# REGULATORY ANALYSIS

# OF THE

# LIGHT-DUTY DIESEL PARTICULATE REGULATIONS

# FOR 1982 AND LATER MODEL YEAR LIGHT-DUTY DIESEL VEHICLES


ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF AIR, NOISE, AND RADIATION

OFFICE OF MOBILE SOURCE AIR POLLUTION CONTROL



FEBRUARY 20, 1980

# Regulatory Analysis

# Light-Duty Diesel Particulate Regulations

Environmental Protection Agency
Office of Air, Noise, and Radiation
Mobile Source Air Pollution Control

Approved by:

Michael P. Walsh

Michael P. Walsh, Deputy Assistant Administrator
for Mobile Source Air Pollution Control

Date: February 20, 1980

## NOTE

This document has been prepared in satisfaction of the Regulatory Analysis required by Executive Order 12044 and the Economic Impact Assessment required by Section 317 of the amended Clean Air Act. This document also contains an Environmental Impact Statement for the proposed Rulemaking Action.

## Table of Contents

# CHAPTER I

# SUMMARY

## A. Background

Light-duty vehicles powered by diesel engines are projected to be a significant source of particulate emissions in the late 1980's. Currently, this is not the case due to the small number of light-duty diesels on the road today. By 1990, though, it is projected that diesels could comprise as much as 20 percent of light-duty vehicle sales. By 1990, they are projected to become the seventh largest source of particulate emissions and to have the third greatest available potential for total particulate emission reduction of any source, mobile or stationary. The majority of these emissions will occur in urban areas, where the total suspended particulate problems are most acute.

Based on the above and the fact that Congress has required the control of particulate emissions from these vehicles through the 1977 Amendments to the Clean Air Act, EPA is establishing emission standards to control particulate emissions from light-duty vehicles and trucks powered by diesel engines. Also included are changes in the test equipment and procedures currently used to measure gaseous emissions from these vehicles. These changes will allow the measurement of particulate emissions concurrently with the measurement of the currently regulated gaseous emissions without affecting the stringency of current gaseous emission standards.

## B. Proposed Rulemaking

Section 202(a)(3)(A)(iii) of the Clean Air Act as amended, requires the Administrator to prescribe particulate emission standards by the 1981 model year. It is under this authority that EPA is now promulgating Federal light-duty diesel particulate emission standards for 1982 and later model year vehicles. The changes to the existing regulations include:

1. The addition of a dilution tunnel and other equipment to measure particulate emissions;

2. The implementation of exhaust emission standards for particulate matter from diesel-powered light-duty vehicles and light-duty trucks of 0.60 gram per mile (0.37 gram per kilometer (g/km)) beginning with the 1982 model year; and

3. The reduction of the standards to 0.20 g/mi (0.12 g/km) for diesel-powered light-duty vehicles and 0.26 g/mi (0.16 g/km) for diesel-powered light-duty trucks beginning with the 1985 model year.

## C. Light-Duty Diesel Characterization and Industry Description

The particulate regulations being promulgated apply to two classes of diesel-powered vehicles. The first class consists of diesel-powered light-duty vehicles (LDV-D), which are defined as passenger cars or passenger car derivatives capable of seating 12 persons or less. The second class is the diesel-powered light-duty truck (LDT-D) class, which consists of vehicles rated at 8,500 pounds (3,546 kg) gross vehicle weight rating (GVWR) or less designed primarily for transportation of property or for transportation of more than 12 passengers. While LDT-D's are designed for periodic carrying of cargo, these vehicles are used most often in ways more analogous to passenger cars than to cargo-carrying trucks.

Currently, only about 0.5 percent of all light-duty vehicles are powered by diesel engines. Over the next 10 years, the use of diesel engines in light-duty vehicles is expected to increase dramatically. Current projections foresee as many as 25 percent diesels in these markets by 1990. Two maximum penetrations of 15 percent and 25 percent were used for determining the range of environmental and economic impacts described below.

The primary manufacturers of these vehicles, both gasoline and diesel-fueled, produce vehicles in both classes. The three largest are General Motors, Ford, and Chrysler. Most foreign manufacturers, such as Toyota, Datsun and VW, produce only light-duty vehicles and trucks under 6,000 pounds GVWR.

## D. Standards and Technology

The light-duty diesel vehicle particulate standards of 0.6 g/mi (0.37 g/km) in 1982 and 0.2 g/mi (0.12 g/km) in 1985 are based on several precepts. To comply with the "greatest degree of emission reduction" mandate of Section 202(a)(3)(A)(iii) and to give "appropriate consideration" to leadtime, cost, noise, energy, and safety factors (required by the same Section) as well, EPA based these standards on the lowest particulate levels achievable by the worst light-duty diesel with respect to particulate emissions. This basis requires best available control technology, at least for those diesels which have the highest particulate emission levels. The initial standard was based on the lowest particulate level determined to be achievable by the worst case diesel in 1981, as there was too little leadtime to expect any major technological breakthroughs. In fact, due to certification leadtime constraints, EPA has had to delay the implementation date of the initial standard until 1982. The second standard was based on the lowest particulate level determined to be achievable by 1985, as EPA expects significant particulate reductions by then due to the successful application of trap-oxidizers. The 0.2 g/mi (0.12 g/km) level clearly cannot be met by all diesel vehicles at this time, thus the 1985 standard is a technology-forcing standard. EPA is confident that a concerted effort by the industry will produce a successful trap-oxidizer by the 1985 model year.

Exhaust gas recirculation (EGR), the primary NOx emission control technique used at this time, is known to increase diesel particulate emissions. Presently, there is a trade-off involved between diesel NOx and particulate emissions. While the statutory NOx standard is 1.0 g/mi (0.62 g/km) beginning in 1981, EPA has the authority to waive the standard to 1.5 g/mi (0.93 g/km) for model years 1981 to 1984. EPA has decided that manufacturers are eligible for the NOx waiver if they can meet the 1.0 g/mi (0.62 g/km) NOx standard only by significantly increasing the particulate emission levels of their vehicles. EPA has already granted NOx waivers for several 1981-82 model year light-duty diesel engine families and those manufacturers which had waiver applications rejected due to insufficient information are eligible to re-apply for the waiver.

EPA recognizes the necessity of designing prototype vehicles to emission levels below those of the standards, due to prototype-to-certification slippage, car-to-car variability, test-to-test variability, and deterioration factors. Analysis has shown that the safety margins claimed to be necessary by the manufacturers are often exaggerated; at most a 20 percent margin seems quite adequate.

The technical analysis has indicated that the manufacturers could all meet the 0.6 gpm (0.37 g/km) particulate standard in 1981. Many of the manufacturers (Daimler-Benz, Peugeot, Fiat) admitted or strongly implied such in their comments to the NPRM. The technical staff has determined that, based on the data provided during the comment period, General Motors and Volkswagen (which claimed the Audi 5000D could not meet the proposed standard in 1981) could meet the 0.6 g/mi (0.37 g/km) level in 1981 as well. The significant particulate reductions that have been achieved, especially on the largest diesel vehicles which had the highest baseline levels, have been almost completely due to engine modifications and optimizations, the effect of which EPA had underestimated in its original analysis. Turbocharging, which EPA had emphasized as a particulate control strategem, has been adopted only by Fiat and Peugeot, with Mercedes continuing to market one turbocharged model.

Although it has been determined that the 0.6 g/mi (0.37 g/km) standard is technologically feasible for the 1981 model year for those manufacturers (mentioned above) which reported on their particulate control programs, certification leadtime requirements dictate the delay of its implementation until the 1982 model year. For those manufacturers which did not report any particulate data to EPA, we can only conclude that the 0.6 g/mi (0.37 g/km) standard can be met, and must be met, in order for them to sell light-duty diesel vehicles during the 1982, 1983 and 1984 model years.

The 0.2 g/mi (0.12 g/km) standard in 1985 is predicated upon the successful development of trap-oxidizer technology. The research that has been done to date has convinced the technical staff that trap-oxidizers will be feasible for production application by the 1985 model year, though improvements are necessary in the areas of efficiency (need approximately 60 percent efficiency), durability (must last 50,000 + miles), and regeneration initiation and control. Experience has shown that in the absence of direct regulatory incentive, manufacturers have rarely invested the necessary resources into new emission control technologies. With such an incentive, EPA is confident that the trap-oxidizer will be successfully applied by the 1985 model year.

The last data EPA received concerning trap-oxidizers was in response to the NPRM. It was determined that approximately 2 to 2-1/2 years of development leadtime was still necessary from that time. Allowing the manufacturers an additional 2 to 2-1/2 years of production leadtime (during which minor engineering changes could still be made) would delay implementation until approximately 4-1/2 years from the publication of the NPRM, or until the 1984 model year.

While our technical analysis concluded that there is a strong likelihood that trap-oxidizers will be feasible for vehicle application by 1984, the uncertainty that exists with regard to trap-oxidizer durability and vehicle application has convinced EPA to minimize the economic risk of this rulemaking by delaying the implementation of the 0.20 g/mi (0.12 g/km) standard until 1985. This extra year will have only a marginal effect on ambient suspended particulate levels yet will ensure that the manufacturers have enough time to optimize trap-oxidizer development.

In addition to the 0.2 g/mi (0.12 g/km) particulate standard in 1985, the diesel manufacturers will also have to comply with the 1.0 g/mi (0.62 g/km) NOx standard in 1985 or possibly earlier (depending on future NOx waiver decisions). This may likely require the use of higher EGR rates which would be expected to increase particulate levels. EPA expects that as the particulate/EGR relationship becomes better understood, the deleterious effect of EGR on particulate levels will be lessened. It is also likely that other NOx control strategies will be developed which will not impact as much (or at all) on particulate levels. Finally, in addition to the particulate reduction expected from the successful application of trap-oxidizers, EPA expects additional particulate reductions due to further engine modifications and engine system optimizations, turbocharging, and downsizing, the latter motivated by the progressively higher corporate average fuel economy standards in the early 1980's.

