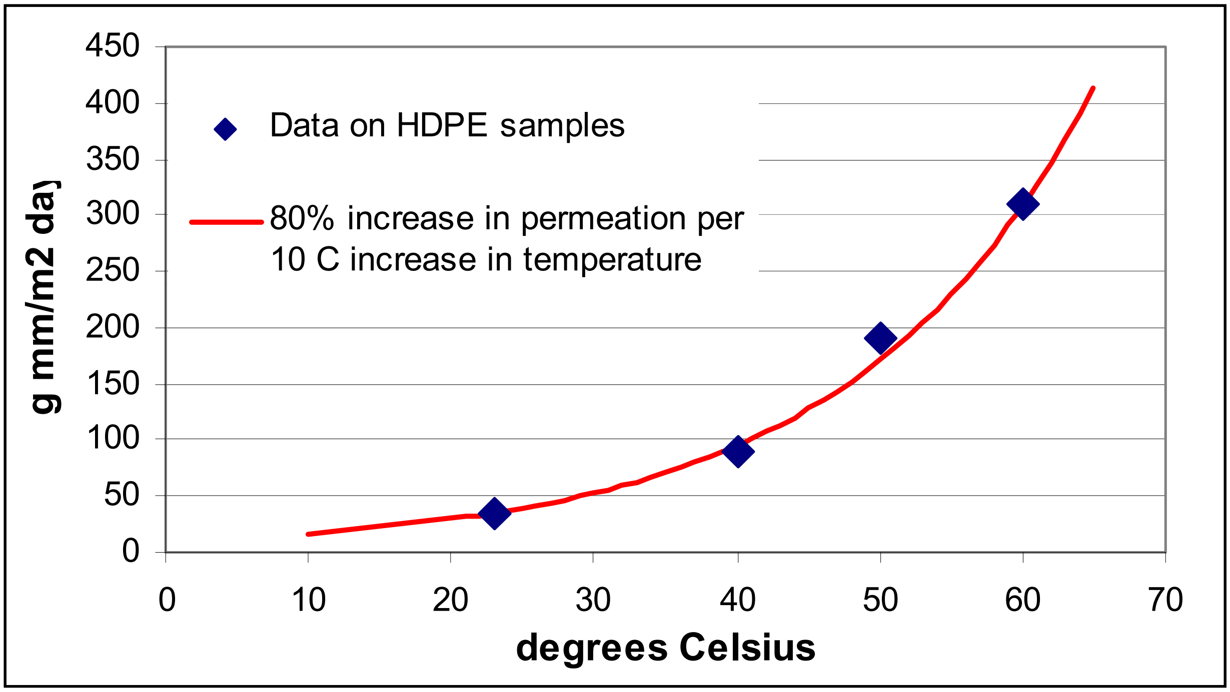
The California Air Resources Board (ARB) investigated permeation rates from portable fuel containers and lawn & garden equipment fuel tanks. Although this testing was not on motorcycle fuel tanks, the fuel tanks tested are of similar construction. The ARB data is compiled in several data reports on their web site and is included in our docket.[5,6,7,8,9] Table 4.2-2 presents a summary of this data which was collected using the ARB test procedures described in Section 4.2.3. Although the test temperature is cycled from 18 - 41°C rather than held at a constant temperature, the results would likely be similar if the data were collected at the average temperature of 29°C used in the EPA testing. The average for these 36 fuel tanks is 1.07 grams per gallon per day.

Table 4.2-2
Permeation Rates for Plastic Fuel Containers Tested by ARB Over a 18-41°C Diurnal

Tank Capacity [gallons]	Permeation Loss [g/gal/day]	Tank Type
1.0	1.63	portable fuel container
1.0	1.63	portable fuel container
1.0	1.51	portable fuel container
1.0	0.80	portable fuel container
1.0	0.75	portable fuel container
1.0	0.75	portable fuel container
1.3	0.50	portable fuel container
1.3	0.49	portable fuel container
1.3	0.51	portable fuel container
1.3	0.52	portable fuel container
1.3	0.51	portable fuel container
1.3	0.51	portable fuel container
1.3	1.51	portable fuel container
1.3	1.52	portable fuel container
1.4	1.27	lawn & garden
1.7	0.67	lawn & garden
2.1	1.88	portable fuel container
2.1	1.95	portable fuel container
2.1	1.91	portable fuel container
2.1	1.78	portable fuel container
2.5	1.46	portable fuel container
2.5	1.09	portable fuel container
3.9	0.77	lawn & garden
3.9	0.88	lawn & garden
5.0	0.89	portable fuel container
5.0	0.62	portable fuel container
5.0	0.99	portable fuel container
5.0	0.55	lawn & garden
5.0	0.77	lawn & garden
5.0	0.64	lawn & garden
5.0	1.39	portable fuel container
5.0	1.46	portable fuel container
5.0	1.41	portable fuel container
5.0	1.47	portable fuel container
6.6	1.09	portable fuel container
7.5	0.35	lawn & garden

It is well known that the rate of permeation is a function of temperature. For most materials, permeability increases by about a factor of 2 for every 10°C increase in temperature.[10] Based on data collected on HDPE samples at four temperatures,[11,12] we estimate that the permeation of gasoline through HDPE increases by about 80 percent for every 10°C increase in temperature. This relationship is presented in Figure 4.2-1, and the numeric data can be found in Section 4.2.2.3.

Figure 4.2-1: Effect of Temperature on HDPE Permeation



Based on the data from 46 fuel tanks in Tables 4.2-1 and 4.2-2, the average permeation rate at 29°C is 1.12 grams per gallon per day. However, the standard is based on units of grams per square meter per day at 28°C. Based on measurements of cut away fuel tanks of this size, we have found that the wall thickness ranges from 4 to 5 mm. Using an average wall thickness of 4.5 mm and a permeation rate for HDPE of 47 g mm/m^2/day at 28°C (Figure 4.2-1) we estimate that the baseline permeation rate is about 10.4 g/m^2/day. Data presented later in this chapter (see Section 4.2.8.3) shows that the permeation rate of fuel through HDPE is fairly insensitive to the amount of alcohol in the fuel.

4.2.1.2 Fuel Hoses

Fuel hoses produced for use in motorcycles are generally extruded nitrile rubber with a cover for abrasion resistance. These hoses are generally designed to meet the requirements under SAE J30[13] for an R7 classification. R7 hose has a maximum permeation rate of 550 g/m^2/day at 23°C on ASTM Fuel C (50% toluene, 50% iso-octane). On a fuel containing an alcohol blend, permeation would likely be higher from these fuel hoses. R7 hose is made primarily of nitrile rubber (NBR). Based on the data presented in Section 4.2.8.3, permeation through NBR is about 50 percent higher when tested on Fuel CE10 (10% ethanol) compared to testing on Fuel C.

4.2.2 Permeation Reduction Technologies

4.2.2.1 Fuel Tanks

As discussed in Chapter 3, there are several strategies that can be used to reduce permeation from plastic fuel tanks. This section presents data collected on five permeation control strategies: sulfonation, fluorination, non-continuous barrier platelets, coextruded continuous barrier, and alternative materials.

4.2.2.1.1 Sulfonation

We tested sulfonated, HDPE fuel tanks at 29°C (85°F) with gasoline, E10, and M15. Prior to testing, the fuel tanks had been stored with gasoline in it for 10-20 weeks to stabilize the permeation rate. Table 4.2-3 presents the emission results. This data demonstrates more than a 90% reduction in permeation for sulfonated fuel tanks.

Table 4.2-3
Permeation Rates for Sulfonated HDPE Fuel Tanks at 29°C

Test Fuel	6 gallon portable marine tank		4 gallon ATV tank	
	g/gal/day	g/m^2/day	g/gal/day	g/m^2/day
gasoline	0.06	0.67	0.09	0.73
10% ethanol	0.13	1.48	0.10	0.78
15% methanol	0.06	0.70	0.06	0.50

The California Air Resources Board (ARB) collected test data on permeation rates from sulfonated portable fuel containers using California certification fuel.[14] The results show that sulfonation can be used to achieve significant reductions in permeation from plastic fuel containers. This data was collected using a diurnal cycle from 18-41°C which is roughly equivalent to steady-state permeation testing at 30°C. The average emission rate for the 32 sulfonated fuel tanks is 0.35 g/gal/day; however, there was a wide range in variation in the effectiveness of the sulfonation process for these fuel tanks. Some of the data outliers were actually higher than baseline emissions. This was likely due to leaks in the fuel tank which would result in large emission increases due to pressure built up with temperature variation over the diurnal cycle. Removing these five outliers, the average permeation rate is 0.17 g/gal/day with a minimum of 0.01 g/gal/day and a maximum of 0.64 g/gal/day.

Variation can occur in the effectiveness of this surface treatment if the sulfonation process is not properly matched to the plastic and additives used in the fuel tank material. For instance, if the sulfonater does not know what UV inhibitors or plasticizers are used, they cannot maximize the effectiveness of their process. In this test program, the sulfonater was not aware of the chemical make up of the fuel tanks. This is the likely reason for the variation in the data even when the obvious outliers are removed. In support of this theory, the permeation rates were consistently low for tanks provided by two of the four tank manufacturers. For these 11 fuel tanks, the average permeation rate was 0.07 which represents more than a 90 percent reduction from baseline. Earlier data collected by ARB showed consistently high emissions from sulfonated fuel tanks; however, ARB and the treatment manufacturers agree that this was due to inexperience with treating fuel tanks and that these issues have since been largely resolved.[15] For this reason we do not include the earlier data in this analysis. Table 4.2-4 includes all of the permeation data, including the outliers.

Table 4.2-4
Permeation Rates for Sulfonated Plastic Fuel Containers Tested by ARB Over a 18-41°C Diurnal

Tank Capacity [gallons]	Permeation Loss [g/gal/day]
1	0.05
1	0.05
1	0.05
1	0.06
1	0.06
1	0.06
1	0.08
1	0.12
1	0.14
1	1.23
1	1.47
1	1.87
2	0.02
2	0.02
2	0.48
2	0.54
2	1.21
2.5	0.03
2.5	0.08
2.5	0.32
2.5	0.38
2.5	0.42
2.5	0.52
2.5	0.64
2.5	0.80
5	0.01
5	0.04
5	0.05
5	0.06
5	0.11
5	0.13
5	0.15

ARB also investigated the effect of fuel slosh on the durability of sulfonated surfaces. Two sets of sulfonated fuel tanks were tested for permeation before and after being rocked with fuel in them 1.2 million times.[16,17] The results of this testing show that more than an 85% reduction in permeation was possible even after the slosh testing was performed. Table 4.2-5 presents these results which were recorded in units of g/m^2/day. The baseline level for Set #1 is an approximation based on testing of similar fuel tanks, while the baseline level for Set #2 is based on testing of those tanks.

As with earlier tests performed by ARB, the sulfonater was not aware of the materials used in the fuel tanks sulfonated for the slosh testing. After the tests were performed, the sulfonater was able to get some information on the chemical make up of the fuel tanks and how it might affect the sulfonation process. For example, the UV inhibitor used in some of the fuel tanks is known as HALS. HALS also has the effect of reducing the effectiveness of the sulfonation process. Two other UV inhibitors, known as carbon black and adsorber UV, are also used in similar fuel tank applications. These UV inhibitors cost about the same as HALS, but have the benefit of not interfering with the sulfonation process. The sulfonater claimed that if HALS were not used in the fuel tanks, a 97% reduction in permeation would have been seen.[18] To confirm this, one manufacturer tested a sulfonated tank similar to those in Set #2 except that carbon black, rather than HALS, was used as the UV inhibitor. This fuel tank showed a permeation rate of 0.88 g/m^2/day at 40°C[19] which was less than half of what the CARB testing showed on their constant temperature test at 40°C.[20] A list of resins and additives that are compatible with the sulfonation process is included in the docket.[21,22]

Table 4.2-5
Permeation Rates for Sulfonated Fuel Tanks
with Slosh Testing by ARB Over a 18-41°C Diurnal

Technology Configuration	Units	Tank 1	Tank 2	Tank 3	Average
Set #1 Approximate Baseline	g/m^2/day	10.4	10.4	10.4	10.4
Set #1 Sulfonated	g/m^2/day % reduction	0.73 93%	0.82 92%	1.78 83%	1.11 89%
Set #1 Sulfonated & Sloshed	g/m^2/day % reduction	1.04 90%	1.17 89%	2.49 76%	1.57 85%
Set #2 Average Baseline	g/m^2/day	12.1	12.1	12.1	12.1
Set #2 Sulfonated	g/m^2/day % reduction	1.57 87%	1.67 86%	1.29 89%	1.51 88%
Set #2 Sulfonated & Sloshed	g/m^2/day % reduction	2.09 83%	2.16 82%	1.70 86%	1.98 84%

An in-use durability testing program was also completed for sulfonated HDPE fuel tanks and bottles.[23] The fuel tank had a 25 gallon capacity and was removed from a station wagon that had been in use in southern California for five years (35,000 miles). The fuel tank was made of HDPE with carbon black used as an additive. After five years, the sulfonation level measured on the surface of the plastic fuel tank did not change. Tests before and after the aging both showed a 92 percent reduction in gasoline permeation due to the sulfonation barrier compared to the permeation rate of a new untreated tank. Testing was also done on 1 gallon bottles made of HDPE with 3% carbon black. These bottles were shown to retain over a 99 percent barrier after five years. This study also looked at other properties such as yield strength and mechanical fatigue and saw no significant deterioration.

One study looked at the effect of alcohol in the fuel on permeation rates from sulfonated fuel tanks.[24] In this study, the fuel tanks were tested with both gasoline and various methanol blends. No significant increase in permeation due to methanol in the fuel was observed.

4.2.2.1.2 Fluorination

We tested one fluorinated, 6 gallon, HDPE, portable marine fuel tank at 29°C (85°F) with gasoline. Prior to testing, the fuel tank had been stored with gasoline in it for about 20 weeks to stabilize the permeation rate. We measured a permeation rate of 0.07 g/gallon/day (0.76 g/m^2/day) which represents more than a 90 percent reduction from baseline.

The California Air Resources Board (ARB) collected test data on permeation rates from fluorinated portable fuel containers using California certification fuel.[25,26] The results, presented in Table 4.2-6, show that fluorination can be used to achieve significant reductions in permeation from plastic fuel containers. This data was collected using a diurnal cycle from 18-41°C which is roughly equivalent to steady-state permeation testing at 30°C. Four different levels of fluorination treatment were tested. The average permeation rate for the 87 fluorinated fuel tanks is 0.21 g/gal/day which represents about a 75 percent reduction from baseline. However, for the highest level of fluorination, the average permeation rate was 0.04 g/gal/day which represents a 95 percent reduction from baseline. Earlier data collected by ARB showed consistently high emissions from fluorinated fuel tanks; however, ARB and the treatment manufacturers agree that this was due to inexperience with treating fuel tanks and that these issues have since been largely resolved.[27] For this reason we do not include the earlier data in this analysis.

Table 4.2-6
Permeation Rates for Fluorinated Plastic Fuel Containers Tested by ARB Over a 18-41°C Diurnal

Barrier Treatment*	Tank Capacity [gallons]	Permeation Loss [g/gal/day]

Level 3 (average = 0.27 g/gal/day)	1	0.04
	1	0.06
	1	0.25
	2	0.12
	2	0.15
	2	0.17
	2	0.09
	2	0.15
	2	0.12
	2	0.18
	2	0.17
	2	0.14
	2	0.18
	2	0.34
	2	0.41
	2	0.41
	2	0.36
	2	0.41
	2	0.23
	2	0.29
	2	0.31
	2	0.24
	2	0.32
	2	0.16
	2	0.19
	2	0.20
	2	0.11
	2	0.20
	5	0.06
	5	0.06
	5	0.07
	5	0.09
	5	0.10
	5	0.11
	5	0.15
	5	0.23
	5	0.31
	5	0.33
	5	0.24
	5	0.33
	5	0.33
	5	0.51
	5	0.47
	5	0.41
	5	0.45
	5	0.45
	5	0.35
	5	0.37
	5	0.28
	5	0.26
	5	0.35
	5	0.35
	5	0.37
	5	0.28
	5	0.35
	5	0.41
	5	0.47
	5	0.43
	5	0.39
	5	0.47
	5	0.55

Level 4	1	0.05
	1	0.05
(average =0.09 g/gal/day)	1	0.06
	5	0.11
	5	0.11
	5	0.15
Level 5	1	0.03
	1	0.04
(average =0.07 g/gal/day)	1	0.05
	1	0.05
	1	0.07
	1	0.08
	1	0.11
	1	0.11
	1	0.12
	2.5	0.04
	2.5	0.04
	2.5	0.05
	2.5	0.07
	2.5	0.07
	5	0.05
	5	0.10
	5	0.11
SPAL	5	0.04
(average =0.04 g/gal/day)	5	0.04
	5	0.04

*designations used in ARB report; shown in order of increasing treatment

All of the data on fluorinated fuel tanks presented above were based on fuel tanks fluorinated by the same company. Available data from another company that fluorinates fuel tanks shows a 98 percent reduction in gasoline permeation through a HDPE fuel tank due to fluorination.[28]

ARB investigated the effect of fuel slosh on the durability of fluorinated surfaces. Two sets of three fluorinated fuel tanks were tested for permeation before and after being sloshed with fuel in them 1.2 million times.[29,30] The results of this testing show that an 80% reduction in permeation was achieved on average even after the slosh testing was performed for Set #1. However, this data also showed a 99 percent reduction for Set #2. This shows the value of matching the barrier treatment process to the fuel tank material. Table 4.2-7 presents these results which were recorded in units of g/m^2/day. The baseline level for Set #1 is an approximation based on testing of similar fuel tanks, while the baseline for Set #2 is based on testing of those tanks.

Table 4.2-7
Permeation Rates for Fluorinated Fuel Tanks
with Slosh Testing by ARB Over a 18-41°C Diurnal

Technology Configuration	Units	Tank 1	Tank 2	Tank 3	Average
Set #1 Approximate Baseline	g/m^2/day	10.4	10.4	10.4	10.4
Set #1 Fluorinated	g/m^2/day % reduction	1.17 89%	1.58 85%	0.47 96%	1.07 90%
Set #1 Fluorinated & Sloshed	g/m^2/day % reduction	2.38 77%	2.86 73%	1.13 89%	2.12 80%
Set #2 Approximate Baseline	g/m^2/day	12.1	12.1	12.1	12.1
Set #2 Fluorinated	g/m^2/day % reduction	0.03 >99%	0.00 >99%	0.00 >99%	0.01 >99%
Set #2 Fluorinated & Sloshed	g/m^2/day % reduction	0.07 99%	0.11 99%	0.05 >99%	0.01 99%

One study looked at the effect of alcohol in the fuel on permeation rates from fluorinated fuel tanks.[31] In this study, the fuel tanks were tested with both gasoline and various methanol blends. No significant increase in permeation due to methanol in the fuel was observed.

4.2.2.1.3 Barrier Platelets

We tested portable gas cans molded with low permeation non-continuous barrier platelets 29°C (85°F). Three of the tank types were blended with nylon and tested with gasoline. The other three tanks represented three different blends with ethylene vinyl alcohol (EVOH) to optimize permeation control on E10 fuel. Prior to testing, the fuel tanks had been stored with fuel in it for 10-20 weeks to stabilize the permeation rate. Table 4.2-8 presents the emission results. This data suggests that EVOH-based Selar® is capable of meeting the permeation standard on E10.

Table 4.2-8
Permeation Rates for Plastic Fuel Containers with Barrier Platelets Tested by EPA at 29°C

Selar® Type*	Fuel Type	Tank Capacity [gallons]	Permeation Loss [g/gal/day]	Permeation Loss [g/m^2/day]
2% nylon	Gasoline	5	0.34	4.0
4% nylon	Gasoline	5.3	0.10	1.1
4% nylon	Gasoline	6.6	0.14	1.5
2% EVOH	E10	6.6	0.23	2.8
4% EVOH	E10	6.6	0.14	1.7
6% EVOH	E10	6.6	0.09	1.0

*trade name for barrier platelet technology used in test program

The California Air Resources Board (ARB) collected test data on permeation rates from portable fuel containers molded with low permeation non-continuous barrier platelets using California certification fuel. The results show that this technology can be used to achieve significant reductions in permeation from plastic fuel containers. This data was collected using a diurnal cycle from 18-41°C which is roughly equivalent to steady-state permeation testing at 30°C. Five different percentages of the barrier material were tested. The average permeation rate for the 67 fuel tanks is 0.24 g/gal/day; however, there was a wide range in variation in the effectiveness of the barrier platelets for these fuel tanks. Some of the data outliers were actually higher than baseline emissions. This was likely due to leaks in the fuel tank which would result in large emission increases due to pressure built up with temperature variation over the diurnal cycle. Removing these six outliers, the average permeation rate is 0.15 g/gal/day with a minimum of 0.04 g/gal/day and a maximum of 0.47 g/gal/day. This represents more than an 85 percent reduction from the average baseline. Table 4.2-9 includes all of the ARB test data, including the outliers.