EPA has determined that the combined effect of the greater inertia weight and road load horsepower settings of the heaviest typical light-duty truck (compared to the heaviest typical light-duty vehicle) justify particulate standards 20 percent greater than the light-duty vehicle standards, all other things being equal. Light-duty trucks will have a NOx standard of 2.3 g/mi (1.43 g/km) until model year 1985 while diesel light-duty vehicles will be required to meet a NOx level in the range of 1.0 to 1.5 g/mi (0.62 to 0.93 g/km), depending on the NOx waiver decisions, until model year 1985. At the minimum, light-duty diesel trucks will have a 53 percent greater NOx standard than will light-duty diesel vehicles. This NOx cushion can account for both the greater NOx emissions (approximately 20 to 30 percent) that would be expected from light-duty diesel trucks, and the 20 percent greater particulate emissions. The trade-off is feasible because of the relationship of particulate and NOx emission levels to EGR. Thus, the 1982 standard of 0.6 g/mi (0.37 g/km) will apply to both light-duty vehicles and light-duty trucks. An examination of current light-duty truck particulate levels has shown that they all can meet the standard.

In 1985, the cushion that now exists for light-duty truck NOx emissions is expected to disappear. Thus, the light-duty truck particulate standard should be 20 percent greater than the light-duty vehicle standard, all other things being equal. In addition, it has been determined that an additional 10 percent factor should be applied to the standard because downsizing and the use of smaller engines will likely not take place as rapidly with light-duty trucks as with light-duty vehicles. The 1985 light-duty truck particulate standard has thus been set at 0.26 g/mi (0.16 g/km).

## E. Environmental Impact

Despite significant gains made in the control of particulate emissions from stationary sources, there are many air quality regions which are not able to meet the primary National Ambient Air Quality Standard (NAAQS) for total suspended particulate matter (TSP) of 75 micrograms per cubic meter (annual mean). As diesel-fueled vehicles assume an increasing portion of the light-duty vehicle market, their contribution to ambient TSP levels will increase, because diesel-fueled engines emit approximately 40 times the amount of particulate that is emitted by gasoline-fueled engines equipped with catalytic converters.

It is expected that between 15 and 25 percent of all new light-duty vehicles and trucks sold by the late 1980s will be powered by diesel engines. These light-duty diesels would have emitted between 152,000 and 253,000 metric tons of particulate matter annually by 1990 without control. EPA arrived at this figure by estimating that between 10 and 17 percent of all light-duty travel would be by diesels in 1990. Urban areas would have been the areas most heavily affected by these emissions. Ambient particulate levels from light-duty diesels alone would have reached 2-11 micrograms per cubic meter (annual geometric mean) in cities such as Chicago, Los Angeles, New York, and Dallas. Somewhat smaller levels of 2-4 micrograms per cubic meter (annual geometric mean) would have occurred in smaller cities such as St. Louis, Denver, and Phoenix. These levels would have been expected to occur over large-scale areas within these cities. Additional particulate levels of 5-9 micrograms per cubic meter (annual geometric mean) would have been expected in localized areas within 90 meters of very busy roadways.

This regulation will reduce particulate emissions from light-duty diesels by 74 percent in 1990 with respect to what would be expected without these regulations. National particulate emissions in 1990 from light-duty diesels will be reduced by approximately 112,000-187,000 metric tons per year to 40,000-66,000 metric tons per year. Urban emissions from these vehicles will also decrease 74 percent in 1990 from 84,000-141,000 metric tons per year to 22,000-37,000 metric tons per year. This emission reduction will reduce ambient light-duty diesel particulate levels in large cities (e.g., New York, Chicago, Dallas) by 1.5-8 micrograms per cubic meter down to 0.5-3 micrograms per cubic meter. Light-duty diesel particulate levels in smaller cities (e.g., St. Louis, Phoenix) will also decrease by 1-3 micrograms per cubic meter to a level of 0.5-1.0 micrograms per cubic meter. Localized levels which occur over and above these larger-scale impacts will also decrease by 4-6 micrograms per cubic meter to 1-2 micrograms per cubic meter. These latter impacts could occur as far as 90 meters from very busy roadways.

## F. Economic Impact

It is expected that the retail price of light-duty diesel vehicles and trucks will increase by approximately $11-12 in 1982 and $138-164 in 1985 due to the vehicle modifications necessitated by this regulation. In addition, lifetime maintenance costs are expected to decrease by $50 beginning in 1985. Due to past and future increases in the price of gasoline-fueled vehicles due to emission controls, EPA expects no decrease in diesel sales relative to the sales of gasoline-fueled vehicles due to aggregate environmental regulation. The aggregate cost of the first standard over the three years it will be in effect will be $42-76 million depending on total light-duty diesel sales. The aggregate cost of the second standard over five years (1985-1989) will be $897-1857 million (present value in 1985). All these costs are in 1979 dollars.

The range of per vehicle costs for the 1985 standard is due to possible differences in trap-oxidizer systems which may be used on various models. The wider ranges given for the aggregate cost of the two standards is due to uncertainty in the actual number of light-duty diesels which will be built in that time frame. The lower limit of the aggregate cost in each case assumes the lower per vehicle cost and the lower limit of EPA's estimate of light-duty diesel production. The upper limit of the aggregate cost assumes the higher limit of both these factors.

G. Cost Effectiveness

In addition to determining the cost effectiveness of the 1982 and 1985 standards, the traditional methodology used to determine cost effectiveness was examined and found to be inadequate when used to compare the cost effectiveness of different particulate control strategies. In general, the traditional methodology only focuses on total emission reductions, which may not relate directly to air quality, health and welfare improvements with respect to particulate emissions.

For example, the traditional measure of cost effectiveness (dollars per metric ton of particulate controlled) can be made more relevant to health improvements by considering only the inhalable or fine particulate that is controlled. Based on available data, the inhalable and, especially, the fine fractions of suspended particulate may have the greatest potential adverse health impact. When this is done, the marginal cost-effectiveness ratio for the 1985 standard is $2,400-3,025 per metric ton of inhalable particulate and $2,500-3,150 per metric ton of fine particulate. When these bases are used the cost effectiveness of the 1985 diesel standard is found to be consistent with stationary source control strategies which have been adopted in the past.

There is another step which can be taken to improve the measure of cost effectiveness and that is to relate it to reductions in ambient pollutant concentrations instead of emission reductions. People's exposure to pollutants is directly related to the ambient pollutant concentration of the air they breathe, but only indirectly related to the emissions from various sources. However, the data necessary to perform such an analysis are difficult to obtain and not generally available. Still, to indicate the potential effects such factors can have on a cost-effectiveness analysis, some rough calculations were performed. Using some rough indicators of a source's impact on air quality relative to its emissions, it was found that light-duty diesels produce between 32 and 134 times the ambient pollutant concentration as the largest power plants (2,920 megawatt heat input) based on equivalent emission rates. Similarly, light-duty diesels produce between 0.8 and 3.4 times the ambient pollutant concentration as smaller power plants (73 megawatt heat input), based on equivalent emission rates. Only large-scale impacts were examined. Had localized impacts been included, the results could have been different. Similarly, a comparison of a different stationary source to light-duty diesels could have a much different result. One can imagine the potential effects of adding five to ten such factors to the cost-effectiveness analysis. The results of the previous paragraph could be made meaningless. Thus, while the cost-effectiveness of light-duty diesel control appears to be consistent with that of past EPA actions, the use of cost-effectiveness to compare different source strategies should be taken very cautiously. The type of factors which need to be included are simply not available and could drastically affect the results. The size of these factors also shows the need to further develop the methodology used to determine particulate cost effectiveness before it can really be used to identify strategies which should be implemented from those which should not.

The marginal cost effectiveness of the 1985 standard could only be compared with those from a few other strategies. Because the use of a marginal cost effectiveness is relatively new, these values are not readily available for most existing control strategies. Similarly, it was available for only one future control strategy, the control of emissions from mid-sized steam generators (3-73 megawatt heat input). As more future control will be needed than this regulation being promulgated and this one additional NSPS if the nation is to meet the national ambient air quality standard for suspended particulate, the cost effectiveness of the 1985 standard should really be compared to those strategies which will be needed in the future, which haven't yet been developed and implemented. These strategies will likely be more costly than those of the past, since EPA has been attempting to implement the most cost effective strategies first. This being the case, the cost effectiveness of the 1985 standard would appear even more cost effective than it did against the past strategies. This is all the more reason why the 1985 standard appears to be a reasonable control strategy.

## H. Alternative Actions Considered

Control of particulate emissions from light-duty diesel vehicles and trucks is required by the Clean Air Act. Thus, EPA does not have the authority to forego control of light-duty diesel particulate emissions in favor of other particulate control strategies. However, other control strategies were examined in the course of this rulemaking. Further control of stationary sources and other mobile sources of particulate emissions was considered. Various techniques which would apply the emission standard to the average emissions of a manufacturer's fleet were also considered. Finally, per vehicle emission standards for light-duty diesels of varying stringency were also considered as alternatives.

The alternative of further controlling stationary sources of particulate emissions as a substitute for these regulations was rejected for two reasons. First, while stationary source controls can mitigate the effects of future growth, they cannot be expected to reduce TSP concentrations in urban areas. Secondly, further control of stationary sources would not diminish the high levels of diesel particulate near roadways where significant adverse impacts occur.

The control of other mobile sources was also considered as an alternative to these regulations. It was determined that control of heavy-duty diesel particulate emissions will be necessary, but even the removal of these emissions would not remove the necessity of these light-duty regulations. The Clean Air Act requires heavy-duty diesel particulate regulations. Regulations for heavy-duty diesel particulate emissions are not being proposed at this time, however, as a transient test procedure is necessary to adequately measure heavy-duty diesel particulate emissions. This type of test procedure will not be required for diesels until 1985, when it will be used to measure gaseous emissions and when heavy-duty particulate regulations are currently planned to come into effect.

Two distinct averaging approaches were proposed by commenters as alternatives to EPA's individual per vehicle particulate standards. General Motors' proposal would require each manufacturer's sales-weighted average particulate level over its entire (diesel and gasoline-powered) light-duty vehicle fleet to be equal to or less than the Corporate Average Particulate Standard (CAPS). Volkswagen proposed that the particulate emission levels from diesel vehicles only be averaged, and that each manufacturer's sales-weighted particulate level be required to comply with the Diesel Average Particulate Standard (DAPS). The primary advantage of both proposals is the added flexibility the manufacturers would have in meeting the standards, both with respect to model line mix and economics. Theoretically, CAPS allows the maximum flexibility since its inclusion of gasoline-powered vehicles allows the averaging of near-zero particulate emission levels. DAPS allows somewhat less flexibility since it can only "balance out" high-particulate emitting diesels with low-particulate emitting diesels, and there is a limit to the extent to which this can be effective. In practice, the adoption of either CAPS or DAPS would necessitate lower average levels than those proposed by the manufacturers, and these lower levels would limit the flexibility even more. There would likely be very little flexibility with DAPS at average levels consistent with the concept of best available control technology. CAPS would place an implicit ceiling on the total light-duty diesel particulate loading to the atmosphere (assuming total light-duty vehicle sales to be relatively constant). DAPS would limit only the average diesel particulate level of a manufacturer.

While CAPS does provide the advantages discussed above, EPA finds far too many difficulties associated with its implementation and we reject it as an alternative to the individual vehicle standards. CAPS would violate the regulatory tenet that all light-duty vehicles should be required to meet the same emissions standards. Each engine family, in effect, would have a different standard. This is difficult to reconcile with the structure of Title II of the Clean Air Act which assumes individual vehicle standards. It would also allow vehicle A to legally emit more than vehicle B, even though both vehicles satisfied the same general function. A final drawback in this regard involves manufacturer equity. Since the CAPS concept averages diesel and gasoline-powered vehicle particulate levels, and since the latter are typically very low, a manufacturer's corporate average particulate level would be dependent not only on its diesel vehicle particulate levels but also on its relative proportion of diesel to gasoline-powered vehicles. A manufacturer which produces a small percentage of diesels could tolerate much higher particulate levels on its diesels, and still comply with a specific CAPS, than could a manufacturer which markets a much higher percentage of diesels. CAPS licenses a manufacturer to produce greater quantities of and progressively higher-particulate emitting diesels as it increases its gasoline-powered vehicle production. EPA considers this to be unacceptable. CAPS might also act to restrain competition in the industry as a firm which wanted to produce light-duty diesel vehicles would likely find it impossible to comply with CAPS without also producing similar quantities of gasoline-powered vehicles. This implicit limitation on diesel sales is inconsistent with the statutory authority for this Rulemaking. Another major problem with CAPS concerns enforcement. Changing from enforcement on an engine family basis with each family having to meet the same standard to enforcement on a fleetwide basis with a multitude of different standards would require a whole new enforcement apparatus and would likely result in a whole new series of problems. Finally, CAPS would allow the possibility of localized particulate impact problems in certain cities, downtown areas, or roadways which might have an unusually high concentration of diesels emitting at or near the maximum level allowed.

DAPS is much more equitable to diesel manufacturers than is CAPS. Regardless of the quantity of gasoline-powered or diesel vehicles a manufacturer produces, each manufacturer would have to comply with the same average diesel particulate level. Analysis has shown that DAPS levels consistent with best available control technology would not provide much flexibility to the manufacturers, however, since DAPS precludes the averaging of gasoline-powered vehicle particulate levels and since it becomes more difficult to "balance out" a high particulate-emitting diesel with lower particulate-emitting diesels as the standard decreases. Although DAPS does not share the manufacturer inequity problems of CAPS, it does share the remaining problems discussed above: it is inconsistent with Title II of the Clean Air Act, it would allow vehicle/vehicle inequities, it would involve cumbersome enforcement problems, and it would increase the likelihood of localized impact problems. Based on these problems, and the fact that DAPS would not really provide very much flexibility to the manufacturers anyway, EPA rejects the use of DAPS in favor of the individual vehicle standards.

Alternative per vehicle standards were also examined for 1982 and 1985, as well as adjustments to the years of implementation. With respect to 1982, a standard significantly more stringent than 0.6 g/mi (0.37 g/km) would have prevented some current light-duty diesels from being sold. This would have been against EPA's policy of basing the standard on the worst case vehicle, which was outlined in the Preamble to the Proposed Rulemaking. A standard less stringent than 0.6 g/mi (0.37 g/km), for example 0.8 g/mi (0.50 g/km) or 1.0 g/mi (0.62 g/km), would certainly reduce the effort needed to comply with the initial standard and would only marginally affect air quality. On the other hand, 1) these levels would hardly require any control, 2) the 0.6 g/mi (0.37 g/km) standard is clearly achievable, and 3) the cost effectiveness of the 0.6 g/mi (0.37 g/km) standard is very good. Given these three reasons, any standard higher than 0.6 g/mi (0.37 g/km) was rejected.

Two alternatives to the 1982 implementation date were examined, 1981 and 1983. It appeared that the technology necessary to meet a 0.6 g/mi (0.37 g/km) standard would be available in time for the 1981 model year. However, the date of promulgation of the regulation would have been too late to allow the manufacturers to certify all of their vehicles in time for the start of the 1981 model year. To prevent the introduction of 1981 model year light-duty diesels from being delayed, 1981 was rejected. Postponing the standard to 1983 would have allowed the manufacturers an additional year to meet the standard. If it was actually achievable in 1981 and was delayed a year only because of a lack of testing time, there would appear to be little need to delay another year. Thus, 1983 was also rejected.

In determining the second level of control and its timing, the analysis focused on the trap-oxidizer, its cost, effectiveness and availability. The primary alternatives examined were 0.2 g/mi (0.12 g/km) and 0.5 g/mi (0.31 g/km) standards being implemented in 1984 or 1985. (For simplicity of discussion, only the light-duty vehicle standard will be stated.) The more stringent standard represented the level achievable using trap-oxidizer technology and the less stringent standard represented what was achievable without trap-oxidizers. The air quality difference between the two standards was significant. Regional particulate levels in the nation's largest cities would be 0.7-7 microgram per cubic meter higher under the less stringent standard than the more stringent standard. Also, while the cost of trap-oxidizer technology is high, the incremental cost effectiveness of adding trap-oxidizers was not out of line with those of past strategies. Thus, the air quality benefits appeared to be well worth the cost and the 0.5 g/mi (0.31 g/km) standard was rejected.

With respect to the implementation date of the 0.2 g/mi (0.12 g/km) standard, the question revolved around the date that trap-oxidizer technology would be available. This was determined to be 1984 or 1985. The delay until 1985 will ensure a more optimum application of trap-oxidizer technology but will marginally worsen air quality. Because of the major economic commitment and technological uncertanties involved, EPA decided to delay implementation until the 1985 model year.

The analysis for light-duty trucks was the same as that for light-duty vehicles described above. The only alternative not yet addressed was that of alternate levels other than 0.26 g/mi (0.16 g/km) in 1985. The available data on the effects of inertia weight and road load on particulate emissions show that light-duty trucks could have up to 30 percent higher emissions than light-duty vehicles using equivalent technology. A standard either lower or higher than 0.26 g/mi (0.16 g/km) then would either be less or more stringent than the light-duty vehicle standard of 0.2 g/mi (0.12 g/km). This would create an artificial bias toward the sale of the worst polluting class and have a negative impact on air quality. Thus, any standard other than 0.26 g/mi (0.16 g/km) was rejected.

# CHAPTER II

# INTRODUCTION

## A. Background of Light-Duty Diesel Particulate Emission Regulation

The regulations examined in this document are intended to limit the emission of particulate matter from light-duty diesels. The regulations were mandated by Congress via the 1977 Amendments to the Clean Air Act and apply to diesel-powered light-duty vehicles (LDV-D's) and trucks (LDT-D's) hereafter designated light-duty diesels. Section 202(a)(3)(A)(iii) of the Act as amended states:

> The Administrator shall prescribe regulations under paragraph (1) of this subsection applicable to emissions of particulate matter from classes or categories of vehicles manufactured during and after model year 1981 (or during any earlier model year, if practicable). Such regulations shall contain standards which reflect the greatest degree of emission reduction achievable through the application of technology which the Administrator determines will be available for the model year to which such standards apply, giving appropriate consideration to the cost of applying such technology within the period of time available to manufacturers and to noise, energy, and safety factors associated with the application of such technology. Such standards shall be promulgated and shall take effect as expeditiously as practicable taking into account the period necessary for compliance.

These regulations were necessitated because of the current national urban particulate problem.1/,2/ With current projections showing a likely 20% penetration of diesels into the light-duty and medium-duty market by the late 1980's, particulate emissions from these diesel-powered vehicles will become a significant source of particulate emissions in urban areas and a major source in areas immediately nearby busy roadways.