Table 4.2-9: Permeation Rates for Plastic Fuel Containers with Barrier Platelets Tested by ARB Over a 18-41°C Diurnal

Percent Selar®*	Tank Capacity [gallons]	Permeation Loss [g/gal/day]
4%	5.00	0.08
	5.00	0.09
(average =0.12 g/gal/day)	5.00	0.13
	5.00	0.16
	5.00	0.17
	6.00	0.08
	6.00	0.10

6% (average =0.16 g/gal/day)	2.00	0.06
	2.00	0.07
	2.00	0.10
	2.00	0.10
	2.00	0.11
	2.00	0.11
	2.00	0.28
	2.00	0.44
	2.00	0.45
	2.00	0.47
	5.00	0.07
	5.00	0.07
	5.00	0.07
	5.00	0.08
	5.00	0.12
	5.00	0.17
	6.00	0.06
	6.00	0.07
8% (average =0.32 g/gal/day)	1.00	0.14
	1.00	0.17
	1.00	0.21
	1.00	0.21
	1.00	0.21
	1.00	0.65
	1.00	0.85
	1.00	0.98
	1.00	1.66
	2.00	0.04
	2.00	0.05
	2.00	0.07
	2.00	0.09
	2.00	0.12
	2.00	0.16
	2.00	0.44
	5.00	0.08
	5.00	0.10
	6.00	0.05
	6.00	0.06

10% (average =0.28 g/gal/day)	1.00	0.15
	1.00	0.19
	1.00	0.19
	1.00	0.21
	1.00	0.23
	1.00	0.26
	1.00	0.79
	1.00	0.83
	1.00	0.88
	2.00	0.06
	2.00	0.06
	2.00	0.07
	2.00	0.08
	2.00	0.13
	2.00	0.14
	2.00	0.23
12% (average =0.21 g/gal/day)	1.00	0.13
	1.00	0.14
	1.00	0.20
	1.00	0.21
	1.00	0.23
	1.00	0.35

*trade name for barrier platelet technology used in test program

The fuel containers tested by ARB used a technology known as Selar® which uses nylon as the barrier resin. Dupont, who manufacturers Selar®, has recently developed a new resin (Selar RB®) that uses ethylene vinyl alcohol (EVOH) as the barrier resin. EVOH has much lower permeation than nylon, especially with alcohol fuel blends (see Section 4.2.2.3). Table 4.2-10 presents permeation rates for HDPE and three Selar RB® blends when tested at 60°C on xylene.[32] Xylene is a component of gasoline and gives a rough indication of the permeation rates on gasoline. This report also shows a reduction of 99% on naptha and 98% on toluene for 8% Selar RB®.

Table 4.2-10
Xylene Permeation Results for Selar RB® at 60°C

Composition	Permeation, g mm/m^2/day	% Reduction
100% HDPE	285	–
10% RB 215/HDPE	0.4	99.9%
10% RB 300/HDPE	3.5	98.8%
15% RB 421/HDPE	0.8	99.7%

4.2.2.1.4 Coextruded barrier

One study looks at the permeation rates, using ARB test procedures, through multi-layer fuel tanks.[33] The fuel tanks in this study were 6 layer coextruded plastic tanks with EVOH as the barrier layer (3% of wall thickness). The outer layers were HDPE and two adhesive layers were needed to bond the EVOH to the polyethylene. The sixth layer was made of recycled polyethylene. The two test fuels were a 10 percent ethanol blend (CE10) and a 15 percent methanol blend (CM15). See Table 4.2-11.

Table 4.2-11
Permeation Results for a Coextruded Fuel Tank Over a 18-41°C Diurnal

Composition	Permeation, g/day	% Reduction
100% HDPE (approximate)	6 - 8	–
3% EVOH, 10% ethanol (CE10)	0.2	97%
3% EVOH, 15% methanol (CM15)	0.3	96%

4.2.2.1.5 Alternative Materials

Permeation can also be reduced from fuel tanks by constructing them out of a lower permeation material than HDPE. For instance, a material that would reduce permeation is the use of metal fuel tanks because gasoline does not permeate through metal. In addition, there are grades of plastics other than HDPE that could be molded into fuel tanks. One material that has been considered by manufacturers is nylon; however, although nylon has excellent permeation resistance on gasoline, it has poor chemical resistance to alcohol-blended fuels. As shown in Table 4.2-16, nylon would result in about a 98 percent reduction in permeation compared to HDPE for gasoline. However, for a 10 percent ethanol blend, this reduction would only be about 40-60 percent depending on the grade of nylon. For a 15 percent methanol blend, the permeation would actually be several times higher through nylon than HDPE.

Other materials, which have excellent permeation even with alcohol-blended fuels are acetal copolymers and thermoplastic polyesters. These polymers can be used to form fuel tanks in the blow-molding, rotational-molding, and injection-molding processes. An example of an acetal copolymer is known as Celcon® which has excellent chemical resistance to fuel and has been shown to be durable based on exposure to automotive fuels for 5000 hours at high temperatures.[34] As shown in Table 4.2-16, Celcon® would result in more than a 99 percent reduction in permeation compared to HDPE for gasoline. On a 10 percent ethanol blend, the use of Celcon® would result in more than a 95 percent reduction in permeation. Two thermoplastic polyesters, known as Celanex® and Vandar®, are being considered for fuel tank construction and are being evaluated for permeation resistance by the manufacturer.

4.2.2.2 Fuel Hoses

Thermoplastic fuel lines for automotive applications are generally built to SAE J2260 specifications.[35] Category 1 fuel lines under this specification have permeation rates of less than

25 g/m^2/day at 60°C on CM15 fuel. One thermoplastic used in automotive fuel line construction is polyvinylidene fluoride (PVDF). Based on the data presented in Section 4.2.2.3, a PDVF fuel line with a typical wall thickness (1 mm) would have a permeation rate of 0.2 g/m^2/day at 23°C on CM15 fuel. However, manufacturers have expressed concern that this fuel line would not be flexible enough to use in their applications because they require flexible rubber hose to fit tight radii and to resist vibration. In addition, using plastic fuel line rather than rubber hose would require the additional cost of changing hose fittings on the vehicles.

Manufacturers expressed concern about basing the standards on testing with 10% ethanol fuel. If we were to base the standards on gasoline as a test fuel, then SAE J30 R9[36] fuel hose would meet the permeation requirement. This hose is designated for fuel injection systems and has a maximum permeation rate of 15 g/m^2/day on ASTM Fuel C. On a fuel containing an alcohol blend, permeation would likely be much higher from these fuel hoses. SAE J30 specifically notes that "exposure of this hose to gasoline or diesel fuel which contain high levels, greater than 5% by volume, of oxygenates, i.e., ethanol, methanol, or MTBE, may result in significantly higher permeation rates than realized with ASTM Fuel C." R9 hose is made with a thin low permeation barrier sandwiched between layers of rubber. A typical barrier material used in this construction is FKM. Based on the data presented in Section 4.2.8.3 for FKM, the permeation rate is 3-5 times higher on Fuel CE10 than Fuel C. Therefore, a typical R9 hose meeting 15 g/m^2/day at 23°C on Fuel C may actually permeate at a level of 40-50 g/m^2/day on fuel with a 10 percent ethanol blend.

SAE J30 also designates R11 and R12 hose which are intended for use as low permeation fuel feed and return hose. R11 has thee classes known as A, B, and C. Of these, R11-A has the lowest permeation specification which is a maximum of 25 g/m^2/day at 40°C on CM15 fuel. Because permeation rates are generally higher on CM15 than CE10 and because they are 2-4 times higher at 40°C than at 23°C, hose designed for this specification would likely meet our permeation requirement. R12 hose has a permeation requirement of 100 g/m^2/day at 60°C on CM15 fuel. This is roughly equivalent in stringency as the R11-A permeation requirement.

There are lower permeation fuel hoses available today that are manufactured for automotive applications. These hoses are generally used either as vapor hoses or as short sections of fuel line to provide flexibility and absorb vibration. One example of such a hose[37] is labeled by General Motors as "construction 6" which is a multilayer hose with an inner layer of THV sandwiched in inner and outer layers of a rubber known as ECO.[19] A hose of this construction would have less than 8 g/m^2/day at 40°C when tested on CE10. In look and flexibility, this hose is not significantly different than the SAE J30 R7 hose generally used in motorcycle applications.

Permeation data on several low permeation hose designs were provided to EPA by an automotive fuel hose manufacturer.[38] This hose, which is as flexible as R9 hose, was designed

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[19] THV = tetrafluoroethylene hexafluoropropylene, ECO = epichlorohydrin/ethylene oxide

for automotive applications and is available today. Table 4.2-12 presents permeation data on three hose designs that use THV 800 as the barrier layer. The difference in the three designs is the material used on the inner layer of the hose. This material does not significantly affect permeation emissions through the hose but can affect leakage at the plug during testing (or connector in use) and fuel that passes out of the end of the hose which is known as wicking. The permeation testing was performed using the ARB 18-41°C diurnal cycle using a fuel with a 10 percent ethanol blend (E10).

Table 4.2-12
Hose Permeation Rates with THV 800 Barrier over ARB Cycle (g/m^2/day)

Hose Name	Inner Layer	Permeation	Wicking	Leaking	Total
CADBAR 9610	THV	0.16	0.00	0.02	0.18
CADBAR 9710	NBR	0.17	0.29	0.01	0.47
CADBAR 9510	FKM	0.16	0.01	0.00	0.18

The data presented above shows that there is hose available that can easily meet the hose permeation standard on E10 fuel. Although hose using THV 800 is available, it is produced for automobiles that will need to meet the tighter evaporative emission requirements in the upcoming Tier 2 standards. Hose produced in mass quantities today uses THV 500. This hose is less expensive and could be used to meet the motorcycle permeation requirements. Table 4.2-13 presents information comparing hose using THV 500 with the hose described above using THV 800 as a barrier layer.[39] In addition, this data shows that permeation rates more than double when tested on CE10 versus Fuel C.

Table 4.2-13
Comparison of Hose Permeation Rates with THV 500 and 800 (g/m^2/day)*

Hose Inner Diameter, mm	THV 500		THV 800	
	Fuel C	Fuel CE10	Fuel C	Fuel CE10
6	0.5	1.4	0.2	0.5
8	0.5	1.4	0.3	0.5
10	0.5	1.5	0.2	0.5

* Calculated using data from Thwing Albert materials testing (may overstate permeation)

We contracted with an independent testing laboratory to test a section of R9 hose and a section of automotive vent line hose for permeation.[40] These hoses had a six mm inner diameter. The test lab used the SAE J30 test procedures for R9 hose with both Fuel C and Fuel CE10. We purchased the R9 hose (which was labeled as such) from a local auto parts store. According to this testing, the R9 hose is well below the SAE specification of 15 g/m^2/day. In fact, it meets this limit on Fuel CE10 as well. The automotive vent line showed similar results. This data is presented in Table 4.2-14.

Table 4.2-14
Test Results on Commercially Available Hose Samples (g/m^2/day)

Hose Sample	Fuel C	Fuel CE10
R9	10.1	12.1
Automotive vent line	10.9	9.0

Another hose construction that can be used to meet the motorcycle hose permeation standards is known as F200 which uses Teflon® as a barrier layer. Teflon has a permeation rate of 0.03-0.05 g-mm/m^2/day on 15% methanol fuel. F200 hose is used today to meet SAE J30 R11 and R12 requirements for automotive applications. Table 4.2-15 presents data on permeation rates for F200 constructions.[41]

Table 4.2-15
F200 Typical Fuel Permeation

Film Thickness [mils]	Hose Diameter [in.]	Fuel	g/m^2/day @23°C	g/m^2/day @40°C
2	0.375	TF-2		0.7
2	0.275	TF-2		1
2	0.275	M25	0.5	4
2	0.470	CE10		3
2	0.625	CE10		3
1	0.625	CE10		4
1	1.5	CE10	1.5	

4.2.2.3 Material Properties

This section presents data on permeation rates for a wide range of materials that can be used in fuel tanks and hoses. The data also includes effects of temperature and fuel type on permeation. Because the data was collected from several sources, there is not complete data on each of the materials tested in terms of temperature and test fuel. Table 4.2-16 gives an overview of the fuel systems materials included in the data set. Tables 4.2-17 through 4.2-20 present permeation rates using Fuel C, a 10% ethanol blend (CE10), and a 15% methanol blend (CE15) for the test temperatures of 23, 40, 50, and 60°C.

Table 4.2-16
Fuel System Materials

Material Name	Composition
Nylon 12	thermoplastic
EVOH	ethylene vinyl alcohol, thermoplastic
Polyacetal	thermoplastic
PBT	polybutylene terephthalate, thermoplastic
PVDF	polyvinylidene fluoride, fluorothermoplastic
NBR	nitrile rubber
HNBR	hydrogenated nitrile rubber
FVMQ	flourosilicone
FKM	fluoroelastomer
FEB	fluorothermoplastic
PFA	fluorothermoplastic
Carilon	aliphatic poly-ketone thermoplastic
HDPE	high density polyethylene
LDPE	low density polyethylene
Celcon	acetal copolymer
THV	tetra-fluoro-ethylene, hexa-fluoro-propylene, vinyledene fluoride
E14659	fluoropolymer film
E14944	fluoropolymer film
ETFE	ethylene-tetrafluoro-ethylene, fluoroplastic
GFLT	fluoroelastomer
FEP	fluorothermoplastic
PTFE	polytetrafluoroethylene, fluoroplastic
FPA	copolymer of tetrafluoroethylene and perfluoroalkoxy monomer

Table 4.2-17
Fuel System Material Permeation Rates at 23°C by Fuel Type [42,43,44,45,46,47]

Material Name	Fuel C g-mm/m^2/day	Fuel CE10 g-mm/m^2/day	CM15 g-mm/m^2/day
HDPE	35	–	35
Nylon 12, rigid	0.2	–	64
EVOH	–	–	10
Polyacetal	–	–	3.1
PBT	–	–	0.4
PVDF	–	–	0.2
NBR (33% ACN)	669	1028	1188
HNBR (44%ACN)	230	553	828
FVMQ	455	584	635
FKM Viton A200 (66%F)	0.80	7.5	36
FKM Viton B70 (66%F)	0.80	6.7	32
FKM Viton GLT (65%F)	2.60	14	60
FKM Viton B200 (68%F)	0.70	4.1	12
FKM Viton GF (70%F)	0.70	1.1	3.0
FKM Viton GFLT (67%F)	1.80	6.5	14
FKM - 2120	8	–	44
FKM - 5830	1.1	–	8
Teflon FEP 1000L	0.03	0.03	0.03
Teflon PTFE	–	–	0.05
Teflon PFA 1000LP	0.18	0.03	0.13
Tefzel ETFE 1000LZ	0.03	0.05	0.20
Nylon 12 (GM grade)	6.0	24	83
Nitrile	130	635	1150
Silicone Rubber	–	–	6500
Fluorosilicone	–	–	635
FKM	–	16	–
FE 5620Q (65.9% fluorine)	–	7	–
FE 5840Q (70.2% fluorine)	–	4	–
PTFE	0.05	–	0.08*
ETFE	0.02	–	0.04*
PFA	0.01	–	0.05*
THV 500	0.03	–	0.3

* tested on CM20.

Table 4.2-18
Fuel System Material Permeation Rates at 40°C by Fuel Type [48,49,50]

Material Name	Fuel C g-mm/m^2/day	Fuel CE10 g-mm/m^2/day	CM15 g-mm/m^2/day
Carilon	0.06	1.5	13
EVOH - F101	<0.0001	0.013	3.5
EVOH - XEP380	<0.0001	–	5.3
HDPE	90	69	71
LDPE	420	350	330
Nylon 12 (L2101F)	2.0	28	250
Nylon 12 (L2140)	1.8	44	–
Celcon	0.38	2.7	–
Fortron PPS SKX-382	–	0.12	–
Celcon Acetal M90	–	0.35	–
Celanex PBT 3300 (30% GR)	–	3	–
Nylon 6	–	26	–
Dyneon E14659	0.25	–	2.1
Dyneon E14944	0.14	–	1.7
ETFE Aflon COP	0.24	0.67	1.8
m-ETFE	0.27	–	1.6
ETFE Aflon LM730 AP	0.41	0.79	2.6
FKM-70 16286	11	35	–
GFLT 19797	13	38	–
Nitrile	–	1540	3500
FKM	–	86	120
FE 5620Q (65.9% fluorine)	–	40	180
FE 5840Q (70.2% fluorine)	–	12	45
THV-310 X	–	–	5.0
THV-500	0.31	–	3.0
THV-610 X	–	–	2.1

Table 4.2-19
Fuel System Material Permeation Rates at 50°C by Fuel Type [51]

Material Name	Fuel C g-mm/m^2/day	Fuel CE10 g-mm/m^2/day	CM15 g-mm/m^2/day
Carilon	0.2	3.6	–
HDPE	190	150	–
Nylon 12 (L2140)	4.9	83	–
Celcon	0.76	5.8	–
ETFE Afcon COP	–	1.7	–
FKM-70 16286	25	79	–
GFLT 19797	28	77	–

Table 4.2-20
Fuel System Material Permeation Rates at 60°C by Fuel Type [52,53,54,55]

Material Name	Fuel C g-mm/m^2/day	Fuel CE10 g-mm/m^2/day	CM15 g-mm/m^2/day
Carilon	0.55	7.5	–
HDPE	310	230	–
Nylon 12 (L2140)	9.5	140	–
Celcon	1.7	11	–
ETFE Afcon COP	–	3.8	–
FKM-70 16286	56	170	–
GFLT 19797	60	130	–
polyeurethane (bladder)	285	460	–
THV-200	–	54	–
THV-310 X	–	–	38
THV-510 ESD	6.1	18	35
THV-500	–	11	20
THV-500 G	4.1	10	22
THV-610 X	2.4	5.4	9.0
ETFE 6235 G	1.1	3.0	6.5
THV-800	1.0	2.9	6.0
FEP	0.2	0.4	1.1

4.2.3 Test Procedures

4.2.3.1 Fuel Tanks

Essentially, two options may be used to test fuel tanks for certification. The first option is to perform all of the durability tests on a fuel tank and then test the permeation rate. The second option is to test a fuel tank that has been preconditioned and adjust the results using a deterioration factor. The deterioration factor would need to be based on testing of that tank or a similar tank unless you can use good engineering judgment to apply the results of previous durability testing with a different fuel system. Figure 4.2-2 provides flow charts for these two options.

4.2.3.1.1 Option 1: full test procedure

Under the first option, the fuel tank is tested both before and after a series of durability tests. We estimate that this test procedure would take about 49 weeks to complete. Prior to the first test, the fuel tank must be preconditioned to ensure that the hydrocarbon permeation rate has stabilized. Under this step, the fuel tank must be filled with a 10 percent ethanol blend (E10), sealed, and soaked for 20 weeks at a temperature of 28 °C ± 5 °C. Once the permeation rate has stabilized, the fuel tank is drained and refilled with E10, sealed, and tested for a baseline permeation rate. The baseline permeation rate from the fuel tank is determined by measuring the weight difference the fuel tank before and after soaking at a temperature of 28 °C ± 2 °C over a period of at least 2 weeks.