These regulations were proposed on February 1, 1979.3/ A public meeting was held on March 16, 1979 to allow General Motors to present its corporate averaging proposal and a public hearing was held March 19-20, 1979 for all interested parties to comment on the proposed regulations. The comment period for the submittal of written comments was held open until April 19, 1979. A detailed summary and analysis of these comments is contained in a separate document.4/

* Bracketed numbers (1/) indicate references at the end of this chapter.

## B. Description of Particulate Emission ontrol from Light-Duty Diesels

### 1. Test Procedure and Instrumentation

The test procedure under which particulate emissions will be determined is essentially the same test procedure currently used to determine gaseous exhaust emissions. The test for particulate emissions will be performed simultaneously with the test for gaseous pollutants. Thus, the driving cycles, weighting procedure, inertia weight and road load determination procedures, etc., will remain the same as currently set forth in the current Federal Test Procedure. The changes required include the need for additional equipment and instrumentation to allow for the determination of the amount of particulate matter being emitted.

The most significant change in the test equipment will be the substitution of a dilution tunnel for the current baffle box. The baffle box causes a measurable decrease in particulate emissions from diesels due to particle deposition on the baffles.5/ The dilution tunnel will allow the diesel exhaust to be diluted with ambient air with a minimum of particle deposition.

Also, a larger constant volume sampler than is currently necessary for light-duty testing may be required for the larger diesel engines. The need to reduce the exhaust temperature to less than 125°F (52°C) dilution with ambient air will require more dilution air than is currently available in these cases. Thus, the purchase of CVS units as large as 600 cfm (0.28 cubic meters per second) may be required.

### 2. Emission Standards

Light-duty vehicles and trucks are currently required to meet emission standards for hydrocarbons, carbon monoxide, and oxides of nitrogen, but no standards exist for particulate emissions. The current and future standards for the gaseous pollutants are shown in Tables II-1 and II-2. The initial standard for particulate emissions from LDV-D's and LDT-D's is 0.60 gram per mile (g/mi) (0.37 gram per kilometer (g/km)) beginning with the 1982 model year. This level of control is expected to be reached via minor engine modifications. The second and more stringent particulate standard is being implemented in 1985 and is 0.20 g/mi (0.12 g/km) for LDV-D's and 0.26 g/mi (0.16 g/km) for LDT-D's. This level of control is expected to require the use of trap-oxidizers on most vehicles.

If a final market penetration for diesels of 15-25% is estimated, these standards will result in a 74% reduction in particulate emissions from these motor vehicle classes in 1990 with

Table II-1

Gaseous Emission Standards for Light-Duty Vehicles
Grams Per Mile (grams per kilometer)

| Federal | HC | CO | NOx | HC Evap. 1/ |
|---|---|---|---|---|
| 1978-79 | 1.5 (0.93) | 15.0 (9.3) | 2.0 (1.24) | 6.0 |
| 1980 | 0.41 (0.25) | 7.0 (4.3) | 2.0 (1.24) | 6.0 |
| 1981 and on | 0.41 (0.25) | 3.4 (2.1) | 1.0 (0.62) 4/ | 2.0 |

| California | HC | CO | NOx | HC Evap. 1/ |
|---|---|---|---|---|
| 1978-79 | 0.41 (0.25) | 9.0 (5.6) | 1.5 (0.93) | 6.0 |
| 1980 3/ | 0.41 (0.25) | 9.0 (5.6) | 1.0 (0.62) | 2.0 |
| 1981-A 2/,3/ | 0.41 (0.25) | 3.4 (2.1) | 1.0 (0.62) | 2.0 |
| -B | 0.39/0.41 (0.24/0.25) | 7.0 (4.3) | 0.7 (0.43) | 2.0 |
| 1982-A 2/,3/ | 0.39/0.41 (0.24/0.25) | 7.0 (4.3) | 0.4 (0.25) | 2.0 |
| -B | 0.39/0.41 (0.24/0.25) | 7.0 (4.3) | 0.7 (0.43) | 2.0 |
| 1983 3/ and on | 0.39/0.41 (0.24/0.25) | 7.0 (4.3) | 0.4 (0.25) | 2.0 |

1/ SHED test (grams per test).

2/ Manufacturers have the option of using "A" for 1981 and 1982 or of using "B" for 1981 and 1982. Also, manufacturers have a choice between a 0.24 g/km non-methane hydrocarbon standard and the 0.25 g/km total hydrocarbon standard.

3/ If emission durability is established for 160,000 km (100,000 miles) the NOx standards for Option A are 0.93 g/km (1980-81) and 0.62 g/km (1982-83).

4/ Waiver to 1.5 g/mi (0.93 g/km) possible until 1985.

Table II-2

Gaseous Emission Standards for Light-Duty Trucks
Grams Per Mile (grams per kilometer)

| Federal | HC | CO | NOx | HC Evap. 1/ |
|---|---|---|---|---|
| 1978 | 2.00 (1.24) | 20.0 (12.4) | 3.1 (1.93) | 6.0 |
| 1979 2/ | 1.70 (1.06) | 18.0 (11.2) | 2.3 (1.43) | 6.0 |
| 1980 and on | 1.70 (1.06) | 18.0 (11.2) | 2.3 (1.43) | 6.0 |
| 1981 and on | | | | 2.0 |

| California (0-5999 GVWR) | HC | CO | NOx | HC Evap. 1/ |
|---|---|---|---|---|
| 1978 | 0.90 (0.56) | 17.0 (10.6) | 2.0 (1.24) | 6.0 |
| 1979-80 | | | | |
| (0-3999 IW) | 0.41 (0.25) | 9.0 (5.6) | 1.5 (0.93) | |
| (4-5999 IW) | 0.50 (0.31) | 9.0 (5.6) | 2.0 (1.24) | |
| 1979 | | | | 6.0 |
| 1980 and on | | | | 2.0 |
| 1981-82 | | | | |
| (0-3999 IW) | 0.41 (0.25) | 9.0 (5.6) | 1.0 (0.62) 3/ | |
| (4-5999 IW) | 0.50 (0.31) | 9.0 (5.6) | 2.0 (1.24) 4/ | |
| 1983 and on | | | | |
| (0-3999 IW) | 0.41 (0.25) | 9.0 (5.6) | 0.4 (0.25) 5/ | |
| (4-5999 IW) | 0.50 (0.31) | 9.0 (5.6) | 1.0 (0.62) 3/ | |

| California (6,000 and Larger GVWR) | HC | CO | NOx | HC Evap. 1/ |
|---|---|---|---|---|
| 1978-80 | 0.90 (0.56) | 17.0 (10.6) | 2.3 (1.43) | |
| 1978-79 | | | | 6.0 |
| 1980 and on | | | | 2.0 |
| 1981-82 | 0.60 (0.37) | 9.0 (5.6) | 2.0 (1.24) 6/ | |
| 1983 and on | 0.60 (0.37) | 9.0 (5.6) | 1.5 (0.93) 4/ | |

---

1/ SHED test (grams per test).
2/ Federal weight class for LDT changes from 0-6000 GVWR to 0-8500 pounds GVWR.
3/,4/,5/,6/ If emission durability is established for 160,900 kilometers the NOx standard is: 0.93,3/ 1.24,4/ 0.62,5/ or 1.43,6/ grams per kilometer.

respect to what would be expected without these regulations. National particulate emissions in 1990 from light-duty diesels will be reduced from approximately 152,000-253,000 metric tons per year to 40,000-66,000 metric tons per year. Urban emissions from these vehicles will also decrease 74% in 1990 from 84,000-141,000 metric tons per year to 22,000-37,000 metric tons per year. This emission reduction will reduce light-duty ambient diesel particulate levels in large cities (e.g., New York, Chicago, Dallas) from 2-11 to 0.5-2.9 micrograms per cubic meter. Light-duty diesel particulate levels in smaller cities (e.g., St. Louis, Phoenix) will also decrease from 2-4 to 0.5-1.0 micrograms per cubic meter. Localized levels which occur over and above these larger-scale impacts will also decrease from 5-9 to 1-2 micrograms per cubic meter. These latter impacts could occur as far as 90 meters away from very busy roadways. The primary national ambient air quality standard (NAAQS) for TSP is 75 micrograms per cubic meter.

While these standards are projected to reduce particulate emissions from light-duty deisels by 74%, particulate emissions from these vehicles will still be about 15 times greater than the particulate emissions from a typical catalyst-equipped vehicle powered by a gasoline engine. Thus, while the standards call for significant control, they do not call for control to a level attainable by an alternative type of motor vehicle.

No standards are being promulgated at this time to control any other aspects of diesel particulate besides its total weight. While EPA health effects studies performed thus far indicate that certain organic materials present on the filter used to determine diesel particulate mass emissions may present a greater health hazard than the particulate's effect on ambient TSP levels, there is currently not enough data available on which to base special control of these substances. It is possible, though, that additional standards will be promulgated in the future to control the emission of any particularly dangerous compounds as more becomes known about their effect on health.

The new standard for particulate emissions could affect the stringency of current gaseous emission standards, especially the NOx standard, since some techniques for controlling NOx emissions increase particulate emissions. This effect has been taken into account in setting the level of the particulate standards contained in this regulation and should not be a problem. The accompanying changes in the test equipment are not expected to affect the stringency of the gaseous emission standards already in effect. The dilution tunnel should be equally effective as the baffle box in mixing the exhaust with the dilution air and the additional dilution air should not affect the measurement of gaseous emissions.

C. Organization of the Statement

This statement presents an assessment of the environmental and economic impacts of the particulate emission regulations for light-duty diesels which EPA is promulgating. It provides a description of the information and analyses used to review all reasonable alternative actions and make the final decision.