To determine a permeation emission deterioration factor, we are specifying three durability tests: slosh testing, pressure-vacuum cycling, and ultra-violet (UV) light exposure. The purpose of these deterioration tests is to help ensure that the technology is durable and the measured emissions are representative of in-use permeation rates. For slosh testing, the fuel tank is filled to 40 percent capacity with E10 fuel and rocked for 1 million cycles. The pressure-vacuum testing contains 10,000 cycles from -0.5 to 2.0 psi. The slosh testing is designed to assess treatment durability as discussed above. These tests are designed to assess surface microcracking concerns. These two durability tests are based on a draft recommended SAE practice.[56] The third durability test is intended to assess potential impacts of UV sunlight (0.2 μm - 0.4 μm) on the durability of the surface treatment. Because most of the irradiance from sunlight in this range is seen in wavelengths above 0.3 μm, we recommend testing with an average wavelength above 0.3 μm such as the UVA lamp described in SAE J2020.[57] In the UV exposure test, the tank must be exposed to a UV light of at least 24 W/m^2 (0.40 $W\text{-}hr/m^2$ /min) on the tank surface for 15 hours per day for 30 days. Alternatively, it can be exposed to direct natural sunlight for an equivalent period of time in exposure hours. To allow for weekends and rainy days, these exposure days to not need to be continuous.

The order of the durability tests is optional. However, we require that the fuel tank be soaked to ensure that the permeation rate is stabilized just prior to the final permeation test. If the slosh test is run last, the length of the slosh test may be considered as part of this soak period. Where possible, the deterioration tests may be run concurrently. For example, the fuel tank could be exposed to UV light during the slosh test. In addition, if a durability test can clearly be shown to not be appropriate for a given product, manufacturers may petition to have this test waived. For example, a fuel tank that is only used in vehicles where an outer shell prevents the tank from being exposed to sunlight may not benefit from UV testing.

After the durability testing, once the permeation rate has stabilized, the fuel tank is drained and refilled with E10, sealed, and tested for a final permeation rate. The final permeation rate from the fuel tank is determined using the same measurement method as for the baseline permeation rate. The final permeation rate would be used for the emission rate from this fuel tank. The difference between the baseline and final permeation rates would be used to determine a deterioration factor for use on subsequent testing of similar fuel tanks.

4.2.3.1.2 Option 2: base test with DF

Under the second option, the fuel tank is tested for baseline permeation only, then a deterioration factor (DF) is applied. We estimate that this test procedure would take about 22 weeks to complete. As with Option 1 baseline testing, the fuel tank must be preconditioned to ensure that the hydrocarbon permeation rate has stabilized. Under this step, the fuel tank must be filled with a 10 percent ethanol blend (E10), sealed, and soaked for 20 weeks at a temperature of 28 °C ± 5 °C. Once the permeation rate has stabilized, the fuel tank is drained and refilled with E10, sealed, and tested for a baseline permeation rate. The baseline permeation rate from the fuel tank is determined by measuring the weight difference the fuel tank before and after soaking at a temperature of 28 °C ± 2 °C over a period of at least 2 weeks.

The final permeation rate is then determined by applying a DF to the baseline permeation rate. The DF, in units of $g/m^2/day$, is added to the baseline permeation rate. This DF must be determined with testing on a fuel tank in the same emission family.

4.2.3.2 Fuel Hoses

The permeation rate from fuel hoses would be measured at a temperature of 23 °C ± 2 °C over a period of at least 2 weeks. A longer period may be necessary for an accurate measurement for hose with low permeation rates. Permeation would be measured through the weight loss technique described in SAE J30.[58] The hose must be preconditioned with a fuel soak to ensure that the permeation rate has stabilized. Based on times to achieve equilibrium for permeation measurement described in SAE J2260[59] for automotive fuel lines, and adjusting for temperature and test fuel type, we estimate a minimum soak time of 4 weeks. The fuel used for this testing would be a blend of 90 percent gasoline and ten percent ethanol. This fuel is consistent with the test fuel used for on-highway evaporative emission testing.

4.2.4 Conclusion

We believe that manufacturers will be able to meet the fuel tank permeation requirements through several design strategies that include sulfonation, fluorination, barrier platelets, and coextruded barriers. Our cost analysis, presented in Chapter 5, indicates that sulfonation would likely be the most attractive technology. However, conversations with manufacturers have revealed interest in each of these low permeation strategies. We believe the data presented above supports a final standard which requires about an 85% reduction in permeation, compared baseline HDPE fuel tanks, throughout the useful life of the motorcycle.

As discussed above, fuel hose is available today that meets the permeation requirements for motorcycles. Low permeation hose was generally developed for automotive applications; however, we believe that this fuel hose can be used in motorcycle applications. Even assuming that new hose clamps would be required, our analyses in Chapters 5 and 6 show that the low permeation hose would be inexpensive yet effective.

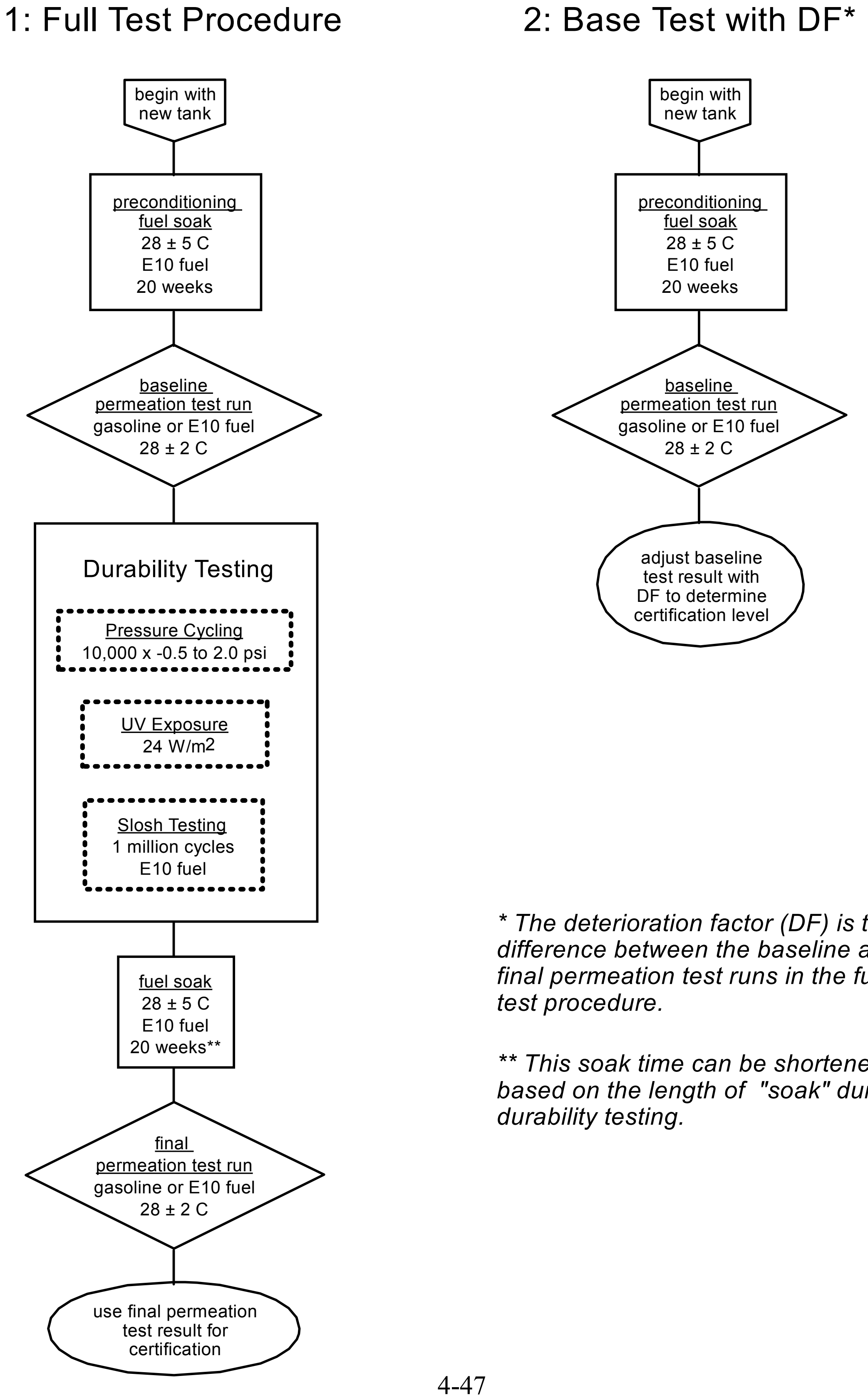
4.2.5 Impacts on Noise, Energy, and Safety

We would not expect evaporative emission controls to have any impact on noise from a motorcycle because noise from the fuel system is insignificant.

We anticipate that permeation emission standards will have a positive impact on energy. By capturing or preventing the loss of fuel through permeation, we estimate that the average lifetime fuel savings will be 9 gallons for motorcycles which translates to a fuel savings of about 12 million gallons in 2030 when most motorcycles used in the U.S. are expected to have permeation emission control.

We believe that permeation emission standards will have no negative impacts on safety, and may even have some benefits due to the reduction of fuel vapor around a motorcycle.

Figure 4.2-2: Flow Chart of Permeation Certification Test Options



** The deterioration factor (DF) is the difference between the baseline and final permeation test runs in the full test procedure.*

*** This soak time can be shortened based on the length of "soak" during durability testing.*

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CHAPTER 5: Costs of Control

This chapter describes our approach to estimating the cost of complying with emission standards. We start with a general description of the approach to estimating costs, then provide estimated costs for the technologies we expect manufacturers to use to meet new standards, and average per vehicle costs. This analysis is largely divided into discussions of the costs for three areas of the rulemaking: permeation emission control, Class III motorcycle exhaust emission control, and <50cc motorcycle exhaust emission control. We have not included costs (or emission reductions) for exhaust standards for Class I/Class II motorcycles at or above 50 cc, because most already meet the new standards, and therefore, we do not expect significant additional costs. Class III motorcycles represent about 90 percent of total motorcycle sales. In addition to per vehicle costs, we also present total costs and an analysis of the estimated aggregate cost to society.

5.1 - Methodology

We developed the costs for individual technologies using information provided by ICF, Incorporated and Arthur D. Little, as cited below. The technology characterization and cost figures reflect our current best judgment based on engineering analysis, information from manufacturers, and the published literature. The analysis combines cost figures including markups to the retail level.

Costs of control include variable costs (for incremental hardware costs, assembly costs, and associated markups) and fixed costs (for tooling, R&D, and certification). Variable costs are marked up at a rate of 29 percent to account for the manufacturers' overhead and profit.[1] For technologies sold by a supplier to the engine manufacturers, an additional 29 percent markup is included for the supplier's overhead and profit. All costs are in 2001 dollars. For fixed costs, we estimated that R&D and facility costs will be incurred three years prior to production on average and tooling and certification costs will be incurred one year prior to production. These fixed costs were then increased seven percent for each year prior to the start of production to reflect the time value on money. Warranty costs are estimated to be 5 percent of hardware costs on average. Actual warranty costs may be somewhat higher in the first few years of the program and lower in the long-term, as any warranty problems that arise are addressed by manufacturers.

Fixed costs are assessed for eight years, after which they are fully amortized and are therefore no longer part of the cost calculation.[20] Manufacturers commented that eight years is the appropriate time frame for amortization of costs for the motorcycle industry.[2] Manufacturers are expected to meet the Tier 1 and Tier 2 standards using the same technologies, but on fewer

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[20] Except for Tier 1 certification costs, which are assessed over 4 years, because manufacturers may certify again for the Tier 2 standards.

models for Tier 1. This approach is facilitated by the averaging program, where low emissions can be achieved on some models while others exceed the standards, as long as the standards are met on average. It is also facilitated by the lead time provided to manufacturers to meet the standards which allows them to plan out product development. We believe this approach makes sense because the manufacturers would not invest in an engine line to meet Tier 1 and then revise the engine line again to meet Tier 2. It is effectively the same approach as one would take if there were no Tier 1 standards but the Tier 2 standards were phased in earlier to achieve the same emissions reductions. For these reasons, we believe it is appropriate to use a fixed cost recovery period of eight years for both the Tier 1 and Tier 2 standards. Manufacturers will likely invest in engine lines only once during the course of meeting the Tier 1 and Tier 2 standards. Those investments continue to provide benefits long-term.

The analysis presents an estimate of costs that would apply in the first year of new emission standards and the corresponding long-term costs. Long-term costs decrease due to two principal factors. First, fixed costs are assessed over the first eight years of sales, after which they are fully amortized and are therefore no longer part of the cost calculation. Second, manufacturers are expected to learn over time to produce the engines with the new technologies at a lower cost. Because of relatively low sales volumes, manufacturers are less likely to put in the extra R&D effort for low-cost manufacturing. As production starts, assemblers and production engineers will then be expected to find significant improvements in fine-tuning the designs and production processes. Consistent with analyses from other programs, we reduce estimated variable costs by 20 percent beginning with the third year of production.[3] Based on comments we received that many of the technologies have already been used on at least some models and therefore manufacturers already have experience with them, we are not including additional cost reductions due to learning. We believe it is appropriate to apply one 20 percent reduction here, given that the industries are facing emission regulations for the first time in many years and it is reasonable to expect learning to occur with the experience of producing and improving emission-control technologies.

Even though the analysis does not reflect all the possible technology variations and options that are available to manufacturers, we believe the projections presented here provide a cost estimate representative of the different approaches manufacturers may ultimately take. We expect manufacturers in many cases to find and develop approaches to achieve the emission standards at a lower cost than we describe in this analysis.

We received several comments on our cost analysis and aspects of the analysis have been changed for the Final RSD based on these comments. A full discussion of the comments and subsequent changes is provided in Chapter 5 of the Summary and Analysis of Comments document for this rule.

5.2 Costs for Permeation Evaporative Emission Control

5.2.1 - Technologies and Estimated Costs for Permeation Control

As discussed in earlier chapters, we believe that there are several technologies that could be used to meet the permeation emission standards. Table 5.2-1 presents our best estimates of the costs of applying various evaporative emission control technologies to motorcycles using the average fuel tank size and hose length discussed in Chapter 6.

The cost for including low permeation barrier platelets in blow-molded fuel tanks (generally known as Selar®) is based on increased material costs. No changes should be necessary to the blow-molding equipment. We used 10 percent EVOH which is about $3 per pound and 90 percent HDPE which is about $0.55 per pound. This equates to a price increase of about $0.30 per pound. Depending on the shape of the fuel tank and the wall thickness, motorcycle fuel tanks weigh about 1-1.3 pounds per gallon of capacity. Another option would be to mold the entire fuel tank of a low permeation material such as nylon, an acetal copolymer, or a thermoplastic polyester. These materials have list prices of about $1-2 per pound[4]; therefore, the cost of using these alternative materials would be about 3-7 times higher than presented below for barrier platelets with 10 percent EVOH.

There are now regulations that require permeation controls on over one million recreational vehicles (ATVs, off-highway motorcycles, snowmobiles) beginning in 2008. Such requirements are soon now being consdered for lawn and garden equipment in California as well. One strategy that fuel tank manufacturers may use to meet these existing recreational vehicle standards and pending California small engine fuel tank standards would be molding multi-layer fuel tanks with continuous barriers. Industry experts tell us that a rotomolding machine can produce about 150,000 units per year. These manufacturers would likely purchase new blow-molding machines with four or five additional injection screws for the barrier layer, two adhesion layers, an additional HDPE layer, and potentially a regrind layer. A machine that could blow-mold multi-layer tanks would cost about 2 million dollars. In addition, tooling costs for each new tank design would be about $50,000. EPA believes that motorcycle vehicle manufacturers may have the option of purchasing multi-layer fuel tanks from vendors set up to manufacture multi-layer fuel tanks for these other applications. If they purchase their tanks from a vendor, which is more likely, the cost of the rotomolding equipment would be spread over total production rather than just the motorcycle tanks. For the motorcycle analysis, we considered a fuel tank with a material composition of 3% EVOH at $3/lb, 4% adhesive layer at $1/lb and the remainder HDPE. We anticipate that motorcycle manufacturers may only use 10,000 to 15,000 plastic fuel tanks per year (10% of sales x (550,000 to 600,000 units) divided by 5 to 6 manufacturers). Assuming total annual production of 150,000 blow-molded tanks per machine, with 10 different molds, and an amortization of the capital costs over 8 years, we get a cost per tank of $2.49. This includes a prorated portion of the new blow-molding machine, the appropriate mold, and additional materials as described above.

Surface treatment costs are based on price quotes from companies that specialize in this fluorination[5] and sulfonation.[6] The fluorination costs are a function of the geometry of the fuel tanks because they are based on how many fuel tanks can be fit in a treatment chamber. The price sheet referenced for our fluorination prices assumes rectangular shaped containers. For irregular shaped fuel tanks, the costs would be higher because they would have to be fit into baskets with volumes larger than the volume of the fuel tanks. Therefore, we consider a void space equal to about 25 percent of the volume of the fuel tank. For sulfonation, the shape of the fuel tanks is less of an issue because the treatment process is limited only by the spacing on the production line which is roughly the same for the range of fuel tank sizes used in recreational vehicles. These prices do not include the cost of transporting the tanks; we estimated that shipping, handling and overhead costs would be an additional $0.30-$0.50 per fuel tank depending on tank size and shape.[7]

Barrier fuel hose incremental costs estimates are based on costs of existing products used in marine and automotive applications.[8,9,10] We estimate that the cost increment compared to non-barrier hose used in most motorcycles today is about $0.60 per foot.[11] To be conservative, we consider the cost of upgrading hose clamps to all applications to account for any stiffness in barrier hose. We estimate a cost increase of about $0.40 for two clamps.[12]

Table 5.2-1
Permeation Control Technologies and Incremental Costs*

Technology		*5 gallon tank, 1.5 ft. hose*
barrier platelets (10% EVOH)		$2.20
coextrusion (3% EVOH, 4% adhesive)		$3.14
sulfonation	treatment	$1.20
	shipping/handling	$0.48
fluorination	treatment	$3.25
	shipping/handling	$0.48
barrier hose	fuel hose	$1.16
	hose clamps	$0.52

* includes a 29% markup for overhead and profit

To determine the total costs per motorcycle we use the scenario that all manufacturers use sulfonation to reduce permeation from their fuel tanks and use barrier fuel hose. For this analysis, we consider the cost of shipping fuel tanks to an outside vendor for treatment rather than using the lower cost of in-house sulfonation. For motorcycles with metal fuel tanks, which we estimate make up about 90 percent of motorcycle sales,[13] we assume that no low permeation technology would be used on the fuel tank. We estimate the total per vehicle costs would be $3.36 for motorcycles with plastic fuel tanks and $1.68 for motorcycles with metal fuel tanks. Weighting the costs across motorcycles with metal and plastic fuel tanks, we get an average cost of $1.85 per motorcycle. These costs do not include the fuel savings associated with a reduction permeation which is discussed below in section 5.2.2.

5.2.2 - Operating Cost Savings for Permeation Control

Permeation evaporative emissions are essentially fuel that is lost to the atmosphere. Over the lifetime of a typical motorcycle, this can result in a significant loss in fuel. The anticipated reduction in evaporative emissions due to the tank and hose permeation standards will result in significant fuel savings. Table 5.2.-2 presents the value of the fuel savings for control of permeation emissions. These numbers are calculated using an estimated fuel cost of $1.10 per gallon and fuel density of 6 lbs/gallon (for lighter hydrocarbons which evaporate first). The figures in Table 5.2-2 are based on the per motorcycle emissions described in Chapter 6. Note that the fuel savings are significantly larger than the costs.

Table 5.2-2
Fuel Savings Per Motorcycle Due to Permeation Control

	motorcycle with a plastic fuel tank	motorcycle with a metal fuel tank	aggregate
Evaporative HC reduced [tons/life]	0.036	0.025	0.026
Fuel savings [gallons/life]	12.0	8.1	8.5
Undiscounted savings [$/life @$1.10/gal]	$13.19	$8.93	$9.35
Lifetime fuel savings (NPV, 7%)	$9.20	$6.23	$6.52

5.2.3 - Compliance Costs for Permeation Emission Control

We expect that in the early years, manufacturers will perform durability and permeation testing on their fuel tanks for certification. They will be able to carry over this data in future years and will be able to carry across this data to other fuel tanks made of similar materials and using the same permeation control strategy regardless of tank size or shape. For the first year we estimate durability and certification testing to cost about $15,000 per manufacturer on the assumption that they will use the same materials and permeation control strategy for all of their fuel tanks to reduce costs. This cost would not apply to manufacturers who only use metal fuel tanks. Because manufacturers can design-certify by using hose meeting SAE J30 R11-A or R12, we do not anticipate that testing costs are likely for hose. However, to be conservative, we consider an additional $1,000 for hose testing, if a manufacturer wishes to demonstrate that alternative hoses meet the EPA requirements. In addition, we estimate about $10,000 for engineering and clerical work. As with other fixed costs, we amortized the cost over 8 years of engine sales to calculate per unit certification costs shown in Table 5.2-3. These compliance costs are in addition to the exhaust emission compliance costs discussed in section 5.3.2.

Table 5.2-3
Estimated Per Unit Certification Costs (with plastic tanks)

	Highway Motorcycles	
units/year	10,000	25,000
certification costs	$0.33	$0.13

5.3 - Exhaust Emission Control for Class III Highway Motorcycles

Costs estimated for Class III highway motorcycles were developed in cooperation with ICF Incorporated and Arthur D. Little - Acurex Environmental. The analysis was built upon an analysis completed by the California Air Resources Board (ARB) when they proposed new emission standards in October of 1998. The ARB standards, finalized in 1999 and applicable only to Class III motorcycles (280 cc and greater), will occur in two phases. A Tier 1 standard of 1.4 g/km HC+NOx will apply to Class III motorcycles for the 2004 through 2007 model years, and a Tier 2 standard of 0.8 g/km HC+NOx will apply to Class III motorcycles for the 2008 and later model years. These new standards may be met on a corporate-average basis. Our analysis, while following the general methodology used by the ARB, incorporates some changes to the methodology as well as some component cost estimates that differ from those used by the ARB.[14]

The ARB Staff Report estimated costs for two displacement ranges for Class III motorcycles: 280 to 699 cc and 700 cc and greater. Currently the smaller range is subject to an HC standard of 1.0 g/km in California, while the larger displacement range is subject to an HC standard of 1.4 g/km in California. In order to simplify the calculations, two specific engine displacements were used to compare with the ARB displacement categories. The ARB Staff Report indicates that the sales-weighted average for the 280cc to 699cc class was 600cc and the sales weighted average for the greater than 700cc category was 1200cc. EPA certification data shows that the national averages for the two displacement categories are 593cc and 1260cc, thus demonstrating that the ARB analysis is reasonably representative of the national market. These sales weighted averages were used in developing the cost estimates. The costs include a mark-up to the retail level.

The analysis for Class III motorcycles combines the fixed costs and individual technology costs into a total estimated cost package. The composite analysis weights the costs by the projected percentage of use of the technologies both in the baseline and control scenarios to project industry-wide average per vehicle costs. The full analysis for Class III is followed by an analysis of costs for motorcycles under 50cc in Section 5.4.

5.3.1 - Research and Development Costs

Rather than estimate the R&D associated with applying technologies on an individual technology-by-technology basis, for the Final Rule we have estimated a per manufacturer cost for R&D and then spread those costs over eight years of average production per manufacturer. We have changed our approach to R&D costs, based in part on comments submitted by MIC, and our engineering judgment.[15] We would not expect manufacturers to develop each emission control system component separately with multiple staff years devoted to each component. Manufacturers have experience with the technologies being considered and these technologies are already being used on some models. We would expect that for each engine line there would be a systems approach where emissions controls would be developed in combination and then optimized for each model.

Since the technologies are well known and have been applied to at least some models, we would expect that an average of 4 staff years per engine line would be more than a sufficient amount of development time. Manufacturers typically have about 8 engine lines, according to MIC, which would mean that each manufacturer would spend a total of about 32 engineering staff years (about $3.8 million, at $120,000 per staff year) to meet the standards. We have also included $175,000 per line for equipment-related R&D costs. This would cover the costs of prototype hardware and test vehicles. We believe that these are conservatively high estimates given the state of technology today, with about 49 percent of sales already equipped with fuel injection and 46 percent of sales equipped with secondary air systems. Models already equipped with technologies such as fuel injection or pulse air would require much less work than more basic models. With regard to catalysts, catalysts systems are highly developed and have already been used on some motorcycles. We would expect some additional R&D for system optimization and would also expect R&D efforts to focus on durable system designs that discourage accidental removal and tampering.

We also expect manufacturers to modify products in an orderly manner over time. Models that are modified later will benefit from the R&D experience from earlier models. We believe this approach is likely both because several years of lead-time is provided for the Tier 2 standards and due to the averaging approach for the standards. Averaging allows manufacturers to balance emissions across their Class III product line. Averaging also allows Tier 1 and Tier 2 to be met using the same technological approaches, but on fewer models for Tier 1. We have assigned 25 percent of the total R&D to Tier 1 and 75 percent to Tier 2, based on the fact that more technology changes will be need for Tier 1 than Tier 2, as shown in section 5.3.3, below. Also, manufacturers are expected to take advantage of averaging and make significant modifications only once during the course of implementing the Tier 1 and Tier 2 standards.

To determine an average per vehicle cost for R&D, we used estimated annual sales per manufacturer, an 8 year recovery period, and a rate of return of 7 percent. R&D costs are projected to be incurred 3 years prior to production, and increased 7 percent for each year prior to the start of production to reflect the time value on money. MIC estimates 2001 sales of on-highway motorcycles (including dual sport models) to be about 575,000 units, and they estimate that about 91 percent of all motorcycles are sold by the six large manufacturers.[21] These

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[21] "Statistical Annual 2002", Motorcycle Industry Council, pp.7-8.

estimates are consistent with estimated sales projection data for the 2003 model year from our certification database submitted by manufacturers on a confidential business information basis. Based on the certification data, we have estimated that Class III annual sales are about 528,000 and we are using this to calculate a per manufacturer sales estimate for large manufacturers. For our analysis, we have used an updated per manufacturer sales estimate of 80,000 units per manufacturer (528,000*0.91/6). We did not attempt to include any potential future changes in unit sales or number of engine lines per manufacturer in the analysis. The results on the analysis are shown in the table below.

Table 5.3-1
Average Per Vehicle R&D Costs

R&D cost per manufacturer	$5.24 million
Annual sales per manufacturer	80,000
Years to recover	8
Per unit R&D costs	$13

The above analysis presents an average R&D cost using average numbers of engine lines and average annual sales estimates. Manufacturers with lower than average sales per engine line may experience proportionately higher per unit R&D costs while those with higher than average sales per engine line would experience lower per unit costs. It should be noted that because the California standards were adopted in 1998 and EPA standards lag the California standards by two years, much of the R&D would take place before EPA standards have to be met. Therefore, those costs could be attributed to California's action rather than new EPA standards. We believe that this argument is strong for costs incurred prior to our proposal. We would not necessarily assign costs to standards where those costs were incurred prior to the standards being proposed or the costs were incurred for some other reason or some other benefit ensued. We understand that according to MIC, it is the stated business practice of their member companies to amortize future costs over 50 state production for models sold nationwide. This seems reasonable to us provided the benefits of such R&D are enjoyed by all riders. Now that we have finalized standards, manufacturers will incorporate the EPA standards into their product plans along with California standards. We have revised our approach to R&D costs for the final analysis to take this into account.

5.3.2 - Technologies and Estimated Costs for Class III Exhaust Emission Control

Highway motorcycles are currently powered mostly by carbureted four-stroke engines. However, even in the absence of new regulation, the penetration of fuel-injected models is increasing, most likely due to the improvements in reliability, performance, and fuel economy that fuel injection can offer. EPA's motorcycle certification database for model years 2001 through 2003 indicates that the most prevalent emission controls used to meet the current standards are engine modifications and mechanically-controlled secondary air injection. To an increasingly greater extent manufacturers are now incorporating fuel injection and catalytic converters on some 2001 through 2003 models. Table 5.3-9 shows the increased use of these technologies in the 2003 model year relative to the 2001 model year, based on EPA certification data. For example, catalyst usage increased from 13 to 21 percent, and fuel injection usage increased from 37 to 48 percent, for the larger Class III motorcycles.

While manufacturers will use various means to meet the future standards, there are four basic types of existing emission control technologies on which we have based our cost analysis; engine modifications, electronic fuel injection, pulse air systems, and catalytic converters with oxygen (O_2) sensors. These technologies are being used to varying degrees already and we would expect manufacturers to increase the use of these approaches to meet future standards. In general, we would expect emissions control strategies to include more precise fuel control, better fuel atomization and delivery, reduced engine-out emission levels from engine changes, and increased use of catalysts.

We have included the costs for increased use of engine modifications to meet the Tier 1 standards. We would expect this approach to be used on essentially all engine models. Engine modifications include changes such as improved cylinder honing for better oil control, modified cam profiles to provide increased valve overlap (providing internal exhaust gas recirculation), and piston modifications to improve ring land height, tumble and squish for reduced hydrocarbon emissions and better combustion. As shown in Table 5.3-1, we have estimated the per unit cost of engine modifications to be in the $6 to $8 range.

Table 5.3-1
Engine Modification Costs

Engine Size	600cc	1200cc
Variable Costs		
Improved Pistons	$2	$3
Number Required	2	2
Hardware costs	**$4**	**$6**
Markup @ 29%	$1	$2
Warranty Markup @ 5%	$0	$0
Total Component Costs	**$5.16**	**$7.74**
Fixed Costs		
Tooling Costs	$30,000	$35,000
Units/yr.	10,000	10,000
Years to recover	8	8
Fixed cost/unit	**$0.54**	**$0.63**
Total Costs ($)	**$5.70**	**$8.37**

The combinations of low-emission technologies ultimately chosen by motorcycle manufacturers are dependent on the engine-out emission levels of the vehicle, the effectiveness of the prior emission control system, and individual manufacturer preferences. We believe manufacturers will increase their use of electronic fuel injection in order to achieve better fuel delivery control. We project that the use of electronic fuel injection will increase to meet the Tier-1 and Tier-2 standards, with an accompanying decline in the use of carburetion. Tables 5.3-2 and 5.4-3 provide estimates of the costs of carburetor systems and electronic fuel injection systems. To project the incremental costs of going to electronic fuel injection we have subtracted the costs of the carburetor systems. We have estimated the incremental costs of electronic fuel control to be in the range of $183 and $191.

Table 5.3-2
Carburetor Costs

Engine Size	600cc	1200cc
Carburetor	$60	$60
Number Required	2	2
Hardware Cost to Manufacturer	**$120**	**$120**
Labor @ $28 per hour	$1	$1
Labor overhead @ 40%	$1	$1
Markup @ 29%	$35	$35
Total Component Costs	**$157**	**$157**

Table 5.3-3
Electronic Fuel Injection Costs

Engine Size	600cc	1200cc
Variable Costs		
Injectors (each)	$12	$15
Number Required	2	2
Pressure Regulator	$10	$10
Intake Manifold	$30	$30
Throttle Body/Position Sensor	$35	$35
Fuel Pump	$20	$20
ECM	$100	$100
Air Intake Temperature Sensor	$5	$5
Manifold Air Pressure Sensor	$10	$10
Injection Timing Sensor	$5	$5
Wiring/Related Hardware	$10	$10
Hardware Cost to Manufacturer	**$249**	**$255**
Labor @ $28 per hour	$4	$4
Labor overhead @ 40%	$2	$2
Markup @ 29%	$72	$74
Warranty Markup @ 5%	$12	$13
Total Component Costs	**$339**	**$348**
Fixed Cost		
Tooling Costs	$10,000	$12,000
Units/yr.	10,000	10,000
Years to recover	8	8
Fixed cost/unit	**$0.18**	**$0.22**
Total Costs ($)	**$340**	**$348**

We are also projecting the increased use of pulse air systems and catalyst systems for both the Tier 1 and Tier 2 standards. We have estimated the cost of both a mechanical and an electronically controlled pulse air system and have projected the use of the electronic system for motorcycles equipped with electronic fuel control systems. We have added a $10 cost to the pulse air valve costs shown in Table 5.3-4 to cover the costs of upgraded materials that may be needed to handle the additional heat created by using secondary air. The total cost for secondary air systems are $22 for mechanical systems and $27 for electronic systems. Catalyst cost and oxygen sensor cost estimates are provided in Tables 5.3-5 through 5.3-7. For catalysts, we expect an increase in use both for Tier 1 and Tier 2. While we do not expect catalysts to be used on all models, they will likely remain a key tool for emissions control. We are also projecting the increased use of oxygen sensors and have tied the increase in their use to the use of catalysts. It seems reasonable to expect manufacturers to use oxygen sensors with catalysts to ensure stoichiometric engine operation to optimize catalyst and engine performance.

Table 5.3-4
Pulse Air Valve Costs

Engine Size	600cc		1200cc	
Pulse Air Valve Type	Mechanical	Electronic	Mechanical	Electronic
Variable Costs				
Pulse Air	$8	$12	$8	$12
Labor @ $28 per hour	$1	$1	$1	$1
Labor overhead @ 40%	$0	$0	$0	$0
Markup @ 29%	$3	$4	$3	$4
Warranty Markup @ 5%	$0	$1	$0	$1
Total Component Costs	**$12**	**$17**	**$12**	**$17**
Fixed Costs				
Tooling Costs	$8,000	$8,000	$10,000	$10,000
Units/yr.	10,000	10,000	10,000	10,000
Years to recover	8	8	8	8
Fixed cost/unit	**$0.14**	**$0.14**	**$0.18**	**$0.18**
Total Costs ($)	**$12**	**$17**	**$12**	**$17**

Table 5.3-5
Catalyst Costs to Manufacturer

Emission Level		
Catalyst Volume (L)	**0.30**	**0.60**
Metallic Substrate	$8.80	$11.60
Washcoat	$0.54	$1.09
Precious Metals	$5.65	$11.30
Can (18 gauge 304 SS)	$1.09	$1.52
TOTAL MAT. COST	**$16.08**	**$25.51**
LABOR	**$11.20**	**$11.20**
Labor Overhead @ 40%	$4.48	$4.48
Supplier Markup @ 29%	$9.21	$11.94
Manufacturer Price	**$40.98**	**$53.13**

Table 5.3-6
Catalyst Costs

Engine Size	600cc	1200cc
Variable Costs		
Oxidation Catalyst	$41	$53
Labor @ $28 per hour	$1	$1
Labor overhead @ 40%	$1	$1
OEM markup @ 29%	$12	$16
Warranty Markup @ 5%	$2	$3
Total Component Costs	**$57**	**$74**
Fixed Costs		
Tooling Costs	$10,000	$10,000
Units/yr.	10,000	10,000
Years to recover	8	8
Fixed cost/unit	**$0.18**	**$0.18**
Total Costs ($)	**$58**	**$74**

Table 5.3-7
Oxygen Sensor Costs

Engine Size	600cc	1200cc
Variable Costs		
Oxygen Sensors	$10	$10
Number Required	2	2
Hardware costs	**$20**	**$20**
Markup @ 29%	$6	$6
Warranty Markup @ 5%	$1	$1
Total Component Costs	**$27**	**$27**
Fixed Costs		
Tooling Costs	$5,000	$5,000
Units/yr.	10,000	10,000
Years to recover	8	8
Fixed cost/unit	**$0.09**	**$0.09**
Total Costs ($)	**$27**	**$27**

5.3.2 - Compliance Costs for Class III Exhaust Emission Control

We estimate highway motorcycle chassis-based certification to cost about $25,000 per engine line, including $10,000 for engineering and clerical work and $15,000 for durability and certification testing. Although carry-over of data from Tier 1 to Tier 2 is likely, we have included certification costs for both Tier 1 and Tier 2. As discussed above in section 5.3.1, each large manufacturer on average has 8 engine lines, for a total per manufacturer cost for certification of $200,000 per manufacturer. As with other fixed costs, we amortized the Tier 2 certification cost over 8 years of engine sales to calculate per unit certification costs shown in Table 5.3-8. Tier 1 certification costs are amortized over 4 years. We are not projecting increased facility costs because manufacturers currently are required to certify and therefore have adequate test facilities. In addition, because California standards are schedule to be implemented two years earlier than the EPA standards would be, we would expect actual average certification costs to be much lower than those estimated here. It is likely that data from the California program would be used by manufacturers for EPA certification. Also, the analysis presents an average certification cost using average numbers of engine lines and average annual sales estimates.

Manufacturers with lower than average annual sales may experience proportionately higher per unit certification costs. For example, if sales were only 10,000 units per year for Tier 1 (the cut-off point for reduced certification burden), certification-related costs would be about still be about $0.80 $1.60 since these manufacturers have only one or two engine families which will incur this cost. If a manufacturer was very small (<3,000 total sales and one engine family) then unit costs could be kept to about $2.00 by spreading Tier 1 costs over more years. As a frame of reference, there are about 40 manufacturers. About 80 percent of these qualify for the reduced certification burden provisions (<10,000 units) and have only one or two families. Most of these (about 60%) are quite small (<3000 units) And only one family and at this point do not have to meet Tier 2 .

Table 5.3-8
Estimated Per Unit Costs

	Tier 1	Tier 2
Cost per Manufacturer	$200,000	$200,000
Years to recover	4	8
total units/year	80,000	80,000
certification costs per unit	$0.79	$0.45

5.3.3 - Total Costs for Class III Exhaust Emission Control

The analysis below combines the costs estimated above into a total composite or average cost per vehicle. The composite analysis weights the costs by projecting the percentage of their use, both in the baseline and control scenario, to project industry-wide average per vehicle costs. Baseline estimates were made based on the sales weighted current usage rate indicated by our certification database. The weighting between the two engine displacement ranges is also based on projected sales information submitted by manufacturers at time of certification. The table below presents the baseline technology usage for the most recent three model years for which we have data (2001, 2002, and 2003). The analysis uses the 2003 as the technology baseline, but the 2001 and 2002 penetration of the various technologies is presented to illustrate the progress that already appears to be underway in implementation of technologies such as engine modifications, fuel injection, and catalyst-based systems. For example, almost half of the larger motorcycles (where most U.S. sales are) are fuel-injected as of the most recent model year, a trend that we expect to continue as manufacturers implement designs intended to meet the upcoming California and European standards, both of which are large motorcycle markets.

For electronic fuel injection, we are attributing half the cost to emissions control and the other half to improved performance. We believe this is appropriate because the technology provides substantial benefits in performance and reliability in addition to improved emissions. Discounting the cost by one-half also helps account for the current trend toward increased use of electronic fuel injection in the absence of more stringent federal emissions standards (i.e., to some degree the trend would have continued anyway).

A summary of the estimated near-term and long-term per unit average incremental costs for highway motorcycles is provided in Tables 5.3-9 and 5.3-10. Long-term costs do not include fixed costs, which are retired, and include cost reductions due to the learning curve. It is important to note that these cost estimates are average costs and are based on both the current state of technology and projections of technology needed to meet standards. Our average cost estimates consider, for example, that almost half of current production is already equipped with fuel injection and about 20 percent of production is equipped with catalysts. To estimate average per unit costs, the costs associated with the increased use of emission control technologies due to the new standards are spread over all units produced. Costs for individual models would be higher or lower than the average depending on the changes manufacturers decide to make for their various models. Models already equipped with fuel injection, pulse air, and a catalyst are likely to have low incremental costs compared to models that are not currently equipped with these technologies. The averaging program for the standards provides manufacturers with flexibility in determining what technologies to use on their various models.

Table 5.3-9. Estimated Average Costs For Motorcycles (Tier 1)

		Cost	Baseline Usage Rate			Tier 1 Control Usage Rate	Incremental Cost
			2001	2002	2003		
600 cc (17%)	R&D	$13	0%	0%	0%	25%	$3
	engine modifications	$6	60%	66%	66%	100%	$2
	electronic fuel injection*	$92	20%	23%	54%	54%	$0
	mechanical pulse air valve	$22	53%	48%	69%	60%	($2)
	electronic pulse air valve	$27	0%	0%	0%	40%	$11
	catalyst	$58	10%	15%	16%	15%	$0
	O_2 sensors	$27	0%	1%	0%	15%	$4
	Compliance	$1	0%	0%	0%	100%	$1
	total	--	--	--		--	$18
1200 cc (83%)	R&D	$13	0%	0%	0%	25%	$3
	engine modifications	$8	54%	53%	53%	100%	$4
	electronic fuel injection*	$96	37%	47%	48%	50%	$2
	mechanical pulse air valve	$22	39%	37%	40%	50%	$2
	electronic pulse air valve	$27	0%	0%	0%	50%	$14
	catalyst	$74	13%	20%	21%	25%	$3
	O_2 sensors	$27	5%	5%	5%	25%	$5
	Compliance	$1	0%	0%	0%	100%	$1
	total	--	--	--		--	$33
Near Term Composite Incremental Cost		--	--	--		--	**$30**
Long Term Composite Incremental Cost		--	--	--		--	**$21**

* The electronic fuel injection costs have been discounted by 50 % to reflect the portion of the cost attributed to emissions control.