The remainder of this statement is divided into six major sections. Chapter III presents a brief description of the manufacturers of light-duty vehicles and the market in which they compete.

An analysis of available particulate control technology is presented in Chapter IV. Potential emission standards and their timing are also discussed in detail.

An assessment of the primary and secondary environmental impacts attributed to these particulate regulations is given in Chapter V. The degree of control reflected by the standards is described and a projection of national particulate emissions in 1990 is presented. The impacts of these regulations on urban and roadside air quality are also presented. Secondary effects on other air pollutant emissions, water pollution and noise are also discussed in this section.

An examination of the cost of complying with the new regulations is presented in Chapter VI. These costs include those incurred to install emission control equipment on vehicles and trucks, costs required to purchase new emission testing equipment, and the costs to certify new vehicles for sale, as well as any increased vehicle operating costs which might occur. Analysis is made to determine aggregate cost for the 1982-1989 time frame. Finally, the impact that this regulation will have on industry and consumers will be reviewed.

Chapter VII will present a cost effectiveness analysis of this action and compare the results of this analysis with those performed on other mobile source and stationary source control strategies.

Chapter VIII will examine alternative mobile source control options including alternative approaches to regulating light-duty diesel particulate emissions and alternative per vehicle emission standards. It also will explain why the alternatives of achieving additional reduction of emissions from other mobile sources or stationary sources were not considered to be acceptable substitute actions for these regulations.

References

1/ "National Air Quality and Emissions Trends Report, 1976," OAQPS, OAWM, EPA, December 1977, EPA-450/1-77-002.

2/ "National Assessment of the Urban Particulate Problem, Volume I: National Assessment," OAQPS, OAWM, EPA, July 1976, EPA-450/3-76-024.

3/ "Particulate Regulation for Light-Duty Diesel Vehicles," Federal Register, Vol. 44, No. 23, Thursday, February 1, 1979, pp. 6650-6671.

4/ "Summary and Analysis of Comments, Light-Duty Diesel Particulate Regulations," MSAPC, EPA, October 1979.

5/ Black, Frank, "Comments on Recommended Practice for Measurement of Gaseous and Particulate Emissions from Light-Duty Diesel Vehicles," ORD, EPA, April 13, 1978.

# CHAPTER III

# DESCRIPTION OF LDV AND LDT INDUSTRY

## A. Definition of Product

A light-duty vehicle (LDV) is currently defined as a passenger car or passenger car derivative capable of seating 12 passengers or less.

A light-duty truck (LDT) is any motor vehicle rated at 8500 pounds (3546 kg) Gross Vehicle Weight Rating (GVWR) or less, has a vehicle curb weight of 6000 pounds (2722 kg) or less and a maximum basic vehicle frontal area of 46 square feet (4.3 square meters) and is: a) designed primarily for purposes of transportation of property or is a derivative of such a vehicle, b) designed primarily for transportation of persons having a capacity of more than 12 persons or c) available with special features enabling off-street or off-highway operation and use.

## B. Structure of the Industry (Production and Marketing)

U.S. manufacture of light-duty vehicles is almost entirely done by the five major motor vehicle manufacturers: General Motors, Ford Motor Company, Chrysler Corp., Volkswagen of America, and American Motor Corp. In 1978, sales of passenger cars totalled 11.4 million of which 9.3 million were of domestic origin, 0.8 million were from Canada and 1.3 million were from foreign manufacturers. The major foreign importers were Toyota, Volkswagen, Nissan, Honda and Fiat.

The manufacture of light-duty trucks sold in the U.S. is primarily accomplished by the major domestic passenger car producers. General Motors Corporation (Chevrolet and GMC divisions), Ford Motor Company and Chrysler Corporation (Dodge Truck Division) all have separate truck divisions which produce light-duty as well as heavy-duty trucks. American Motors Corporation operates the Jeep division which manufactures light-duty trucks. The other major domestic manufacturer of LDT's is the International Harvester Corporation (IHC).

Some LDT's sold in the U.S. are imported. The majority of U.S. imports of trucks come from the Canadian plants operated by U.S. domestic producers. Some imports, primarily light pick-up trucks, under 4,000 pounds (1814 kg) GVWR, come from Japanese producers. The major importers are Nissan (Datsun), Toyota, Isuzu, and Toyo Kogyo. Both Toyota and British Leyland Company import utility vehicles under 6,000 lbs. (2722 kg) GVWR. Imports accounted for about 6% of all 1978 factory sales of trucks with a GVWR less than 8500 pounds (3856 kg) GVWR.

Table III-1 shows unit factory sales for LDV's and LDT's from U.S. plants. Most data available on LDT's are presented in a 0-10,000 pound (0-4536 kg) category. Since the definition of LDT's includes only vehicles up to 8,500 pound (3846 kg) GVWR, some adjustment to the 0-10,000 pound category was necessary for this analysis. The industry production data available to EPA indicates that slightly over five percent of all trucks with GVWR's less than 10,000 pounds (4536 kg) have GVWR's of more then 8,500 pounds (3856 kg). This five percent figure is used in Table III-1 and throughout this analysis to adjust production data to fit the new LDT definition.

Table III-2 shows new car and truck registrations for 1974 through 1976. These figures represent the numbers of both domestic and imported vehicles bought by U.S. consumers in those years. This table also includes total passenger car and motor trucks that were registered in 1974 through 1976.

Table III-3 is a breakdown of registrations by manufacturer for 1978 LDV's. Also included is the percent of the passenger car market registrations for each manufacturer.

Table III-4 gives similar information for the LDT industry. It should be noted that Table III-4 gives market shares for 0-10,000 pounds (0-4536 kg) GVW truck sales. Data indicating the portion of sales for 0-8,500 pounds (0-3856 kg) GVW LDT for each manufacturer were not available and the assumption that slightly over 5 percent of sales would be over 8500 lbs. (3856 kg) GVWR is not valid for all manufacturers.

Sales of diesel powered light-duty vehicles and trucks are still a small fraction of total production, but are steadily increasing each year. Diesel penetration into the two markets by the late 1980's has been projected to be a high as 25%. Table III-5 shows past sales and 1979 projections of diesel sales in the U.S.

U.S. light-duty vehicle and truck manufacturers operate with a fair degree of vertical integration. As is typical of many capital intensive industries, the manufacturer seeks to assure itself of some control over the quality and availability of the final product. Thus, the major manufacturing companies have acquired subsidiaries or started divisions to produce many of the parts used in the manufacture of their cars and trucks. None, however, build their vehicles without buying some equipment from independent vendors.

The vertical integration typical of passenger car and truck manufacturers extends beyond the production of the vehicle into its sale. The manufacturers establish franchised dealerships to handle retail trade and servicing of their products. Most also produce and sell the parts and accessories required to service their

Table III-1

LDT and LDT Factory Sales from U.S. Plants 1/

| Type of Vehicle | 1978 2/ | 1977 2/ | 1976 3/ | 1975 3/ | 1974 4/ | 1973 |
|---|---|---|---|---|---|---|
| Light-Duty Vehicle | 9,165,190 | 9,200,849 | 8,497,603 | 6,712,852 | 7,331,946 | 9,657,647 |
| Light-Duty Truck 5/ | 3,099,966 | 2,897,080 | 2,505,448 | 1,848,223 | 2,154,892 | 2,372,269 |
| TOTAL: | 12,265,156 | 12,097,929 | 11,003,051 | 8,561,075 | 9,486,838 | 12,029,916 |

Source: Motor Vehicle Manufacturers Association of the United States, Inc.



---

1/ Includes those vehicles produced in U.S. that are exported.

2/ Data from Automotive News, 1979 Market Data Book, April 25, 1979, pp. 20, 40.

3/ Data from Automotive News, 1977 Market Data Book, pp. 48, 62.

4/ Data from Automotive News Almanac, 1975.

5/ Assumed to be 95% of sales of trucks less than 10,000 lb. GVW.

Table III-2

New Vehicle Registrations 1/

| Source | New Vehicle Registrations | | |
|---|---|---|---|
| | 1976 | 1975 | 1974 |
| LDV | 9,751,485 | 8,261,840 | 8,701,094 |
| LDT | 2,588,213 | 2,397,417 | 2,656,918 |
| TOTAL: | 12,339,698 | 10,659,257 | 11,358,012 |

| Source | Total Vehicle Registrations | | |
|---|---|---|---|
| | 1976 | 1975 | 1974 |
| LDV | 110,583,722 | 107,371,000 | 104,901,066 |
| LDT and HDV | 26,560,296 | 26,356,000 | 25,036,736 |
| TOTAL: | 137,144,018 | 133,727,000 | 129,937,802 |

Source: 1974 and 1975 Data: Automotive News Almanac, 1976.
1976 Data: Automotive News, 1977 Market Data Book Issue.

1/ Includes imports.

Table III-3

New Car Registration of Light-Duty Vehicles by Manufacturer for 1978

| Manufacturer | Number of Units Produced | % of Passenger Vehicle Market |
|---|---|---|
| General Motors | 5,217,554 | 47.7 |
| Ford | 2,508,249 | 22.9 |
| Chrysler | 1,112,111 | 10.2 |
| Toyota | 427,465 | 3.9 |
| Nissan (Datsun) | 337,523 | 3.1 |
| Honda | 258,151 | 2.4 |
| Volkswagen | 239,612 | 2.2 |
| American Motors | 157,797 | 1.4 |
| Other | 687,642 | 6.2 |
| TOTAL | 10,946,104 | 100.0 |

Source: Automotive News, 1979 Market Data Book Issue, p. 14 and 61.