Table 5.3-10
Estimated Average Costs For Motorcycles (Tier 2)

		Cost	Tier 1 Usage Rate	Tier 2 Control Usage Rate	Incremental Cost
600 cc (17%)	R&D	$13	25%	100%	$10
	engine modifications	$6	100%	100%	$0
	electronic fuel injection*	$92	54%	60%	$5
	mechanical pulse air valve	$22	60%	40%	($4)
	electronic pulse air valve	$27	40%	60%	$5
	catalyst	$58	16%	50%	$20
	O_2 sensors	$27	15%	50%	$10
	Compliance	$0.45	0%	100%	$0.45
	total				$46
1200 cc (83%)	R&D	$13	25%	100%	$10
	engine modifications	$8	100%	100%	$0
	electronic fuel injection*	$96	50%	60%	$9
	mechanical pulse air valve	$12	50%	40%	($2)
	electronic pulse air valve	$17	50%	60%	$3
	catalyst	$74	25%	50%	$19
	O_2 sensors	$27	25%	50%	$7
	Compliance	$0.45	0%	100%	$0.45
	total				$46
Near Term Composite Incremental Cost		--	--	--	**$46**
Long Term Composite Incremental Cost		--	--	--	**$28**

* The electronic fuel injection costs have been discounted by 50 % to reflect the portion of the cost attributed to emissions control.

5.3.3 - Costs for Small Manufacturers not Subject to Tier 2 Standards

Based on certification records, we identified 18 small Class 3 motorcycle manufacturers that would not have to meet the Tier 2 standards at this time. These manufacturers would also benefit from longer lead time and other small business flexibilities. We believe, based on conversations with manufacturers and an examination of certification data, that these motorcycle manufacturers will take a much different approach to meeting Tier 1 standards than large manufacturers. Several Class 3 models are currently certified near or below the Tier 1 standards (see Chapter 6) with no electronic fuel injection or catalysts. These small manufacturers are expected to be able to meet the Tier 1 standards through engine modifications and calibration changes alone. As indicated by the certification data and the emissions levels, some of the engines have already been modified for emissions control and would likely meet the Tier 1 standard with little or no additional work. Also, it is important to note that several small motorcycle manufacturers purchase engines from engine manufacturers, such as S&S Cycle, who conduct the R&D necessary for their engines to meet the standards. This means that the R&D costs are spread over many more units than a single vehicle manufacturer would sell. These vehicle manufacturers would be expected to continue to purchase such engines, install them in their bikes, and then certify them, as they do now.

We identified that 12 of the 18 small motorcycle manufacturers purchase engines from separate engine manufacturers, such as S&S Cycle. There are 6 small manufacturers that do not identify a separate engine manufacturer and may make their own engines. Of these six manufacturers, only one manufacturer has certification HC levels above 0.7 g/km. This indicates that the small manufacturers will be able to meet the Tier 1 standards with relatively modest additional changes to their motorcycle engines and costs are likely to be minimal given the lead time provided to small companies for optimization. Additional lead-time allows manufacturers to consider emissions standards during the course of improving their products over time. It is also worth noting that these standards apply in California two model years before they apply in the rest of the US. Overall, we do not see a basis for expecting the Tier 1 standards to cause small manufacturers to be significantly adversely affected or to leave the market.

We have conducted a cost analysis for small manufacturers. The results of the analysis are provided in the table below. Taking the approach used for large manufacturers, described above, we have estimated one staff year of development per small manufacturer, $43,750 (one-fourth the large manufacturer cost) for prototype hardware, and $25,000 for certification. These R&D costs are the same as that projected for the large manufacturers for Tier 1. The R&D estimate is conservatively high considering the current state of technology and emissions performance noted above. The estimated tooling and variable costs for engine modifications are from the draft RSD and have not changed for the final RSD. Fixed costs are projected to be recovered over 8 years of average sales of 1,000 units per year. This estimate of average annual sales is based on current sales for small manufacturers. For purposes of estimating R&D costs, engine manufacturers are considered the primary manufacturer rather than the vehicle manufacturer. As shown in the table, small manufacturers may experience higher per unit fixed costs but these are off-set by lower per unit variable costs associated with technology. The overall per unit cost estimate is somewhat higher for small manufacturers for Tier 1 ($50 compared to $30 for large manufacturers) but is less than the estimated large manufacturer costs for Tier 1 and Tier 2 combined.

	Cost per manufacturer	per unit cost
Variable costs	n/a	$8
R&D	$163,750	$31
Tooling	$35,000	$6
Certification	$25,000	$5
total		$50

As described above, the per unit fixed costs estimated in the table are dependent on the sales per year for the manufacturer. As described above, we used average sales of 1,000 units per year in our analysis. Manufacturers with lower annual sales may experience proportionally higher than average per unit fixed costs, while manufacturers with higher than average sales may experience lower than average fixed costs. For example, a manufacturer with annual sales of 200 units would be estimated to have per unit R&D costs of about $150 (assuming also that the manufacturer incurred an overall R&D cost of $163,750), whereas a manufacturer with sales of 3,000 would be estimated to have a per unit R&D cost of about $10. The median annual sales for small manufacturers making their own engines is about 550 units per year. Using this number in the above analysis of costs would result in an R&D estimate of $57 and an overall cost of $84 per unit. However, the R&D costs per unit will also depend on how much work will be involved in meeting the new standards for a particular manufacturer. Several motorcycles currently certified by small volume manufacturers have emissions certification levels that indicate they can meet the standards with little additional work, if any. In these cases, the estimated R&D costs described above would likely be overstated. Also, manufacturers with relatively high emissions engines may choose to switch engines rather than invest in reducing emissions from their current product. By providing additional lead-time, we believe we are giving manufacturers time to seek out the best overall option for their product.

5.4 - Exhaust Emission Control for Highway Motorcycles Under 50cc

We are establishing standards that are in line with standards already established in the countries and regions that represent the major scooter markets in the world, and which produce millions of scooters. The US scooter market is tiny in comparison to these markets. In costing out changes in technology, it is therefore reasonable to project that the research and development and tooling necessary to meet standards will occur in response to the standards in other countries, rather than EPA standards. US standards would ensure that clean scooters developed for major markets also are the ones brought into the US market rather than traditional 2-strokes. It is also reasonable to expect that the fixed costs of research and development and tooling are spread over the worldwide unit sales for those scooters. Therefore, we would expect those costs to be very small on a per unit basis.

To establish cost estimates for under 50 cc motorcycles, we first looked at the detailed cost analysis performed for our Small SI Engine Phase 2 Standards rulemaking, in which the cost for converting from 2-stroke to 4-stroke was estimated to be about $14 per unit for a small engine (about 25 cc). [16] The unit basis for this analysis was 90,000 units. EPA's estimate was supported in comments received from one small SI engine manufacturer that estimated a cost of about $15 for production less than 1 million units and another that estimated a unit cost of about $10.

We also searched available literature and found a report prepared for the World Bank that estimated the difference in cost between a 2-stroke to a 4-stroke 50 cc scooter to be about $60 per unit.[17] We believe the difference in the two cost estimates can be accounted for in the difference in engine displacement and manufacturer mark-up. The $60 estimate appears to be reasonable for a baseline 4-stroke engine. We are assuming that the cost represents a long-term stabilized cost rather than the initial cost of production. To the extent the $60 estimate reflects costs of initial production, the long-term costs may be somewhat lower due to the learning curve effect. Also, to the extent that some manufacturers currently may have initial costs that are somewhat higher than $60, we believe that costs reductions are likely to take place prior to 2006, due to the learning curve effect and a substantial increase in production in response to the world markets. Costs are likely to be stabilized by 2006.

In addition to the cost of the scooter, manufacturers will also incur costs for certification. Our estimate of average certification costs is $1.52 per vehicle based on average U.S. sales per engine family of 4,300 units. We have used the same methodology and costs for certification used for motorcycles above 50 cc (see section 5.2.2.2 - Compliance Costs) because the requirements are the same. We have established average sales per vehicle line using U.S. sales information provided by the Motorcycle Industry Council for motorcycles under 50cc.

The average cost for motorcycles under 50 cc must account for the fact that some scooters are already equipped with 4-stroke engines and that portion of the market is likely to remain 4-stroke prior to 2006. For those, the costs for meeting the standards would essentially be the cost of certification. Based on current our estimated sales split between two and four-strokes in the less than 50 cc market, we are projecting that 4-strokes will account for about 30 percent of sales prior to 2006.[22] Sales weighting the estimated cost for a 2-stroke of $61.52 and the estimated cost for the 4-stroke of $1.52 (for certification) results in an estimated average cost for motorcycles under 50cc of about $44.

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[22] The approximate sales split is based on available information from MIC, discussions with industry, and the number of 4-stroke 50 cc models currently offered in the US by non MIC manufacturers and importers.

Switching from conventional 2-stroke engines to 4-stroke engines results in a fuel economy savings of at least 30 percent. We have estimated a net present value per vehicle lifetime savings of about $8, using the factors provided in the table below.[18]

Table 5.4-1
Estimate Per vehicle Lifetime Fuel Use and Cost

	2-stroke	4-stroke
Annual Miles (miles/year)	650	650
Average Life (years)	6	6
Fuel consumption (miles per gallon)	70	91
Fuel cost ($/gal pre-tax)	$1.10	$1.10
Discounted Lifetime Fuel Consumption	43.45 gallons	36.43 gallons
Discounted Lifetime Fuel Cost	$47.80	$40.07

5.5 - Highway Motorcycle Aggregate Costs

The above analyses developed incremental per vehicle cost estimates for highway motorcycles. Using these per vehicle costs and projections of future annual sales, we have estimated total aggregate annual costs for the highway motorcycle standards. To estimate future sales for Class III motorcycles, we started with 2002 sales of 534,000 units and projected out using a nominal annual growth rate of 1 percent.[19] For motorcycles below 50cc, we estimated 2002 sales of about 30,000 units and also applied a compound growth rate of 1 percent.[20] Aggregate fuel savings for the motorcycles less than 50cc, has also been estimated based on the usage and fraction of the fleet converted to 4-stroke engines.[21] Fuel savings has also been estimated for permeation evaporative emissions control. Note this analysis does not include costs for Class I motorcycles > 50cc or Class II motorcycles as we believe essentially all meet the Tier 1 standard for 2006. For simplicity, we have included the small volume manufacturer motorcycle sales and costs for Tier 2 in this calculation, even though these manufacturers are not now covered by Tier 2 requirements (small volume manufacturers are only about 1.3 percent of Class III sales). Table 5.5-1 presents the results of this analysis. As shown in the table, annual aggregate costs increase from about $18 million in 2006 to about $42 million in 2010 when the program is fully phased in. Costs are projected to then decline somewhat to about $33 million as fixed costs are retired, after which costs are projected to gradually increase over time due to growth in vehicle sales.

Table 5.5-1
Annual Aggregate Costs for Highway Motorcycles

Calendar Year	Total Cost, Excluding Fuel Savings (Millions $)	Fuel Savings (Millions $)
2006	17.9	0.02
2007	18.1	0.07
2008	16.4	0.5
2009	16.5	1.0
2010	41.7	1.5
2011	42.1	2.0
2012	38.4	2.5
2013	38.7	3.0
2014	37.3	3.5
2015	37.6	4.1
2016	37.9	4.6
2017	38.3	5.2
2018	33.3	5.7
2019	33.7	6.3
2020	34.0	6.8
2021	34.4	7.2
2022	34.7	7.5
2023	35.1	7.8
2024	35.5	8.1
2025	35.8	8.3
2026	36.2	8.6
2027	36.6	8.8
2028	37.0	9.0
2029	37.4	9.3
2030	37.7	9.5

Chapter 5 References

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3. For further information on learning curves, see Chapter 5 of the Economic Impact, from Regulatory Impact Analysis - Control of Air Pollution from New Motor Vehicles Emissions Standards and Gasoline Sulfur Control Requirements, EPA420-R-99-023, December 1999. A copy of this document is included in Air Docket A-2000-01, at Document No. II-A-83. The interested reader should also refer to previous final rules for Tier 2 highway vehicles (65 FR 6698, February 10, 2000), marine diesel engines (64 FR 73300, December 29, 1999), nonroad diesel engines (63 FR 56968, October 23, 1998), and highway diesel engines (62 FR 54694, October 21, 1997).

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5. “Information on Costs and Effectiveness of Fluorination Received from Fluoroseal,” Memorandum from Mike Samulski to Docket A-2000-1, March 27, 2002, Docket A-2000-01, Document IV-B-03.

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13. “Use of Plastic Fuel Tanks in Highway Motorcycles,” Memorandum from Roberts French to Docket A-2000-02, June 5, 2003, Docket A-2000-02.

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17. “Air Pollution from Motor Vehicles, Standards and Technology for Controlling Emissions”, Asif Faiz, Christopher S. Weaver, Michael Walsh, The World Bank, Washington DC, November 1996, Docket A-2000-01, Document IV-A-29.

18. “Spreadsheet for Modeling the Emissions Inventories from On-Highway Motorcycles <50cc under the Proposed Rule”, Memorandum from Phil Carlson to Docket A-2000-01, April 12, 2002, Docket A-2000-01, Document IV-B-09.

19. 2002 Sales by engine size provided by Motorcycle Industry Council, Docket A-2000-01, Document IV-A-21.

20. The Motorcycle Industry Council provided 2001 sales estimates for member companies of 17,166 for scooters below 50 cc. We were unable to find statistics for non-MIC companies which make up a sizable share of the market. To attempt to account for sales for these non-MIC companies we asked several companies for their estimate of the overall 50cc scooter market and have based our final sales estimates on the information they provided.

21. “Spreadsheet for Modeling the Emissions Inventories from On-Highway Motorcycles <50cc under the Proposed Rule”, Memorandum from Phil Carlson to Docket A-2000-01, April 12, 2002, Docket A-2000-01, Document IV-B-09.

CHAPTER 6: Emissions Inventory

6.1 - General Methodology

The following chapter presents our analysis of the emission impact of exhaust and permeation standards for highway motorcycles. We first present an overview of the methodology used to generate the emissions inventories, followed by a discussion of the specific information used in generating the permeation and exhaust emission inventories. Emissions from a typical motorcycle are also presented. This analysis does not monetize the emission reductions or health benefits.

6.1.1 - Highway Motorcycle Exhaust Emissions

The modeling of highway motorcycle >50cc emissions is typically done with our MOBILE model. However, the inputs for motorcycles >50cc used in the MOBILE model have not been updated in many years. In developing the proposal for highway motorcycles, we came across new information on current emission levels, revised scrappage estimates, and revised mileage accumulation rates for such vehicles. Because of this new information, we developed a spreadsheet for modeling the effect of the standards for highway motorcycles >50cc that incorporates this new information. In addition, a similar spreadsheet was developed for modeling the effect of the standards for highway motorcycles <50cc (currently unregulated). A copy of both spreadsheets developed for modeling the effect of the standards on highway motorcycles has been placed in the docket for this rulemaking.[1,2]

6.1.2 - Highway Motorcycle Evaporative Emissions

Evaporative emissions refer to hydrocarbons released into the atmosphere when gasoline, or other volatile fuels, evaporate from a vehicle. For this analysis, we model three types of evaporative emissions:

- <u>permeation</u>: These emissions are due to fuel that works its way through the material used in the fuel system. Permeation is most common through plastic fuel tanks and rubber hoses.

- <u>diurnal</u>: These emissions are due to temperature changes throughout the day. As the day gets warmer, the fuel heats up and begins to evaporate.

- <u>refueling</u>: These emissions are the vapors displaced from the fuel tank when fuel is dispensed into the tank.

Because evaporative emissions are dependent on ambient temperatures and fuel properties which vary through the nation and through the year, we divided the nation into six regions and modeled each region individually for each day of the year. The daily temperatures by region are based on a report which summarizes a survey of dispensed fuel and ambient temperatures in the United States.[3] Because of this temperature effect, the evaporative emission calculations were performed using spreadsheet models rather than by using MOBILE. Copies of the spreadsheets developed for modeling marine evaporative emissions are included in the docket.[4] The calculations in these spreadsheets are described below.

6.1.2.1 - Permeation Emissions

For our permeation emissions modeling, we used the emission data presented in Chapter 4 to determine the mass of hydrocarbons permeated through plastic fuel tanks and rubber fuel hoses on motorcycles. There is no permeation through metal fuel tanks. Because permeation is very sensitive to pressure, we used Arrhenius' relationship[5] to adjust the emission factors by temperature:

$$P(T) = P_0 \times EXP(-\alpha / T) \qquad \textbf{(Eq. 6-1)}$$

where:

T = absolute temperature
$P(T)$ = permeation rate at T
P_0 and α are constants

We determined the constants by relating the equation to the known properties of materials used in fuel tanks and hoses (presented in Chapter 4). Based on data presented in Chapter 4, permeation increases by about 80 percent with each 10°C increase in temperature for high density polyethylene (HDPE). We do not have similar data for nitrile rubber used in hoses; however, in general, permeation doubles with every 10°C increase in temperature.[6] In addition, we have data on the effect of temperature on permeation through FKM which is a fluoroelastomer commonly used as a permeation barrier in hoses. This data, presented in Chapter 4, supports using the general relationship, in our modeling, of doubling permeation through hoses for every 10°C increase in temperature.

6.1.2.2 - Diurnal Emissions

For diurnal emission estimates, we used the Wade equations[7,8,9] to calculate grams of hydrocarbons emitted per day per volume of fuel tank capacity. The Wade equations are well established and are used in both the MOBILE and draft NONROAD models with an adjustment based on empirical data. These calculations are a function of vapor space, fuel vapor pressure, and daily temperature variation and are as follows:

$$\text{Vapor space } (ft^3) = ((1.15 - \text{tank fill}) \times \text{tank size}) / 7.841 \qquad \textbf{(Eq. 6-2)}$$

where:

tank fill = fuel in tank/fuel tank capacity[w]
tank size = fuel tank capacity in gallons

$$T_1\ (°F) = (T_{max} - T_{min}) \times 0.922 + Tmin \qquad \textbf{(Eq. 6-3)}$$

where:

T_{max} = maximum diurnal temperature (°F) of the fuel
T_{min} = minimum diurnal temperature (°F) of the fuel

$$V_{100}\ (psi) = 1.0223 \times RVP + [(0.0357\ X\ RVP)/(1\text{-}0.0368 \times RVP)] \qquad \textbf{(Eq. 6-4)}$$

where:

V_{100} = true vapor pressure at 100°F
RVP = Reid Vapor Pressure of the fuel

$$E_{100}\ (\%) = 66.401\text{-}12.718 \times V_{100} + 1.3067 \times (V_{100})^2 - 0.077934 \times (V_{100})^3 + 0.0018407 \times (V_{100})^4 \qquad \textbf{(Eq. 6-5)}$$

$$D_{min}\ (\%) = E_{100} + [(262 / (0.1667 * E_{100} + 560) - 0.0113] \times (100 - T_{min}) \qquad \textbf{(Eq. 6-6a)}$$

$$D_{max}\ (\%) = E_{100} + [(262 / (0.1667 * E_{100} + 560) - 0.113] \times (100 - T_1) \qquad \textbf{(Eq. 6-6b)}$$

where:

$D_{min/max}$ = distillation percent at the max/min temperatures in the fuel tank
E_{100} = percent of fuel evaporated at 100°F from equation 6-5

$$P_I\ (psi) = 14.697 - 0.53089 \times D_{min} + 0.0077215 \times D_{min}^2 - 0.000055631 \times D_{min}^3 + 0.0000001769 \times D_{min}^4 \qquad \textbf{(Eq. 6-7a)}$$

$$P_F\ (psi) = 14.697 - 0.53089 \times D_{max} + 0.0077215 \times D_{max}^2 - 0.000055631 \times D_{max}^3 + 0.0000001769 \times D_{max}^4 \qquad \textbf{(Eq. 6-7b)}$$

$$\text{Density (lb/gal)} = 6.386 - 0.0186 \times RVP \qquad \textbf{(Eq. 6-8)}$$

$$\text{MW (lb/lb mole)} = (73.23 - 1.274 \times RVP) + [0.5 \times (T_{min} + T_1) - 60] \times 0.059 \qquad \textbf{(Eq. 6-9)}$$

$$\text{Diurnal emissions (grams)} = \text{vapor space} \times 454 \times \text{density} \times [520 / (690 - 4 \times MW)] \times 0.5 \times [P_I / (14.7 - P_I) + P_F / (14.7 - P_F)] \times [(14.7 - P_I) / (T_{min} + 460) - (14.7 - P_F) / (T_1 + 460)] \qquad \textbf{(Eq. 6-10)}$$

where:

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[w] We use 50% fill for our calculations.

MW = molecular weight of hydrocarbons from equation 6-9
$P_{I/F}$ = initial and final pressures from equation 6-7

We use these same equations in our modeling of evaporative emissions from on-highway vehicles. EPA uses a correction factor of 0.78 to the Wade model for automotive diurnal emission modeling based on empirical data collected on automobiles.[10] This correction factor seems reasonable based on data we collected on exposed fuel tanks vented through a hose. This test data is presented in Table 6.1.2-1 compared to calculated theoretical results.

Although the testing was performed on fuel tanks that are larger than motorcycle fuel tanks, we believe that it is appropriate to use these correction factors. We do not believe that fuel tank size will significantly affect the results because the diurnal emissions are a function of vapor space and temperature. The test measurements were normalized using fuel capacity, thereby removing the effect of vapor space on the recorded results. If the thermal inertia of the fuel in the larger tanks were to affect the temperature range seen by the fuel during testing, it would have the effect of reducing the measured results. Therefore, using these correction factors for motorcycles would, if anything, underestimate the diurnal emission inventory.

Table 6.1.2-1
Baseline Diurnal Evaporative Emission Results (varied temperature)

Diurnal Temperature	Tank Size [gallons]	Evaporative HC [g/gallon/day]*	Wade HC [g/gallon/day]*	ratio of measured grams to Wade estimate
72-96F	17	1.4	2.3	0.60
72-96F	30	1.5	2.3	0.65
74-91F	30	1.1	1.3	0.85
71-86F	30	0.9	1.0	0.86
77-88F	30	0.7	0.9	0.75

* based on total capacity of the fuel tank in gallons

6.1.2.3 - Refueling Emissions

We used the MOBILE model to estimate the amount of fuel consumed by motorcycles. To estimate refueling emissions, we used an empirical equation to calculate grams of vapor displaced during refueling events. This equation was developed based on testing of 22 highway vehicles under various refueling scenarios and in the emission benefits calculations for our onboard refueling vapor recovery rulemaking for cars and trucks.[11] These calculations are a function of fuel vapor pressure, ambient temperature, and dispensed fuel temperature. The refueling vapor generation equation is as follows:

$$\text{Refueling vapor (g/gal)} = \text{EXP}(-1.2798 - 0.0049 \times (Td - Tt) + 0.0203 \times Td$$

$$+ 0.1315 \times RVP) \qquad \textbf{(Eq. 6-10)}$$

where:

Td = dispensed fuel temperature (°F)
Tt = fuel temperature in tank (°F)
RVP = Reid Vapor Pressure of the fuel (psi)

For the fuel temperature in the tank, we used average ambient temperature for a surrogate for fuel temperature because we did not have data relating fuel tank temperature during refueling events to ambient temperature. We believe that this is a reasonable assumption because exhaust systems are not generally near the fuel tanks in motorcycles; therefore, the fuel temperature is not likely heated significantly during operation. Title 40, Section 80.27 of the Code of Federal Regulations specifies the maximum allowable fuel vapor pressure allowed for each state in the U.S. for each month of the year. We used these limits as an estimate of fuel vapor pressure in our calculations.

6.2 - Effect of Emission Controls by Engine/Vehicle Type

The remainder of this chapter discusses the inventory results for highway motorcycles exhaust and evaporative emissions. Also, this section provides more details inputs and methodologies used for the motorcycle inventory calculations.

6.2.1 - Exhaust Emissions

As noted above, we projected the annual tons of exhaust HC and NOx, from on-highway motorcycles using one spreadsheet for on-highway motorcycles <50cc and a second spreadsheet for on-highway motorcycles >50cc. Both of the spreadsheets are based on the MOBILE model and incorporate new information on current emission levels, updated scrappage rates, and updated mileage accumulation rates for on-highway motorcycles. This section describes inputs to the calculations that are specific to on-highway motorcycles then presents the resulting emissions inventories. These results are for the nation as a whole and include baseline and control inventory projections. It should be noted that the analysis presented below for motorcycles >50cc focuses on Class III motorcycles only. Consistent with the cost analysis presented in Chapter 5, we have not assumed any emission reductions for Class I/Class II motorcycles at or above 50 cc, because most already meet the new standards. (Class I and II motorcycles currently represent only about five percent of sales of motorcycles >50cc.)

6.2.1.1 - Inputs for the Inventory Calculations

Several usage inputs are specific to the calculations for on-highway motorcycles exhaust emissions. These inputs are annual use, average operating life, and population. Based on data received from an industry trade group, we developed annual usage rates (i.e., mileage accumulation rates), and average operating life estimates for on-highway motorcycles.[12,13] The average operating lifetimes were estimated to be 6.0 years for on-highway motorcycles <50cc and 12.5 years for on-highway motorcycles >50cc. Due to limited information on motorcycles

<50cc, an average mileage accumulation rate of 650 miles/year was used for each year of operation (based on survey information provided by the industry trade group). The annual mileage accumulation rates for motorcycles >50cc used in the analysis (based on the results of a motorcycle user survey provided by the industry trade group) are contained in Table 6.2.1-1. The average mileage accumulation rate over the lifetime of a typical motorcycle >50cc is estimated to be 2,907 miles/year.

Table 6.2.1-1
Mileage Accumulation Rates for On-highway Motorcycles >50cc

Age (yrs)	Annual Mileage
1	3,308
2	3,320
3	3,751
4	3,330
5	1,920
6	2,884
7	3,021
8	3,475
9	4,131
10	3,977
11+	2,032

Source: Motorcycle Industry Council User Survey

In order to generate emission inventories for on-highway motorcycles, the spreadsheets developed for this analysis calculate a fleet-average emission factor (in grams per mile) and multiply the result by the total vehicle miles traveled (VMT) estimate for the appropriate portion of the highway motorcycle fleet (i.e., <50cc and >50cc) in a given year. The on-highway motorcycle fleet VMT estimates used for this analysis are summarized in Table 6.2.1-2. The on-highway motorcycle >50cc fleet VMT estimates were developed for our recent rulemaking for model year 2007 and later heavy-duty engines and vehicles standards.[14] The 2001 VMT estimate for on-highway motorcycles <50cc was calculated based on the estimated 2001 population of on-highway motorcycles <50cc multiplied by the average mileage accumulation rate of 650 miles/year. VMT estimates for future year on-highway motorcycles <50cc were grown at the same rate as on-highway motorcycles >50cc.

Table 6.2.1-2
On-Highway Motorcycle Fleet VMT in Specific Calendar Year (Millions of Miles)

Category	*2000*	*2005*	*2010*	*2020*	*2030*
On-Highway Motorcycles <50cc	75	88	102	130	158
On-Highway Motorcycles >50cc	11,469	13,466	15,562	19,885	24,208

The current fleet of on-highway motorcycles <50cc is powered mostly by two-stroke engines. Beginning in 2002, a number of new vehicles (estimated to be about 30% of the new sales) are being powered by four-stroke engines. The baseline (i.e., pre-control) emission factors for two-strokes used in the spreadsheet analysis for on-highway motorcycles <50cc are based primarily on the results of testing uncontrolled two-stroke mopeds.[15] (Because the emission factors for baseline two-stroke mopeds are the average of over one hundred vehicles of different ages, the emission levels are used to represent a fleet average level; no deterioration is added to the average levels cited in the report.) The baseline four-strokes now being introduced are assumed to have emission factors at the levels described below for Tier 1 vehicles. (As noted in Chapter 4, the Tier 1 standards are expected to result in the conversion of two-strokes to four-strokes. We believe that existing four-stroke designs would meet the Tier 1 standards.) The HC and CO emission factors for Tier 1 on-highway motorcycles <50cc are based on the HC and CO standards factoring in the effect of deterioration under certification conditions. The estimated emission factors also assume that manufacturers will include a compliance margin (estimated to be 20 percent) when certifying. (For NOx, where we do not have a mandatory standard, we have assumed that four-strokes emit at the level of uncontrolled small 4-stroke motorcycles taken from a separate report.[16]) The deterioration factors for Tier 1 on-highway motorcycles <50cc are based on the data for the smallest motorcycles used in the MOBILE model. Table 6.2.1.-3 contains the emission factors and deterioration rates for on-highway motorcycles <50cc used in the spreadsheet analysis.

Table 6.2.1-3
Zero-Mile Level Emission Factors and Deterioration Rates for On-Highway Motorcycles <50cc

Control Category	*THC*		*CO*		*NOx*	
	ZML, g/mi	*DR, g/mi/10k mi*	*ZML, g/mi*	*DR, g/mi/10k mi*	*ZML, g/mi*	*DR, g/mi/10k mi*
Baseline (Pre-control) - two-strokes	9.66	0	16.1	0	0.10	0
Baseline (Pre-control) - four-strokes	1.27	1.31	15.5	2.53	0.32	0
Tier 1	1.27	1.31	15.5	2.53	0.32	0

The baseline (i.e., Tier 0) emission factors used in the spreadsheet analysis for on-highway motorcycles >50cc are based on the average certification levels of current (i.e., model year 2003) on-highway motorcycles >50cc. The baseline deterioration rates were taken from the MOBILE5 model. In order to estimate the control HC+NOx zero-mile level emission level for Tier 1 on-highway motorcycles, we took the Tier 1 HC+NOx standard of 2.26 grams per mile (g/mi) and multiplied it by 0.67, which is the ratio of the baseline zero-mile HC level based on certification data compared to the baseline (i.e., Tier 0) HC standard. (We do not currently have a NOx standard for on-highway motorcycles >50cc.) Because we are including an HC+NOx standard for Class III on-highway motorcycles, we have assumed that the Tier 1 HC/NOx split will remain the same as the baseline HC/NOx split. Because we do not currently regulate NOx for on-highway motorcycles >50cc, we based the HC/NOx split on current on-highway motorcycle >50cc certification data from the California Air Resources Board which does have a NOx standard. For the Tier 1 deterioration rates, we applied a factor of 0.67, which is the ratio of the pre-control HC zero-mile level compared to the estimate Tier 1 HC zero-mile level. For Tier 1 on-highway motorcycles >50cc, the NOx deterioration rate was assumed to be zero (i.e., no deterioration in NOx emissions). (The MOBILE model currently estimates no deterioration in NOx emissions for on-highway motorcycles.) To estimate the emission factors and deterioration rates for Tier 2 on-highway motorcycles >50cc, the Tier 1 emission factors and deterioration rates were multiplied by a factor of 0.57, which is the ratio of the Tier 1 to Tier 2 HC+NOx standards. Table 6.2.1-4 presents the emission factors and deterioration rates used in the spreadsheet analysis for on-highway motorcycles >50cc. (Because we are not changing the CO standard for on-highway motorcycles >50cc, the CO emission factors and deterioration rates are the same for baseline and control cases.)

Table 6.2.1-4
Zero-Mile Level Emission Factors and Deterioration Rates
for On-Highway Motorcycles >50cc

Control Category	*THC*		*CO*		*NOx*	
	ZML, g/mi	*DR, g/mi/10k mi*	*ZML, g/mi*	*DR, g/mi/10k mi*	*ZML, g/mi*	*DR, g/mi/10k mi*
Baseline (Tier 0)	1.42	0.70	17.4	2.46	0.70	0
Tier 1	1.01	0.50	17.4	2.46	0.52	0
Tier 2	0.57	0.28	17.4	2.46	0.30	0

The Tier 1 standards for on-highway motorcycles are scheduled to take effect in 2006. The Tier 2 standards for on-highway motorcycles >50cc are scheduled to take effect in 2010. (The Tier 2 standards apply only to Class III motorcycles. Class I and II motorcycles have Tier 1 standards only that are different than the standard presented for Class III. As noted earlier, we have not assumed any emission reductions for Class I/Class II motorcycles at or above 50 cc, because most already meet the new standards.)

Another piece of information needed to develop the fleet average gram per mile emission factors is information on the scrappage/survival rates of on-highway motorcycles. For our spreadsheet analyses, we used scrappage/survival rate information provided in an industry trade group survey.[17,18] Table 6.2.1-5 presents the scrappage/survival rate information used in the spreadsheet models for on-highway motorcycles.

Table 6.2.1-5
Scrappage/Survival Rates for On-highway Motorcycles

Age	Fraction Surviving		Age	Fraction Surviving	
	<50cc	>50cc		<50cc	>50cc
1	0.94	0.99	14	-	0.40
2	0.88	0.97	15	-	0.34
3	0.79	0.96	16	-	0.29
4	0.71	0.94	17	-	0.25
5	0.60	0.91	18	-	0.18
6	0.50	0.88	19	-	0.12
7	0.36	0.82	20	-	0.09
8	0.28	0.75	21	-	0.06
9	0.23	0.71	22	-	0.04
10	0.13	0.66	23	-	0.03
11	0.08	0.60	24	-	0.01
12	0.05	0.55	25	-	0
13	-	0.45	-	-	-

Source: Motorcycle Industry Council

One final adjustment included in the spreadsheets, is an adjustment to account for temperature effects on emissions. In order to account for these impacts, the MOBILE5 model was run at ambient temperature conditions of 75°F and at typical summertime temperature ambient conditions. The MOBILE5 outputs (in grams per mile) were compared for the two runs. The results showed that HC emissions decreased by 1 percent under summertime conditions and NOx emissions decreased by approximately 8 percent. These adjustments were applied to the emission factors in the spreadsheets.

6.2.1.2 - Reductions Due to the Standards

We anticipate that the exhaust standards for on-highway motorcycles will result in a 50 percent reduction in both exhaust HC and NOx inventories by the year 2020. Tables 6.2.1-6 and 6.2.1.-7 present our projected exhaust HC and NOx emission inventories for on-highway motorcycles (combining both <50cc and >50cc vehicles) and the anticipated emission reductions from the standards.

Table 6.2.1-6
Projected Exhaust HC Inventories and Reductions for On-Highway Motorcycles
(short tons)

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	34,000	34,000	0	0%
2005	39,000	39,000	0	0%
2010	45,000	41,000	4,000	10%
2020	58,000	28,000	29,000	51%
2030	70,000	28,000	43,000	60%

Table 6.2.1-7
Projected Exhaust NOx Inventories and Reductions for On-Highway Motorcycles
(short tons)

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	8,000	8,000	0	0%
2005	10,000	10,000	0	0%
2010	11,000	10,000	1,000	12%
2020	14,000	7,000	7,000	50%
2030	17,000	7,000	10,000	57%

6.2.1.3 - Per Equipment Emissions from On-highway Motorcycles

The following section describes the development of the emission estimates on a per piece of equipment basis over the average lifetime of a typical on-highway motorcycle. The emission estimates were developed to estimate the cost per ton of the standards as presented in Chapter 7.

In order to estimate the emissions from an on-highway motorcycle, information on the emission level of the vehicle, the annual usage rate of the vehicle, and the lifetime of the vehicle are needed. The values used to predict the per piece of equipment emissions for this analysis and the methodology for determining the values are described below.

The information necessary to calculate the emission levels of a piece of equipment over the lifetime of a typical on-highway motorcycle were presented in Table 6.2.1-3 and Table 6.2.1-4. A brand new on-highway motorcycle emits at the zero-mile level presented in the tables. As the on-highway motorcycle ages, the emission levels increase based on the pollutant-specific deterioration rate. Deterioration continues throughout the lifetime of the vehicle and the amount of deterioration is directly proportional to the number of miles accumulated on the on-highway motorcycle.

As described earlier in this section, the annual usage rate for an on-highway motorcycle <50cc is estimated to be 650 miles per year and the average lifetime is estimated to be 6.0 years. For on-highway motorcycles >50cc, the annual usage rate is estimated to be 2,907 miles per year and the average lifetime is estimated to be 12.5 years.

Using the information described above, we calculated the lifetime HC or HC+NOx emissions from typical on-highway motorcycles for both current (i.e., pre-control for <50cc and Tier 0 for >50cc) vehicles and vehicles meeting the standards. Table 6.2.1-8 presents the lifetime HC or HC+NOx emissions for typical on-highway motorcycles on both an undiscounted and discounted basis (using a discount rate of 7 percent). Table 6.2.1-9 presents the corresponding lifetime HC or HC+NOx emission reductions for the standards. HC estimates are shown for on-highway motorcycles <50cc because we are not including a NOx standard. HC+NOx estimates are shown for on-highway motorcycles >50cc because we are using a combined HC+NOx standard. (As noted earlier, the analysis for >50cc motorcycles is based on a Class III motorcycle. We are not projecting any emission reductions from the standards for Class I/Class II motorcycles >50 cc, because most already meet the new standards.)

Table 6.2.1-8
Lifetime Emissions from a Typical On-highway motorcycle (short tons)

Control Level	<50cc Motorcycles		>50cc Motorcycles	
	Exhaust HC		Exhaust HC+NOx	
	Undiscounted	Discounted	Undiscounted	Discounted
Current (Pre-control for <50cc)	0.031	0.026	-	-
Current (Tier 0 for >50cc)	-	-	0.141	0.093
Tier 1	0.007	0.006	0.100	0.066
Tier 2	-	-	0.057	0.038

Table 6.2.1-9
Lifetime Emission Reductions from a Typical On-highway motorcycle (short tons)

Control Increment	<50cc Motorcycles		>50cc Motorcycles	
	Exhaust HC		Exhaust HC+NOx	
	Undiscounted	Discounted	Undiscounted	Discounted
Current (Pre-control) to Tier 1	0.024	0.020	-	-
Current (Tier 0) to Tier 1	-	-	0.041	0.027
Tier 1 to Tier 2	-	-	0.043	0.029

6.2.2 - Evaporative Emissions

We projected the annual tons of hydrocarbons evaporated into the atmosphere from motorcycles using the methodology discussed above in Section 6.1.2. These evaporative emissions include permeation, diurnal, and refueling emissions. Although the standards do not specifically require the control of diurnal and refueling emissions, we model them here for comparison. This section presents our baseline and controlled national inventory projections for evaporative emissions.

6.2.2.1 - Inputs for the Inventory Calculations

Several usage inputs are needed to calculate evaporative emissions from motorcycles. These inputs are fuel tank sizes, population, and distribution throughout the nation. We used an average fuel tank size of 5 gallons and average hose length of 1.5 feet for motorcycles. We assumed that the national fuel tank distribution would be a function of the engine distribution. We estimate that about 10% of motorcycle fuel tanks are plastic, while the remaining fuel tanks are metal.[19] Table 6.2.2-1 presents the vehicle distribution by region based on statistics collected by the Motorcycle Industry Council.[20] The total population for 1998 was estimated to be about 5.4 million on-highway motorcycles.

Table 6.2.2-1
Motorcycle Population Distribution by Region

Region	*Population*	*Fraction of Total*
Northeast	2,413,600	45%
Southeast	952,800	18%
Southwest	486,100	9%
Midwest	527,400	10%
West	767,100	14%
Northwest	227,000	4%
Total	5,374,000	100%

6.2.2.2 Permeation Emissions Inventory and Reductions

Based on the data presented in Chapter 4, we developed the emission factors presented in Table 6.2.2-2. For the purposes of this modeling, fuel tank permeation rates are expressed in terms of g/gallon/day because the defining characteristic of the fuel tanks in our model is tank fuel capacity. The standard requires that the fuel tanks meet an 85 percent reduction in permeation throughout its useful life. For this modeling, we assume that manufacturers will strive to achieve a 95 percent reductions from new tanks and that 85 percent in-use control will be achieved over the the life of an average tank. Hose permeation rates are based on g/m^2/day. We believe that hoses designed to meet the 15 g/m^2/day standard on 10 percent ethanol fuel will permeate at least 50 percent less when gasoline is used. Therefore, we model permeation from this hose to be about half of the permeation from fuel hose designed to meet 15 g/m^2/day on gasoline.[x] To show the effect of temperature on permeation rates, we present emission rates at three temperatures.