Table III-4

U.S. Sales of Light-Duty Trucks by Manufacturer for 1978 1/

| Manufacturer | Number of U.S. Sales | % of Light Truck Market |
|---|---|---|
| Chevrolet | 1,233,932 | 35 |
| GMC | 283,540 | 8 |
| Ford | 1,219,693 | 34 |
| Chrysler | 404,514 | 11 |
| AMC/Jeep | 163,548 | 5 |
| IHC | 36,065 | 1 |
| Other Manufacturers 2/ | 210,041 | 6 |
| TOTAL | 3,551,333 | 100% |

Source: Automotive News, 1979 Market Data Book, P. 44.

1/ LDT defined as 0-10,000 pounds GVW.
2/ Includes imports.

Table III-5

U.S. Sales of Diesel-Powered Light-Duty Vehicles and Trucks

| Model | 1976 | 1977 | 1978 | 1979* |
|---|---|---|---|---|
| Mercedes-Benz 1/ | | | | |
| 240D | 9,024 | 9,770 | 6,600 | 8,600 |
| 300D | 12,521 | 11,333 | 16,000 | 15,300 |
| 300SD | -0- | -0- | 5,200 | 9,300 |
| VW Rabbit 2/ and Dasher | -0- | 7,500 | 36,386 | 110,000 |
| Peugeot 504D 3/ | 4,549 | 4,914 | 5,547 | 8,100 |
| General Motors 4/ | | | | |
| 350 Oldsmobile | -0- | -0- | 35,180 | 118,000 |
| 350 Pick-up | -0- | -0- | 16,920 | 31,000 |
| 260 Oldsmobile | -0- | -0- | -0- | 50,000 |
| IHC Scout 5/ | 970 | 1,237 | 1,231 | 1,000 |
| TOTAL | 27,064 | 34,754 | 123,064 | 351,300 |

* Projections.
1/ Personal communication with Martin Emberger, Mercedes-Benz, April 3, 1978.
2/ Personal communication with L.L. Nutson, Volksagen, April 4, 1978.
3/ Personal communication with Richard Lucki, Peugeot, March 1978.
4/ Personal communication with A. Lucas, General Motors, April 7, 1978.
5/ Personal communication with T.A. Jacquay, IHC, March 1978.

vehicles. Many of the truck dealerships are coupled with the passenger car dealerships. As of January 1979, there was a total of 24,051 passenger car dealerships and 22,189 truck dealerships The total truck dealerships include dealerships for heavy-duty as well as light-duty trucks, and accounts for those dealerships operating jointly with passenger car sales offices.

Table III-6 provides a breakdown of all light-duty vehicle dealerships by manufacturer and Table III-7 provides this information for truck dealerships. The "Others" category in Table III-7 includes dealerships of manufacturers that produce only heavy-duty vehicles, and also 1,211 dealerships for Plymouth which introduced the 4-wheel drive Trail Duster (an off-road utility vehicle) in 1974.

## C. Sales and Revenues

Vehicle sales from domestic manufacturers for 1978 were 14.6 million vehicles at a total wholesale value of about $122 billion. For 1977, 14.4 million vehicles were sold at a wholesale values of $112 billion. Total profits for the domestic manufacturers were $4.9 billion in 1978 and $5.2 billion in 1979.

## D. Employment

It is estimated that about three and a half million workers are employed in the manufacturing, wholesaling and retailing of motor vehicles (passenger cars, trucks, and buses) with a total of about $53 billion in wages paid to those employees. Most employment data are aggregated for producers of all classes of cars and trucks since some production facilities manufacture both cars and trucks. Statistics show that over 14 million workers were employed in 1973 by motor vehicle related industries. The total annual payroll of these workers amounted to over $119 billion (1973). Much of this employment is centered in California, Michigan, Ohio, New York, Indiana, Illinois, Missouri, and Wisconsin.

Table III-6

Passenger Car Dealerships by Manufacturer

| Manufacturer | Total Franchises as of Jan. 1,1979 | Dealers as of Jan. 1, 1979 | Unit Sales Per Outlet 1978 | Unit Sales Per Outlet 1977 |
|---|---|---|---|---|
| American Motors | 1661 | 1661 | 105 | 112 |
| Chrysler Corp. | 9174 | 4786 | | |
| Chrysler | 3343 | | 89 | 96 |
| Dodge | 2816 | | 158 | 162 |
| Plymouth | 3015 | | 133 | 143 |
| Ford Motor Co. | 10190 | 6639 | | |
| Ford | 5564 | | 326 | 335 |
| Lincoln | 1642 | | 115 | 112 |
| Mercury | 2948 | | 195 | 172 |
| General Motors Corp. | 17210 | 11565 | | |
| Buick | 3050 | | 256 | 245 |
| Cadillac | 1635 | | 215 | 207 |
| Chevrolet | 5950 | | 394 | 381 |
| Oldsmobile | 3330 | | 302 | 294 |
| Pontiac | 3245 | | 277 | 249 |
| TOTALS: | 38235 | 24651 | | |
| Minus Intercorporate Dealers | | 600 | | |
| Net Dealers: | | 24051 | | |

Source: Automotive News, 1979 Market Data Book, pp. 62,71.

Table III-7

Truck Retail Outlets by Manufacturer

| Manufacturer | Outlets as of Jan. 1, 1979 | Unit Sales Per Outlet 1978 |
|---|---|---|
| Ford | 5648 | 233 |
| Chevrolet | 5939 | 215 |
| GMC | 2721 | 121 |
| Dodge | 3284 | 141 |
| IHC | 1675 | 70 |
| American Motors | 1768 | 93 |
| Others | 2822 | --- |
| TOTALS: | 23827 | 24651 |
| Adjustment for Multiple Franchises | 1638 | |
| Net Dealers: | 22189 | |

Source: Automotive News, 1979 Market Data Book, pp. 44, 98.

# CHAPTER IV

# STANDARDS AND TECHNOLOGY

## A. Background

### 1. Basis and Nature of Standards

The first federal air pollution legislation was the Air Pollution Control Act passed by Congress in 1955. It was not until 1963, however, that the federal government confronted the seriousness of the air pollution problems then facing the United States. Finding that "the predominant part of the Nation's population is located in its rapidly expanding metropolitan and other urban areas, which generally cross the boundary lines of local jurisdictions and often extend into two or more states,"1/ and that "the growth in the amount and complexity of air pollution brought about by urbanization, industrial development, and the increasing use of motor vehicles, has resulted in mounting dangers to the public health and welfare, including injury to agricultural crops and livestock, damage to and the deterioration of property, and hazards to air and ground transportation,"2/ Congress passed the Clean Air Act of 1963 to (among others) "protect the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population."3/ Since that time, Congress has modified the Clean Air Act with the Motor Vehicle Air Pollution Control Act of 1965, the Clean Air Act Amendments of 1966, the Air Quality Act of 1967, the Clean Air Act Amendments of 1970, and the Clean Air Act Amendments of 1977.

In view of the substantial air pollution contribution made by motor vehicles, and the transient, interstate nature of their usage, the Administrator of the Environmental Protection Agency (EPA) has been given broad authority to: "prescribe (and from time to time revise) in accordance with the provisions of this section, standards applicable to the emission of any air pollutant from any class or classes of new motor vehicles or new motor vehicle engines, which in his judgment cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health or welfare."4/ In many cases, Congress itself has mandated specific motor vehicle emissions reductions, as with hydrocarbon (HC), carbon monoxide (CO), and nitrogen oxides (NOx) emissions.

As a result of the concern over the public health and welfare implications of an increasingly dieselized motor vehicle population, Congress approved an amendment to the Clean Air Act in 1977 that mandates the particulate regulations for motor vehicles. Section 202(a)(3)(A)(iii) states that: "The Administrator shall prescribe regulations under paragraph (1) of this subsection applicable to emissions of particulate matter from classes or categories of vehicles manufactured during and after model year

1981 (or during any earlier model year, if practicable). Such regulations shall contain standards which reflect the greatest degree of emission reduction achievable through the application of technology which the Administrator determines will be available for the model year to which such standards apply, giving appropriate consideration to the cost of applying such technology within the period of time available to manufacturers and to noise, energy, and safety factors associated with the application of such technology. Such standards shall be promulgated and shall take effect as expeditiously as practicable taking into account the period necessary for compliance."

There has been considerable confusion over the role of the carcinogenicity question in this rulemaking. Many diesel health effects programs have been undertaken, with special emphasis on the questions of mutagenicity and carcinogenicity, but these programs will not produce final results for some time. This Rulemaking is in direct response to Section 202(a)(3)(A)(iii) and as such is concerned with total particulate and not with any particular component of the particulate.

Clearly, it is only through the application of best available control technology that "the greatest degree of emission reduction" can be achieved. EPA examined a number of approaches that could have been used in setting the particulate standards. The approaches considered included setting a standard requiring the best available control technology, and:

1) Based on the lowest particulate level achievable by the best light-duty diesel with respect to particulate emissions;

2) Based on the lowest particulate level achievable by the best light-duty vehicle (gasoline or diesel) with respect to particulate emissions;

3) Based on the lowest particulate level achievable by the worst light-duty diesel with respect to particulate emissions;

4) Requiring an equal level of effort by all manufacturers on each of their vehicle lines.