Table 6.2.2-2
Fuel Tank and Hose Permeation Emission Factors

Material	23°C (73°F)	29°C (85°F)	40°C (104°F)
Polyethylene fuel tanks	0.78 g/gal/day	1.12 g/gal/day	2.08 g/gal/day
New barrier treated HDPE fuel tank	0.04 g/gal/day	0.06 g/gal/day	0.10 g/gal/day
Aged barrier treated HDPE fuel tank	0.11 g/gal/day	0.17 g/gal/day	0.31 g/gal/day
Metal fuel tanks	0 g/gal/day	0 g/gal/day	0 g/gal/day
SAE R7 fuel hose	550 g/m^2/day	873 g/m^2/day	1800 g/m^2/day
SAE R9 barrier fuel hose	15 g/m^2/day	24 g/m^2/day	49 g/m^2/day
Alcohol resistant barrier fuel hose	7.5 g/m^2/day	12 g/m^2/day	25 g/m^2/day

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[x] This is appropriate because the baseline emissions are modeled based on the use of gasoline as a fuel. If we were to consider that a fraction of the fuel contains oxygenates, both the baseline and control emission inventory projections would increase.

Using the population and temperature distributions discussed above, we calculated baseline and controlled permeation emission inventories for motorcycles. Tables 6.2.2-3 and 6.2.2-4 present our projected permeation reductions from fuel tanks and hoses.

Table 6.2.2-3
Projected Fuel Tank Permeation Emissions from Motorcycles [short tons]

Vehicle	Baseline	Controlled	Reduction
2005	711	711	0
2010	822	649	173
2015	936	445	491
2020	1,051	231	820
2030	1,279	137	1,142

Table 6.2.2-4
Projected Fuel Hose Permeation Emissions from Motorcycles [short tons]

Vehicle	Baseline	Controlled	Reduction
2005	13,526	13,526	0
2010	15,631	12,183	3,448
2015	17,802	7,812	9,989
2020	19,973	2,950	17,023
2030	24,315	422	23,893

6.2.2.3 Per Motorcycle Permeation Emissions

In developing the cost per ton estimates in Chapter 7, we need to know the lifetime emissions per motorcycle. We determine annual per motorcycle evaporative emissions by dividing the total annual evaporative emissions by the motorcycle population. Per motorcycle emission reductions are based on the modeling described above. Table 6.2.2-5 presents these results with and without the consideration of a 7 percent per year discount on the value of emission reductions. The figures presented here weight the fuel tank emissions between motorcycles with metal (90%) and with plastic tanks (10%). If only motorcycles with plastic fuel tanks were considered, the per motorcycle tank permeation would be ten times higher than presented below.

Table 6.2.2-5
Typical Lifetime Permeation Emissions Per Motorcycle (short tons)

	Baseline		Control		Reduction	
	Undiscounted	Discounted	Undiscounted	Discounted	Undiscounted	Discounted
Tank*	0.0013	0.0009	0.0001	0.0001	0.0012	0.0008
Hose	0.0249	0.0174	0.0003	0.0002	0.0246	0.0172
Total	0.0262	0.0183	0.0005	0.0003	0.0258	0.0180

* Would be ten times higher if only motorcycles with plastic tanks were considered.

6.2.2.4 Other Evaporative Emissions

We calculated diurnal and refueling vapor loss emissions using the general inputs in section 6.2.2.1 and the methodology described in sections 6.1.2.2 and 6.2.1.3. Although we are not regulating these emissions, we present the inventory projections for comparison. Table 6.2.2-6 presents the baseline diurnal emission factors for the certification test conditions and a typical summer day with low vapor pressure fuel and a fill level of 50%. (This comparison is for illustrative purposes; as discussed above, we modeled daily temperature for 365 days over 6 regions of the U.S.) Decreasing temperature and fuel RVP and increasing fill level all have the effect of reducing the diurnal emission factor. Table 6.2.2-7 presents our diurnal emission projections.

Table 6.2.2-6
Diurnal Emission Factors for Test Conditions and Typical Summer Day

Evaporative Control	72-96°F, 9 RVP* Fuel, 40% fill	60-84°F, 8 RVP* Fuel, 50% fill
baseline	1.6 g/gallon/day	0.65 g/gallon/day

* Reid Vapor Pressure

Table 6.2.2-7
Projected Diurnal Emissions from Motorcycles

Calendar Year	HC [Short Tons]
2000	5,332
2005	6,248
2010	7,221
2020	9,227
2030	11,233

To calculate the refueling vapor displacement emissions from motorcycles, we needed to know the amount of fuel added to the fuel tank per year. Therefore, we used the VMT estimates in 6.2.1-2 coupled with a fuel consumption rate of 50 miles per gallon to determine the amount of fuel consumed by motorcycles. We then used the amount of fuel consumed as the amount of fuel added to the tank. Table 6.2.2-8 contains the estimated refueling emission inventories for motorcycles.

Table 6.2.2-8
Projected Refueling Emissions from Motorcycles

Calendar Year	HC [Short Tons]
2000	1,036
2005	1,216
2010	1,406
2020	1,601
2030	2,186

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CHAPTER 7 Cost Per Ton

7.1 - Cost Per Ton for Exhaust and Permeation Control

7.1.1 - Introduction

This chapter presents our estimate of the cost per ton of control for the emission standards contained in this program. The analysis relies on the costs estimates presented in Chapter 5 and the estimated lifetime emissions reductions using the information presented in Chapter 6. Cost per ton estimates are presented for motorcycles less than 50 cc and for Class 3 motorcycles. We noted in Chapters 5 and 6, we are not expecting significant costs or emissions reductions for Class 1 and 2 motorcycles above 50cc from the new exhaust standards. Therefore, we have not calculated cost per ton estimates for these classes for the exhaust standards. The chapter also presents a summary of the cost per ton values of other recent EPA mobile source rulemakings for comparison purposes. Finally, this chapter presents the estimated costs and emission reductions as incurred over the first twenty years after the standards are implemented.

In calculating net present values that were used in our cost-per-ton estimates, we used a discount rate of 7 percent, consistent with the 7 percent rate reflected in the cost-per-ton analyses for other recent mobile source programs. OMB Circular A-94 requires us to generate benefit and cost estimates reflecting a 7 percent rate. Using the 7 percent rate allows us to make direct comparisons of cost-per-ton estimates with estimates for other, recently adopted, mobile source programs.

However, we consider that the cost and cost-per-ton estimates for future proposed mobile source programs could reflect a 3 percent rate. The 3 percent rate is in the 2 to 3 percent range recommended by the Science Advisory Board's Environmental Economics Advisory Committee for use in EPA social benefit-cost analyses, a recommendation incorporated in EPA's new *Guidelines for Preparing Economic Analyses (November 2000)*. Therefore, we have also calculated the overall cost-effectiveness of today's rule based on a 3 percent rate to facilitate comparison of the cost-per-ton of this rule with future proposed rules which might use the 3 percent rate. The results using both a 3 percent and 7 percent discount rate are provided in this Chapter.

7.1.2 - Permeation Evaporative Emission Control for Motorcycles

This section provides our estimate of the cost per ton of evaporative emissions reduced from motorcycles. The analysis relies on the per motorcycle costs estimated in Chapter 5 and the estimated lifetime emissions reductions (tons) presented in Chapter 6. All costs and emission reductions are discounted to the year of sale of the motorcycles at a rate of 7 percent. Table 7.1.2-1 presents the cost per ton with and without consideration of the significant fuel savings that will result from evaporative emission control assuming a 7 percent discount rate. The cost per ton results assuming a 3 percent discount rate are presented in Table 7.1.2-2. As shown in these tables, the fuel savings more than offset the cost of this evaporative emission control technology.

Table 7.1.2.-1
Estimated Cost Per Ton of Evaporative HC Reduced
(7 percent discount rate)

	Average Cost Per Motor-cycle	Lifetime Fuel Savings Per Motorcycle (NPV)	Lifetime Reductions Per MC (NPV tons)	Discounted Per MC Cost Per Ton without Fuel Savings ($/ton)	Discounted Per MC Cost Per Ton with Fuel Savings ($/ton)
tank permeation	$0.17*	$0.30	0.001	$205	($158)
hose permeation	$1.68	$6.23	0.017	$98	($265)
aggregate	$1.85	$6.52	0.018	$103	($260)

* $1.68 for plastic fuel tanks (10% of sales) and $0 for metal fuel tanks (90% of sales)

Table 7.1.2.-2
Estimated Cost Per Ton of Evaporative HC Reduced
(3 percent discount rate)

	Average Cost Per Motor-cycle	Lifetime Fuel Savings Per Motorcycle (NPV)	Lifetime Reductions Per MC (NPV tons)	Discounted Per MC Cost Per Ton without Fuel Savings ($/ton)	Discounted Per MC Cost Per Ton with Fuel Savings ($/ton)
tank permeation	$0.17*	$0.36	0.001	$169	($194)
hose permeation	$1.68	$7.57	0.021	$80	($238)
aggregate	$1.85	$7.93	0.022	$84	($279)

* $1.68 for plastic fuel tanks and $0 for metal fuel tanks

7.1.3 - Exhaust Emission Control for Motorcycles

This section provides our estimate of the cost per ton of emissions reduced for on-highway motorcycles. For on-highway motorcycles <50 cc, we have calculated cost per ton on the basis of HC only because we are only finalizing an HC standard. For Class 3 on-highway motorcycles, we have calculated cost per ton on the basis of HC plus NOx because we are finalizing HC plus NOx standards. The analysis relies on the per vehicle costs estimated in Chapter 5 and the estimated net present value of the per vehicle lifetime emissions reductions (tons) presented in Chapter 6.

Table 7.1.3.-1 presents the cost per ton estimates for the standards for on-highway motorcycles <50cc. As described in Chapter 5, we expect a decrease in operating costs (i.e., decreased fuel costs) as manufacturers convert from 2-stroke to 4-stroke designs to meet the

standards. Therefore, Table 7.1.3-1 presents cost per ton estimates both without and with the fuel savings included for both a 7 percent and 3 percent discount rate.

Table 7.1.3.-1
Estimated On-Highway Motorcycle <50cc Cost Per Ton of HC Reduced

Discount Rate	Cost per Vehicle (NPV)	Lifetime Fuel Savings (NPV)	Lifetime Reductions (NPV, tons)	Discounted Per Vehicle Cost Per Ton without Fuel Savings ($/ton)	Discounted Per Vehicle Cost Per Ton with Fuel Savings ($/ton)
7%	$43.50	$7.70	0.020	$2,130	$1,750
3%	$43.50	$8.50	0.022	$1,950	$1,570

As described in Chapter 5, the estimated per vehicle costs for on-highway motorcycles >50cc change over time, with reduced costs in the long term. We have estimated both a near-term and long-term cost per ton for both the Tier 1 and Tier 2 standards, with the Tier 2 estimates incremental to Tier 1. The results of the analysis are presented in Table 7.1.3.-2 assuming a 7 percent discount rate. The cost per ton results assuming a 3 percent discount rate as presented in Table 7.1.3.-3.

Table 7.1.3.-2
Estimated Class 3 On-Highway Motorcycle Cost Per Ton of HC+NOx Reduced
(7 percent discount rate)

Standard	Cost per Vehicle (NPV)	Lifetime Reductions (NPV tons)	Discounted Per Vehicle Cost Per Ton ($/ton)
Tier 1 - Near-term	$30	0.026	$1,150
Tier 1 - Long-term	$21		$800
Tier 2 - Near-term	$45	0.029	$1,550
Tier 2 - Long-term	$28		$960

Table 7.1.3.-3
Estimated Class 3 On-Highway Motorcycle Cost Per Ton of HC+NOx Reduced
(3 percent discount rate)

Standard	Cost per Vehicle (NPV)	Lifetime Reductions (NPV tons)	Discounted Per Vehicle Cost Per Ton ($/ton)
Tier 1 - Near-term	$30	0.033	$920
Tier 1 - Long-term	$21		$640
Tier 2 - Near-term	$45	0.036	$1,240
Tier 2 - Long-term	$28		$770

7.2 - Cost Per Ton for Other Mobile Source Control Programs

Because the primary purpose of cost-effectiveness is to compare our program to alternative programs, we made a comparison between the cost per ton values presented in this chapter and the cost-effectiveness of other programs. Table 7.2-1 summarizes the cost effectiveness (with a 7 percent discount rate) of several recent EPA actions for controlled emissions from mobile sources.

Table 7.2-1
Cost-effectiveness of Previously Implemented
Mobile Source Programs (Costs Adjusted to 2001 Dollars)[1]

Program	*$/ton*
Tier 2 vehicle/gasoline sulfur	1,437 - 2,423
2007 Highway HD diesel	1,563-2,002
2004 Highway HD diesel	227 - 444
Off-highway diesel engine	456 - 724
Tier 1 vehicle	2,202 - 2,993
NLEV	2,069
Marine SI engines	1,255 - 1,979
On-board diagnostics	2,480
Marine CI engines	26 - 189

By comparing the cost per ton values presented in earlier in this chapter to those in Table 7.2-1, we can see that the cost effectiveness of the standards for this rulemaking are in or below the range of these other programs. It is true that some previous programs have been more cost efficient than the motorcycle program. However, it should be expected that the next generation of standards will be more expensive than the last, because the least costly means for reducing emissions is generally pursued first.

The primary advantage of making comparisons to previously implemented programs is that their cost-effectiveness values were based on a rigorous analysis and are generally accepted as representative of the efficiency with which those programs reduce emissions. Unfortunately, previously implemented programs can be poor comparisons because they may not be representative of the cost-effectiveness of potential future programs. Therefore, in evaluating the cost-effectiveness of our program, we also considered whether our proposal is cost-effective in comparison with potential future means of controlling emissions. In the context of the Agency's rulemaking which would have revised the ozone and PM NAAQS, the Agency compiled a list of additional known technologies that could be considered in devising new emission reductions strategies.[2] Through this broad review, over 50 technologies were identified that could reduce NOx, VOC, or PM. The cost-effectiveness of these technologies averaged approximately $5,000/ton for VOC, $13,000/ton for NOx, and $40,000/ton for PM. Although a $10,000/ton limit was actually used in the air quality analysis presented in the NAAQS revisions rule, these values clearly indicate that, not only are future emission control strategies likely to be more expensive (less cost-effective) than past strategies, but the cost-effectiveness of our program falls within the range of potential future strategies.

In summary, given the array of controls that will have to be implemented to make progress toward attaining and maintaining the NAAQS, we believe that the weight of the evidence from alternative means of providing substantial NOx + HC emission reductions indicates that our program is cost-effective. This is true from the perspective of other mobile source control programs or from the perspective of other stationary source technologies that might be considered.

7.3 - 20-Year Cost and Benefit Analysis

The following section presents the year-by-year cost and emission benefits associated with the standards for the 20-year period after implementation of the standards.

Table 7.3-1 presents the year-by-year cost and emission benefits for the permeatiom controls. (The numbers presented in Table 7.3-1 are <u>not</u> discounted.) For the permeation standards, where we expect a reduction in fuel consumption due to the standards, the fuel savings are presented separately. The overall cost, incorporating the impact of the fuel savings is also presented.

Table 7.3-1
Cost and Emission Benefits of the Permeation Emission Requirements

Year	HC+NOx* Benefits (tons)	Cost w/o Fuel Savings	Fuel Savings	Cost w/ Fuel Savings
2008	1,154	$1,102,991	$418,932	$684,059
2009	2,362	$1,132,327	$857,231	$275,096
2010	3,621	$1,161,664	$1,314,526	($152,862)
2011	4,918	$1,191,911	$1,785,089	($593,178)
2012	6,259	$1,222,158	$2,271,922	($1,049,764)
2013	7,637	$1,252,404	$2,772,072	($1,519,668)
2014	9,049	$1,282,651	$3,284,794	($2,002,143)
2015	10,480	$1,312,897	$3,804,321	($2,491,424)
2016	11,956	$1,270,569	$4,339,891	($3,069,322)
2017	13,431	$1,300,830	$4,875,284	($3,574,454)
2018	14,916	$1,331,090	$5,414,423	($4,083,333)
2019	16,408	$1,361,351	$5,956,206	($4,594,855)
2020	17,843	$1,391,611	$6,477,017	($5,085,406)
2021	19,023	$1,421,872	$6,905,439	($5,483,567)
2022	19,833	$1,452,133	$7,199,253	($5,747,120)
2023	20,593	$1,482,393	$7,475,201	($5,992,808)
2024	21,333	$1,512,654	$7,744,052	($6,231,398)
2025	22,018	$1,542,915	$7,992,590	($6,449,675)
2026	22,695	$1,573,161	$8,238,364	($6,665,203)
2027	23,328	$1,603,408	$8,468,105	($6,864,697)

* - Permeation benefits are HC only.

Table 7.3-2 presents the sum of the costs and emission benefits over the twenty year period after the permeation requirements will take effect, on both a non-discounted basis and a discounted basis (assuming a seven percent discount rate). The annualized cost and emission benefits for the twenty-year period (assuming the seven percent discount rate) are also presented.

Table 7.3-2
Annualized Cost and Emission Benefits for the Period 2008-2027 due to the Permeation Standards

	Evaporative HC Benefits (short tons)	Cost w/o Fuel Savings (Million $)	Fuel Savings (Million $)	Cost w/ Fuel Savings (Million $)
Undiscounted 20-year Value	269,000	$26.9	$97.6	($70.7)
Discounted 20-year Value	121,000	$14.6	$44.0	($29.4)
Annualized Value	11,400	$1.4	$4.2	($2.8)

Table 7.3.-3 presents the year-by-year cost and emission benefits for the on-highway motorcycle exhaust requirements. (The numbers presented in Table 7.3-3 are not discounted and include the benefits and savings for all on-highway motorcycles, including those <50cc and those >50cc.)

Table 7.3-3
Cost and Emission Benefits of the On-Highway Motorcycle Exhaust Emission Standards

Year	HC+NOx Benefits (tons)	Cost w/o Fuel Savings	Fuel Savings	Cost w/ Fuel Savings
2006	495	$17,910,738	$24,176	$17,886,562
2007	1,593	$18,068,493	$67,997	$18,000,496
2008	2,990	$15,276,796	$106,724	$15,170,073
2009	4,384	$15,408,213	$141,465	$15,266,747
2010	5,869	$40,574,886	$171,344	$40,403,541
2011	8,483	$40,910,636	$197,498	$40,713,138
2012	11,549	$37,134,822	$217,751	$36,917,071
2013	14,805	$37,436,171	$235,520	$37,200,652
2014	17,834	$36,027,234	$251,815	$35,775,419
2015	21,378	$36,334,641	$263,984	$36,070,656
2016	24,222	$36,645,121	$274,101	$36,371,020
2017	27,290	$36,958,706	$282,971	$36,675,735
2018	30,671	$31,988,827	$289,553	$31,699,275
2019	33,982	$32,308,715	$296,134	$32,012,582
2020	36,243	$32,631,803	$302,715	$32,329,088
2021	38,430	$32,958,121	$309,296	$32,648,825
2022	40,454	$33,287,702	$315,877	$32,971,825
2023	42,331	$33,620,579	$322,458	$33,298,121
2024	44,043	$33,956,785	$329,039	$33,627,746
2025	45,646	$34,296,353	$335,620	$33,960,733

Table 7.3-4 presents the sum of the costs and emission benefits over the twenty year period after the exhaust requirements for on-highway motorcycles take effect, on both a non-discounted basis and a discounted basis (assuming a seven percent discount rate). The annualized cost and emission benefits for the twenty-year period (assuming the seven percent discount rate) are also presented.

Table 7.3-4
Annualized Cost and Emission Benefits for the Period 2006-2025 due to the On-Highway Motorcycle Exhaust Emission Standards

	HC+NOx Benefits (short tons)	Cost w/o Fuel Savings (Million $)	Fuel Savings (Million $)	Cost w/ Fuel Savings (Million $)
Undiscounted 20-year Value	453,000	$633.4.	$4.7	$629.0
Discounted 20-year Value	191,000	$339.5	$2.3	$337.2
Annualized Value	18,100	$32.0	$0.2	$31.8

Table 7.3-5 presents the aggregate year-by-year cost and emission benefits for the combination of the permeation and exhaust emission standards. (The numbers presented in Table 7.3-5 are not discounted.)

Table 7.3-5
Cost and Emission Benefits of the Requirements for the Permeation and Exhaust Emission Standards

Year	HC+NOx Benefits (tons)	Cost w/o Fuel Savings	Fuel Savings	Cost w/ Fuel Savings
2006	495	$17,910,738	$24,176	$17,886,562
2007	1,593	$18,068,493	$67,997	$18,000,496
2008	4,144	$16,379,787	$525,656	$15,854,131
2009	6,746	$16,540,540	$998,696	$15,541,844
2010	9,490	$41,736,550	$1,485,871	$40,250,679
2011	13,401	$42,102,547	$1,982,587	$40,119,960
2012	17,808	$38,356,980	$2,489,673	$35,867,307
2013	22,442	$38,688,575	$3,007,591	$35,680,984
2014	26,883	$37,309,885	$3,536,610	$33,773,276
2015	31,858	$37,647,538	$4,068,305	$33,579,232
2016	36,178	$37,915,690	$4,613,993	$33,301,697
2017	40,721	$38,259,536	$5,158,256	$33,101,280
2018	45,587	$33,319,917	$5,703,976	$27,615,942
2019	50,390	$33,670,066	$6,252,340	$27,417,727
2020	54,086	$34,023,414	$6,779,732	$27,243,682
2021	57,453	$34,379,993	$7,214,735	$27,165,257
2022	60,287	$34,739,835	$7,515,130	$27,224,705
2023	62,924	$35,102,972	$7,797,659	$27,305,313
2024	65,376	$35,469,439	$8,073,091	$27,396,347
2025	67,664	$35,839,268	$8,328,210	$27,511,057
2026	69,843	$36,212,477	$8,580,565	$27,631,912
2027	71,825	$36,589,117	$8,816,887	$27,772,230

Table 7.3-6 presents the sum of the costs and emission benefits over the twenty-two year period after all of the requirements take effect, on both a non-discounted basis and a discounted basis (assuming a seven percent discount rate). The annualized cost and emission benefits for the twenty-two year period (assuming the seven percent discount rate) are also presented. (A twenty-two period is used in this aggregate analysis to cover the first twenty years of each of standards which begins in 2006 for exhaust emissions and concludes in 2008 for the permeation requirements.)

Table 7.3-6
Annualized Cost and Emission Benefits for the Period 2006-2027 due to the Exhaust and Permeation Standards

	HC+NOx Benefits (short tons)	Cost w/o Fuel Savings (Million $)	Fuel Savings (Million $)	Cost w/ Fuel Savings (Million $)
Undiscounted 22-year Value	817,000	$730.3	$103.0	$627.2
Discounted 22-year Value	321,000	$369.7	$40.9	$328.7
Annualized Value	29,000	$33.4	$3.7	$29.7

Chapter 7 References

1. Gross Domestic Product Implicit Price Deflator, U.S. Department of Commerce, Bureau of Economic Analysis, http://www.stls.frb.org/fred/data/gdp/gdpdef, April 12, 2002, Docket A-2000-01, Document IV-A-31.

2. "Regulatory Impact Analyses for the Particulate Matter and Ozone National Ambient Air Quality Standards and Regional Haze Rule," Appendix B, "Summary of control measures in the PM, regional haze, and ozone partial attainment analyses," Innovative Strategies and Economics Group, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC, July 17, 1997, Docket A-2000-01, Document II-A-77.

CHAPTER 8: Small Business Flexibility Analysis

This section presents our Small Business Flexibility Analysis (SBFA) which evaluates the impacts of the rule on small businesses. Prior to issuing the proposal, we analyzed the potential impacts of our program on small businesses. As a part of this analysis, we convened a Small Business Advocacy Review (SBAR) Panel, in accordance with the Regulatory Flexibility Act (RFA) as amended by the Small Business Regulatory Enforcement Fairness Act of 1996 (SBREFA), 5 USC 601 *et seq*. Through the Panel process, we gathered advice and recommendations from small entity representatives (SERs) who would be affected by our rulemaking. The final report of the Panel has been placed in the rulemaking record.

8.1 - Requirements of the Regulatory Flexibility Act

The Regulatory Flexibility Act was amended by SBREFA to ensure that concerns regarding small entities are adequately considered during the development of new regulations that may affect them. Although we are not required by the Clean Air Act (CAA or the Act) to provide special treatment to small businesses, the Regulatory Flexibility Act requires that we carefully consider the economic impacts that our proposed rules will have on small entities. In general, the Regulatory Flexibility Act calls for determining, to the extent feasible, a rule's economic impact on small entities, exploring regulatory options for reducing any significant economic impact on a substantial number of such small entities, and explaining the ultimate choice of regulatory approach.

When proposing rules subject to notice and comment under the CAA, we are generally required under the Regulatory Flexibility Act to conduct an Initial Regulatory Flexibility Analysis (IRFA), unless we certify that the requirements of a regulation will not cause a significant impact on a substantial number of small entities. Although we are not required to conduct a Final Regulatory Flexibility Analysis (FRFA), EPA has decided to prepare an assessment of the impacts of the final rule on small entities. This SBFA would meet the requirements of a FRFA, were we required to prepare one.

In accordance with section 609(b) of the Regulatory Flexibility Act, we conducted outreach to affected small entities and convened an SBAR Panel before conducting the IRFA for the proposal. Through the SBAR Panel we obtained advice and recommendations of representatives of small entities that would potentially be subject to the rulemaking requirements. A summary of the recommendations of the SBAR Panel and small entities is presented in the Final Panel Report (*Final Report of the Small Business Advocacy Review Panel on Control of Emissions from Nonroad Large Spark Ignition Engines, Recreational Engines (Marine and Land-based), and Highway Motorcycles*, July 17, 2001). An IRFA was prepared, in accordance with section 603 of the Regulatory Flexibility Act. The IRFA can be found in Chapter 8 of the Draft Regulatory Support Document for the Notice of Proposed Rulemaking (NPRM).

We proposed the majority of the Panel recommendations, and took comments on this and other issues. Since highway motorcycles have had to meet emission standards for more than twenty years, EPA has good information on the number of companies that manufacture or market highway motorcycles for the U.S. market in each model year. In addition to the largest six manufacturers (BMW, Harley-Davidson, Honda, Kawasaki, Suzuki, Yamaha), we find as many as several dozen more companies that have operated in the U.S. market in the last couple of model years. Most of these are U.S. companies that are either manufacturing or importing motorcycles, although a few are U.S. affiliates of larger companies in Europe or Asia. Some of the U.S. manufacturers employ only a few people and produce only a handful of custom motorcycles per year, while others may employ several hundred and produce up to several thousand motorcycles per year. These new emission standards impose no new development or certification costs for any company producing compliant engines for the California market. In fact, implementing the California standards with a two-year delay also allows manufacturers to streamline their production to further reduce the cost of compliance. The estimated hardware costs are less than one percent of the cost of producing a highway motorcycle, so none of these companies should have a compliance burden greater than one percent of revenues. We expect that a small number of companies affected by EPA emission standards will not already be certifying products in California. For these companies, the modest effort associated with applying established technology will add compliance costs representing between 1 and 3 percent of revenues. The flexible approach we are adopting to limit testing, reporting, and recordkeeping burden prevents excessive costs for all these companies. Thus, EPA has determined that this final rule will not have a significant impact on a substantial number of small entities. However, we have included several provisions designed to reduce the burden on small entities. A full description of the regulatory flexibilities that are being offered to small entities to minimize their burden is located in Section 8.6, "Steps Taken to Minimize the Economic Impact on Small Entities."

Although this final rule will not have a significant impact on a substantial number of small entities, we have prepared this Small Business Flexibility Analysis that examines the impact of the rule on small entities, along with regulatory alternatives that could reduce that impact. This analysis would meet the requirements for a Final Regulatory Flexibility Analysis (FRFA) has that analysis been required. The key elements of an SBFA are:

- the need for, and objectives of, the rule;
- the significant issues raised by public comments, a summary of the Agency's assessment of those issues, and a statement of any changes made to the rule as a result of those comments;
- the types and number of affected small entities to which this rule will apply;
- the projected reporting, record keeping, and other compliance requirements of the regulation, including the classes of small entities that would be affected and the type of professional skills necessary for the preparation of the report or record; and,
- the steps taken to minimize the economic impacts of the regulation on small entities, consistent with the stated objectives of the applicable statutes.

8.2 - Need For and Objectives of the Rule

Emission standards have been in place for motorcycles since 1978. These cover exhaust HC and CO and crankcase emissions. Prior to this rule, there were no standards controlling NOx from highway motorcycles. The current standards do not apply to motorcycles with engines less than 50 cubic centimeters displacement. Under CAA section 202 (a)(3)(E), EPA is required to "consider the need to achieve equivalency of emission reductions between motorcycles and other vehicles to the maximum extent practicable." Light-duty vehicles, light-duty trucks and engines used in heavy-duty vehicles have each gone through several generations of emission standards since 1978, and indeed each of these categories is facing tough new standards in the next few years. With these developments and the recent promulgation of emission standards for off-road motorcycles, this was an appropriate time for EPA to reconsider the existing standards.

On December 7, 2000, EPA issued an Advance Notice of Proposed Rulemaking (ANPRM), and then issued a Notice of Proposed Rulemaking (NPRM) on September 14, 2001. This final rule contains new standards and related requirements for on-highway motorcycles.

8.3 - Issues Raised by the Public Comments

The SBAR Panel considered a range of options to assist small motorcycle manufacturers and provide regulatory flexibilities to help in decreasing the burden on small manufacturers. In the NPRM, we took comment on many of the options suggested by the Panel and SERs during the SBREFA process. The SBREFA Final Panel Report details all of the comments and regulatory alternatives suggested by SERs. The regulatory alternatives recommended by the Panel are located in Section 9 of the Report. While the SBREFA process included many types vehicles, there were specific recommendations aimed at highway motorcycles. The Panel-recommended alternatives for motorcycle manufacturers qualifying as small manufacturers that we proposed in the NPRM are listed below.

(1) Delay of Proposed Standards
As laid out in the Final Panel Report, we proposed a delay of the proposed standards- Tier 1 in 2008 and no Tier 2; we also pledged to participate with the California Air Resources Board in a 2006 technology review.

(2) Broader Engine Families
We proposed to leave the existing provisions that currently allow broader engine families unchanged.

(3) Exemption from production line testing
There is no production line testing (PLT) currently, and we did not propose PLT in the NPRM although we were considering it at the time we met with the SERs.

(4) Averaging, banking, and trading
We proposed an averaging program to enhance compliance and we requested comment on banking and trading programs to supplement this flexibility.

(5) Hardship provisions

We proposed hardship provisions, not only for small manufacturers, but for all manufacturers as recommended by the Panel.

(6) Reduced Cert Data Submittal and Testing Requirements
These already exist for manufacturers with fewer than 10,000 unit sales per year. The Panel recommended no changes to this and we did not propose any changes.

We received comments on the above Panel-recommended proposals in relation to small as well as large manufacturers. Of these, we are finalizing a delay in the standards, an emissions averaging program, and hardship provisions for all manufacturers. We are not finalizing PLT and we are finalizing no changes to the current reduced certification data submittal/testing requirements for manufacturers with fewer than 10,000 yearly unit sales. Lastly, we will not be changing the current provisions that allow for broader engine families.

We also received a number of other comments during the public comment process relating to small businesses. These comments were mainly focused on the following six subject areas: 1) the impact on the broader motorcycle industry, especially small/independent and aftermarket shops and the assertion that EPA did not fulfill its SBREFA obligations with regard to these shops ; 2) the customer rejection of products; 3) fewer options for customers and lower sales; 4) an increase in the cost of ownership and the inability to service motorcycles; 5) the reduction/elimination of competition from aftermarket and specialty shops, elimination of aftermarket supplies and services, and consumers will be forced to purchase only manufacturer-offered products; 6) the Barcia Act/H.R. 5433. A detailed summary of all of the comments that we received regarding the NPRM can be found in the Final Summary and Analysis of Comments located in the public docket for this rulemaking.

8.4 - Description of Affected Entities

Small entities include small businesses, small organizations, and small governmental jurisdictions. For the purposes of assessing the impacts of the proposed rule on small entities, a small entity is defined as: (1) a small business that meets the definition for business based on the Small Business Administration's (SBA) size standards (see Table 11-1); (2) a small governmental jurisdiction that is a government of a city, county, town, school district or special district with a population of less than 50,000; and (3) a small organization that is any not-for-profit enterprise which is independently owned and operated and is not dominant in its field. Table 8.4-1 provides an overview of the primary SBA small business categories potentially affected by this regulation.

Table 8.4-1
Primary SBA Small Business Categories Potentially Affected by this Regulation

Industry	NAICS[a] Codes	Defined by SBA as a Small Business If:[b]
Motorcycle manufacturers	336991	<500 employees

NOTES:
a. North American Industry Classification System
b. According to SBA's regulations (13 CFR 121), businesses with no more than the listed number of employees or dollars in annual receipts are considered "small entities" for purposes of a regulatory flexibility analysis.

Of the numerous manufacturers supplying the U.S. highway motorcycle market, Honda, Harley Davidson, Yamaha, Kawasaki, Suzuki, and BMW are the largest, accounting for 95 percent or more of the total U.S. sales. All of these companies except Harley-Davidson and BMW also manufacture off-road motorcycles and ATVs for the U.S. market. Harley-Davidson is the only company manufacturing highway motorcycles exclusively in the U.S. for the U.S. market.

Since highway motorcycles have had to meet emission standards for over twenty years, EPA has good information on the number of companies that manufacture or market highway motorcycles for the U.S. market in each model year. In addition to the big six manufacturers noted above, EPA finds as many as several dozen more companies that have operated in the U.S. market in the last couple of model years. Most of these are U.S. companies that are either manufacturing or importing motorcycles, although a few are U.S. affiliates of larger companies in Europe or Asia. Some of the U.S. manufacturers employ only a few people and produce only a handful of custom motorcycles per year, while others may employ several hundred and produce up to several thousand motorcycles per year.

8.5 - Projected Reporting, Recordkeeping, and Other Compliance Requirements of the Regulation

For any emission control program, we must be sure that the regulated engines will meet the standards. Historically, EPA programs have included provisions placing manufacturers responsible for providing these assurances. This final rule includes testing, reporting, and record keeping requirements. Testing requirements for some manufacturers include certification (including deterioration factor testing), and production-line testing. Reporting requirements include test data and technical data on the engines including defect reporting. Manufacturers keep records of this information. Because EPA has regulated motorcycle emissions for almost 25 years, these are generally not new compliance requirements for motorcycle manufacturers, but those that have been in place for many years. The only noteworthy change here is the addition of permeation evaporative emission control requirements for fuel lines and fuel tanks. While essentially all motorcycles will be affected by the fuel line requirements, only about ten percent of motorcycles use fuel tanks which are constructed of material which is not inherently low in permeation. We have designed these programs to involve the absolute minimum of testing and certification reporting requirements.

8.6 - Steps to Minimize Significant Economic Impacts on Small Entities

While the highway motorcycle market is dominated by large companies, there are a large number of small businesses manufacturing motorcycles. The provisions discussed below will reduce the economic burden on small businesses, allowing harmonization with California requirements in a phased, but timely manner. We have developed our special compliance provisions partly in response to the technology, timing, and scope of the requirements that apply to the small businesses in California's program. The flexibilities described below will be available for small entities with U.S. highway motorcycle annual sales of fewer than 3,000 units per model year (combined Class I, II, and III motorcycles) and fewer than 500 employees worldwide. These provisions are appropriate because of the significant research and development resources may be necessary to meet the emission standards and related requirements. These provisions will reduce the burden while ensuring the vast majority of the program is implemented to ensure timely emission reductions. Many small highway motorcycle manufacturers market unique "classic" and "custom" motorcycles, often with a "retro" appearance, that tends to make the addition of new technologies a uniquely resource-intensive prospect.

8.61 Delay of Implementation Timing of the Standards

We are delaying compliance with the Tier 1 standard of 1.4 g/km HC+NOx until the 2008 model year for small manufacturers, and at this time, we are not requiring these manufacturers to meet the Tier 2 standard. The existing California regulations do not require small manufacturers to comply with the Tier 2 standard of 0.8 g/km HC+NOx. The California Air Resources Board (ARB) found that the Tier 2 standard represents a significant technological challenge and is a potentially infeasible limit for these small manufacturers. As noted above, many of these manufacturers market specialty products with a "retro" simplicity and style that may not easily lend itself to the addition of advanced technologies like catalysts and electronic fuel injection. However, the California ARB has acknowledged that, in the course of their progress review planned for 2006, they will revisit their small-manufacturer provisions. We plan to participate with the ARB and others in the 2006 progress review. Following our review of these provisions, as appropriate, we may decide to propose to make changes to the emission standards and related requirements through notice and comment rulemaking, including the applicability of Tier 2 to small businesses. The hardship provisions described above could be used to provide a small manufacturer with yet additional lead time if justified.

8.6.2 Broader Engine Families

Small businesses have met EPA certification requirements since 1978. Nonetheless, certifying motorcycles to revised emission standards has cost and lead time implications.

Relaxing the criteria for what constitutes an engine or vehicle family could potentially allow small businesses to put all of their models into one vehicle or engine family (or more) for certification purposes. Manufacturers would then certify their engines using the "worst case" configuration within the family. This is currently allowed under the existing regulations for small-volume highway motorcycle manufacturers. These provisions remain in place without revision.

8.6.3 Averaging, Banking, and Trading

An emission-credit program allows a manufacturer to produce and sell engines and vehicles that exceed the applicable emission standards, as long as the excess emissions are offset by the production of engines and vehicles emitting at levels below the standards. The sales-weighted average of a manufacturer's total production for a given model year must meet the standards. An emission-credit program typically also allows a manufacturer to bank credits for use in future model years. The emission-credit program we are implementing for all highway motorcycle manufacturers includes emissions averaging within the three classes of motorcycles and allows for averaging between the Classes I and II and averaging between Class III and Classes I/II with the restriction that credits can flow only out of Class III into Classes I and II, and not the opposite. The banking program is limited to the Class III Tier 2 requirements; these do not involve small motorcycle manufacturers at this time. Some credit programs allow manufacturers to buy and sell credits (trade) between and among themselves. We are not implementing such a provision at this time, but such flexibility could be made available to all small manufacturers as part of the upcoming technology review.

8.6.4 Reduced Certification Data Submittal and Testing Requirements

Current regulations allow significant flexibility for certification by manufacturers projecting sales below 10,000 units of combined Class I, II, and III motorcycles. For example, a qualifying manufacturer must submit an application for certification with a statement that their vehicles have been tested and, on the basis of the tests, conform to the applicable emission standards. The manufacturer retains adequate emission test data, for example, but need not submit it. Qualifying manufacturers also need not complete the detailed durability testing required in the regulations. We are incorporating no changes to these existing provisions.

8.6.5 Hardship Provisions

We proposed two types of hardship provisions, one of which was intended specifically for small businesses and the other intended for all manufacturers. The first type of hardship provision allows a small volume motorcycle manufacturer to petition for up to three years additional lead time if the manufacturer can demonstrate that it has taken all possible steps to comply with the standards but the burden of compliance would have a significant impact on the company's solvency. The second type of hardship provision allows a company to apply for hardship relief if circumstances outside of the company's control cause a failure to comply, and the failure to sell the noncompliant product would have a major impact on the company's solvency.

In general, we do not expect that manufacturers will need to use these hardship provisions. However, having such provisions available gives us the flexibility to administratively deal with a unexpected situations that may arise as companies work toward compliance with the regulations. Thus, we are adopting these hardship provisions as proposed.

8.7 - Conclusion

EPA has conducted a substantial outreach program designed to gather information as to the effect of this final rulemaking on small entities. This process included a SBAR Panel, which sought advice and recommendations from potentially affected small entities regarding ways to minimize their compliance burden. We published both an ANPRM and a NPRM which requested comments from potentially affected entities, as well as other interested parties in the public at large. From the information that we have gathered during this process, we have found that there are 42 manufacturers that certified motorcycles in the year 2003. Of these, 30 manufacturers are small by the SBREFA definition given in section 8.4. However, certification emission data indicates that essentially all of these 30 manufacturers are currently meeting the Tier 1 exhaust emission standard. Given small costs of complying with the permeation evaporative emission requirements and the lead time and other flexibilities that are being finalized in this rulemaking, these manufacturers will not be significantly affected by the rule. Therefore, we have determined that this final rulemaking will not have a significant economic impact on a substantial number of small entities.