We rejected the first approach because it would have prevented all diesels from being marketed except for subcompacts and possibly small pick-ups with small engines. The "appropriate consideration" to leadtime, cost, noise, energy, and safety factors required by Section 202(a)(3)(A)(iii) has convinced EPA that Congress did not intend, as a result of this Section, to force any diesel powered vehicles out of production. We did not select the second approach for the same reason; in fact, since gasoline-powered vehicles with three-way catalysts emit very low levels of particulate, a standard based on this approach would likely prevent any light-duty diesel vehicles from being sold in this country. The fourth approach would be workable only if an engine or vehicle parameter could be determined to affect particulate emissions to such an extent that a graduated standard could be based on that parameter. No such parameter has been identified. In addition, adoption of the fourth approach would result in different standards for vehicles competing in the same market. This would conflict with the standard policy of equal treatment towards all light-duty vehicles which have the general purpose of personal transportation. Thus, we based the particulate standards on the lowest particulate levels achievable by the worst light-duty diesel with respect to particulate emissions. This approach allows standards which provide significant particulate reductions, but which do not force any diesel models out of production, unless the manufacturer refuses to make the necessary changes to meet the standards. This approach requires at least some manufacturers to utilize the best available control technology.

When projecting a near-term standard when little time exists for technological advances, it is relatively simple for a regulatory agency to predict what the best available control technology will be, and to set a standard based on its application. It is more difficult to regulate on this basis in the long-term because of the uncertainty that inevitably surrounds expected technological improvements. Nevertheless, to fulfill the "greatest degree of emission reduction" mandate of the Clean Air Act, EPA has concluded that it is absolutely necessary to issue standards which motivate the private sector to maximize its efforts in reducing particulate emissions from light-duty diesel vehicles. Experience has shown that in absence of the regulatory incentive, the automotive industry has often ignored environmental concerns. This is not surprising, as emission control is a classical economic externality to the automotive manufacturer, and as such would receive little or no attention due to pressure from the marketplace. The attempt to require best available control technology in the future often requires technology-forcing standards, standards which are admittedly unattainable at the time they are proposed, but which the regulatory agency expects to be attainable by the time they take effect. While recognizing the inherent uncertainty of technology-forcing standards, EPA reaffirms its support of them in general, and of their application in this particular rulemaking. Both the 1982 and 1985 particulate standards have been based upon the levels achievable by the highest particulate-emitting light-duty diesel vehicle utilizing best available control technology.

2. Particulate/NOx Relationship

One factor that had complicated the diesel particulate regulations was the uncertainty surrounding the diesel NOx standard for the years 1981 to 1984. The Clean Air Act mandated a light-duty vehicle NOx standard of 1.0 g/mi (0.62 g/km) beginning with the 1981 model year,5/ but it included a provision allowing EPA to waive the NOx standard to 1.5 g/mi (0.93 g/km) for light-duty diesel vehicles for model years 1981 to 1984.6/

The primary NOx control technique presently used is exhaust gas recirculation (EGR). It is expected that EGR would be used by many manufacturers to meet a 1.5 g/mi (0.93 g/km) NOx standard, and by practically every manufacturer (at higher rates) to meet a 1.0 g/mi (0.62 g/km) NOx standard. It is well known that EGR increases particulate emissions, and that the greater the EGR rate, the greater the increase in particulate emissions. Thus the level of the diesel NOx standard has a significant effect on the level and feasibility of the diesel particulate standards.

In the Notice of Proposed Rulemaking (NPRM), EPA assumed that the NOx waiver would not be granted to any manufacturer.7/ Thus, the proposed standards were based on the worst-case scenario for particulate emissions, i.e., on the assumption that light-duty diesel vehicles would require relatively large EGR rates to meet the most stringent NOx standard.

Data received from the industry have convinced EPA that with the current state of diesel emission control technology, NOx control to 1.0 g/mi (0.62 g/km) is not feasible at this time with acceptable durability and particulate emissions control for all engine families. Thus, EPA has granted NOx waivers for several 1981-82 model year light-duty diesel engine families. Those waivers which were rejected were rejected based on insufficient information. If sufficient emissions data are provided, the remaining engine families are also eligible for NOx waivers.

In the near-term, it has been important to consider the diesel particulate and diesel NOx issues simultaneously, because of their interrelationship through the use of EGR. EPA has done this in its technical analyses. In the future, EPA expects this interrelationship to lessen as NOx control technologies are developed which do not impact on particulate emissions.

3. Design Targets

EPA recognizes the problems involved in setting emissions standards that future production vehicles will be required to meet, based on data primarily from low-mileage, research-prototype vehicles. We understand the necessity of designing such research prototypes to emissions levels below the standards with which the production and durability vehicles must ultimately comply. Prototype-to-certification slippage, car-to-car variability, test-to-test variability, and deterioration factors must all be taken into account when anticipating the emission level that will be achievable for production vehicles based on low-mileage, research-prototype vehicles.

There will likely be a certain slippage between the particulate levels of research-prototype vehicles and the levels a manufacturer could confidently expect to achieve with certification vehicles. Based on our experience with the certification process, we would expect this margin to be small. It is now fairly common for major manufacturers to perform their emissions control development on duplicate vehicles,8/ which reduces the likelihood of erroneously obtaining very low emissions levels due to an atypical vehicle.

EPA considers the concerns over car-to-car variability to be misplaced. Although there will likely be production variability with respect to particulate emissions, it is expected to be small. The statistical sampling program used in Selective Enforcement Auditing also considers production variability. Test-to-test variability, which can be considered a part of car-to-car variability, also is not a serious problem. EPA has found diesel particulate test-to-test variability to be less than 5 percent and GM has reported similar results.9/ In any case, we expect both car-to-car and test-to-test variability to improve in the future as the manufacturers become more familiar with diesel particulate control techniques and the test procedures.

Our original assumption of a negligible diesel particulate deterioration factor10/ was based on the low HC deterioration factors of 1978 certification diesel vehicles and on the well known stability of the compression ignition engine. The stability of diesel HC with mileage accumulation is reaffirmed by the 1979 certification data; the average HC deterioration factor for light-duty diesel vehicles was 1.06. While we do not claim that HC deterioration factors are perfect indicators of particulate deterioration factors, the former are one gauge we have to predict the latter.

GM was the only manufacturer to report any particulate durability data. GM calculated particulate deterioration factors for four cars, shown in Table IV-1. They were all based on limited data.

It is rather difficult to draw any conclusions from the data in Table IV-1. The 1976 Opel was used for particulate trap development by GM. The data used in the deterioration factor calculation for this vehicle were all gathered as baselines with standard exhaust systems during this development program <u>except</u> for the 5,000-mile data which were gathered prior to the trap development program. If the 5,000-mile data were excluded, the particulate deterioration factor would be very close to 1.0. It should also be noted that the lowest deterioration factors were for the 5.7-liter GM engine, while the higher values were for the Opel 2.1-liter engine that is not sold in the U.S. Finally, particulate data were reported for one other GM 1980 5.7-liter, 4,500-pound vehicle with

Table IV-1

GM Particulate Deterioration Factors 11/

| Car/Displacement | Test | Particulate DF |
| --- | --- | --- |
| 80 Olds Delta 88/5.7 L | 50 K AMA | 1.03 |
| 80 Olds Delta 88/5.7 L + EGR | 27.6 K AMA | 0.66 |
| 78 Opel/2.1 L + EGR | 50 K AMA | 1.26 |
| 76 Opel/2.1 L | Trap development Baseline Tests | 1.53 |

limited mileage accumulation in GM's NOx Waiver Application submitted to EPA in May, 1979.12/ Four emissions tests were performed both at 5,500 and at 19,000 miles on car 86597, two tests with EGR and two tests without EGR at each mileage. All mileage accumulation was with EGR. With EGR the particulate emissions dropped from 0.86 g/mi (0.53 g/km) at 5,500 miles to 0.67 g/mi (0.42 g/km) at 19,000 miles. Without EGR the particulate emissions went from 0.47 g/mi (0.29 g/km) to 0.42 g/mi (0.26 g/km). Thus, for car 86597 the particulate deterioration factor appears to be less than one, both with and without EGR.

GM somehow interpreted the data in Table IV-1 to conclude that particulate deterioration factors would be in the range of 1.2 to 1.4.13/ The foregoing analysis of GM's own data indicates that there is no basis for that conclusion. Rather, GM's durability data, the low diesel HC deterioration factors, and the stable nature of the diesel engine all indicate that particulate deterioration factors will be very low, most likely in the range of 1.0 to 1.1.

The EPA technical staff concludes that the claims made by many manufacturers that they must design to levels 40 to 50 percent lower than the particulate standard are greatly exaggerated. Certainly design targets are necessary, but at most a 20 percent safety margin appears quite adequate.

4. Baseline

As part of the initial particulate characterization process, a comprehensive particulate baseline was developed by testing 25 light-duty diesel vehicles and trucks. The most relevant particulate data, those from 1979 certification diesel vehicles, are given in Table IV-2.

B. 1982 Standard

EPA had proposed that a 0.60 g/mi (0.37 g/km) particulate standard be set for the 1981 model year and had predicted that every manufacturer would be able to meet that standard through engine modifications and minor engine redesign. This position was primarily based on the fact that although many diesel engine designs had been optimized for smoke-limited performance, none had been optimized for particulate emissions. Thus, EPA expected that particulate optimization would be possible, especially at light loads where the correlation between smoke opacity and particulate emissions is not very strong. Recognizing most engine modifications to be manufacturer-specific, the one control technology we predicted to be universally applicable was turbocharging. Data available to us during our initial analysis indicated that turbocharging reduced particulate emissions by approximately one-third. 15/

Table IV-2

1979 Light-Duty Diesel Certification Particulate Baseline 14/

| Vehicle | Particulate (g/mi) | (g/km) |
|---|---|---|
| Typical Gasoline-powered vehicle (w/catalyst) | 0.008 | 0.005 |
| VW Rabbit | 0.23 | 0.14 |
| Peugeot 504 | 0.29 | 0.18 |
| VW Dasher | 0.32 | 0.20 |
| IHC Scout (Nissan) | 0.32-0.47 | 0.20-0.29 |
| Daimler-Benz 300 SD | 0.45 | 0.28 |
| Daimler-Benz 240D | 0.53 | 0.33 |
| Chevrolet Pickup (Oldsmobile) | 0.59 | 0.37 |
| Dodge Pickup (Mitsubishi) | 0.61 | 0.38 |
| Oldsmobile 260 | 0.73-1.02 | 0.45-0.63 |
| Daimler-Benz 300D | 0.83 | 0.52 |
| Oldsmobile 350 | 0.84 | 0.52 |

The position that particulate reductions due to minor engine modifications are dependent on each individual manufacturer and design is supported by the fact that no specific modification was unanimously endorsed by the manufacturers in their comments to the NPRM, yet almost every manufacturer found one or more areas in which improvements could be made. GM and Fiat both claimed that redesigned fuel injectors could be effective; in fact, GM credited much of their very substantial particulate reduction in their 1980 design to their new poppet fuel injectors. Combustion chamber optimization was performed by both GM and Daimler-Benz, with the latter adding a hole in their prechamber. An area where some success has been achieved but where more work is necessary is injector timing adjustments. Daimler-Benz reported particulate reductions due to retarded timing at part load, and GM indicated the possibility of doing likewise, but Peugeot pointed out the necessity of optimizing HC and particulate simultaneously, and Fiat provided data showing particulate increasing with retarded timing; to lower particulate Fiat would have to advance its timing and raise its NOx emissions. Derating was supported by Ricardo and DOE but Fiat claimed it would not work for light-duty diesels because of the part load nature of the FTP. Manufacturers disagreed over whether turbocharging reduced particulate emissions. Peugeot and Fiat both incorporated turbochargers into their 1981 designs and claimed that turbocharging does reduce particulate; Daimler-Benz and GM denied that turbocharging reduced particulate; the remaining manufacturers did not take positions on the issue. EPA is convinced that turbocharging can be an effective particulate control strategy, provided that a concerted effort is made to match and optimize the turbocharger application to the engine's intake, exhaust, and injection systems, and that the increased thermal efficiency is utilized to optimize transmission gearing and axle ratio for emissions rather than for increased performance. (For a more complete discussion of the turbocharging issue, see Reference 16).

Table IV-3 summarizes the most promising particulate/NOx data received from the manufacturers' in-house diesel development programs. The data generally includes the best particulate data at NOx levels of 1.5 g/mi (0.93 g/km) or less, but for Daimler-Benz and Volkswagen the data listed are the only data submitted to EPA. The considerable progress that has been made in particulate emission control can be seen in Table IV-4 which compares the 1981 prototype and 1979 certification particulate levels for those models for which the data is available. It is important to note that the greatest particulate reductions achieved by engine modifications were by GM and Daimler-Benz, the manufacturers which had the highest particulate baseline levels.

Based on the data in Table IV-3, and the analyses that follow, EPA has concluded that all manufacturers would be able to comply with a 0.60 g/mi (0.37 g/km) particulate standard in 1981 with

Table IV-3

Best Particulate/NOx Data as Reported by Manufacturers

| Manufacturer and Model | Engine Size (l) | Vehicle Weight (lb) | Particulate (g/mi) | Particulate (g/km) | NOx (g/mi) | NOx (g/km) | Comments |
|---|---|---|---|---|---|---|---|
| Daimler-Benz 17/, 18/ | | | | | | | |
| 240D | 2.4 | 3,500 | 0.40 | 0.25 | 1.47 | 0.91 | "1981 Projections" w/EGR, 2 tests |
| 300D | 3.0 | 3,875 | 0.30 | 0.19 | 1.31 | 0.81 | "1981 Projections" w/EGR, 2 tests |
| 300SD | 3.0 | 4,000 | 0.47 | 0.29 | 1.21 | 0.75 | "1981 Projections" w/EGR, TC, 2 tests |
| Peugeot 19/ | | | | | | | |
| 504D | 2.3 | 3,500 | 0.49 | 0.30 | 1.51 | 0.94 | Prototype |
| 504D | 2.3 | 3,500 | 0.44 | 0.27 | 1.08 | 0.67 | Prototype w/EGR, TC |
| Volkswagen 20/ | | | | | | | |
| Rabbit | 1.5 | 2,250 | 0.33 | 0.21 | 1.07 | 0.67 | Seven Production Vehicles |
| Dasher | 1.5 | 2,500 | 0.42 | 0.26 | 1.46 | 0.91 | Ten Production Vehicles |
| Audi 5000D | 2.0 | 3,000 | 0.65 | 0.40 | 1.73 | 1.08 | Eight Production Vehicles |
| Audi 5000D | 2.0 | 3,000 | 0.58 | 0.36 | 1.87 | 1.16 | Three Prototypes w/TC |
| Fiat 21/ | 2.4 | 3,000 | 0.53 | 0.33 | 1.19 | 0.74 | Prototype w/EGR, TC |
| General Motors 22/,23/,24/ | | | | | | | |
| "260" | 4.3 | 4,000 | 0.27 | 0.17 | 1.01 | 0.63 | Prototype 72204 w/EGR, 3 tests |
| "260" | 4.3 | 4,000 | 0.41 | 0.25 | 1.06 | 0.66 | Prototype 93516 w/EGR, 4 tests |
| "260" | 4.3 | 4,000 | 0.50 | 0.31 | 1.29 | 0.80 | Prototype 93513 w/EGR, 2 tests |
| "260" | 4.3 | 4,000 | 0.56 | 0.35 | 1.10 | 0.68 | Prototype 93514 w/EGR, 2 tests |
| "350" | 5.7 | 4,500 | 0.43 | 0.27 | 1.20 | 0.75 | Prototype 96558 w/EGR, interpolated from GM graph |
| "350" | 5.7 | 4,500 | 0.36 | 0.22 | 1.15 | 0.71 | Prototype 96589 w/EGR, 3 tests (2/79) |
| "350" | 5.7 | 4,500 | 0.39 | 0.24 | 1.00 | 0.62 | Prototype 96589 w/EGR, 2 tests (6/79) |
| "350" | 5.7 | 4,500 | 0.56 | 0.35 | 1.10 | 0.68 | Prototype 86634 w/EGR, 2 tests 8,000 miles |

Table IV-4

Comparison of Particulate Levels of 1979 Certification Vehicles and 1981 "Best" Prototypes

| Manufacturer | Model | 1979 Baseline Particulate Level 14/ (g/mi) | 1979 Baseline Particulate Level 14/ (g/km) | Best 1981 Prototype Particulate Level* 17/,18/,19/ 22/,23/,24/ (g/mi) | Best 1981 Prototype Particulate Level* 17/,18/,19/ 22/,23/,24/ (g/km) |
|---|---|---|---|---|---|
| General Motors | "260" | 0.73-1.02 | 0.45-0.63 | 0.27-0.56 | 0.17-0.35 |
| | "350" | 0.84 | 0.52 | 0.36-0.56 | 0.22-0.35 |
| Daimler-Benz | 240D | 0.53 | 0.33 | 0.40 | 0.25 |
| | 300D | 0.83 | 0.52 | 0.30 | 0.19 |
| | 300SD | 0.45 | 0.28 | 0.47 | 0.29 |
| Peugeot | 504D | 0.29 | 0.18 | 0.49 | 0.30 |

*At NOx levels of 1.5 gpm or less.

Table IV-5

EPA/Volkswagen Particulate Measurement Comparisons

| Model | EPA Particulate Result (g/mi) | EPA Particulate Result (g/km) | VW Particulate Result 20/ (g/mi) | VW Particulate Result 20/ (g/km) | Difference |
|---|---|---|---|---|---|
| 79 Rabbit | 0.23 14/ | 0.14 | 0.33 | 0.21 | + 43% |
| 79 Dasher | 0.32 14/ | 0.20 | 0.42 | 0.26 | + 31% |
| 79 Audi 5000D | 0.46 26/ | 0.29 | 0.65 | 0.40 | + 41% |
| DOT Special Build Rabbit | 0.20 14/ | 0.12 | 0.25 | 0.16 | + 25% |

currently available designs. Unfortunately, however, there is insufficient certification leadtime available for 1981. A manufacturer which waited until after the final rule was published would not have sufficient time to fulfill durability and certification requirements. Thus, the 0.60 g/mi (0.37 g/km) particulate standard will not apply until the 1982 model year. It must be emphasized that the delay is due to insufficient certification leadtime and not technological infeasibility.

In their comments to the NPRM, Daimler-Benz, Peugeot, and Fiat all stated that it was quite probable that they could meet a 0.60 g/mi (0.37 g/km) particulate standard in 1981 at a NOx level of 1.5 g/mi (0.93 g/km) or less.17/,19/,21/ The data in Table IV-3 support their conclusions. EPA has already granted NOx waivers for several 1981-82 model year light-duty diesel engine families in order to allow those manufacturers which showed an inability to achieve the 1.0 g/mi (0.62 g/km) NOx standard in 1981 sufficient leadtime to reduce NOx emissions with acceptable durability and particulate emissions control (Federal Register, January 23, 1980). Daimler-Benz received the NOx waiver for its 240D, 300D, and 300SD engine families, Peugeot was denied a waiver because of insufficient data, and Fiat did not apply for a waiver. Fiat and Peugeot will be eligible for NOx waivers if and when sufficient emissions data are provided to show that they cannot meet 1.0 g/mi (0.62 g/km) NOx without significantly increasing particulate emissions. The availability of the NOx waiver ensures that Daimler-Benz, Peugeot, and Fiat will all be able to comply with the 0.60 g/mi (0.37 g/km) particulate standard in 1982.

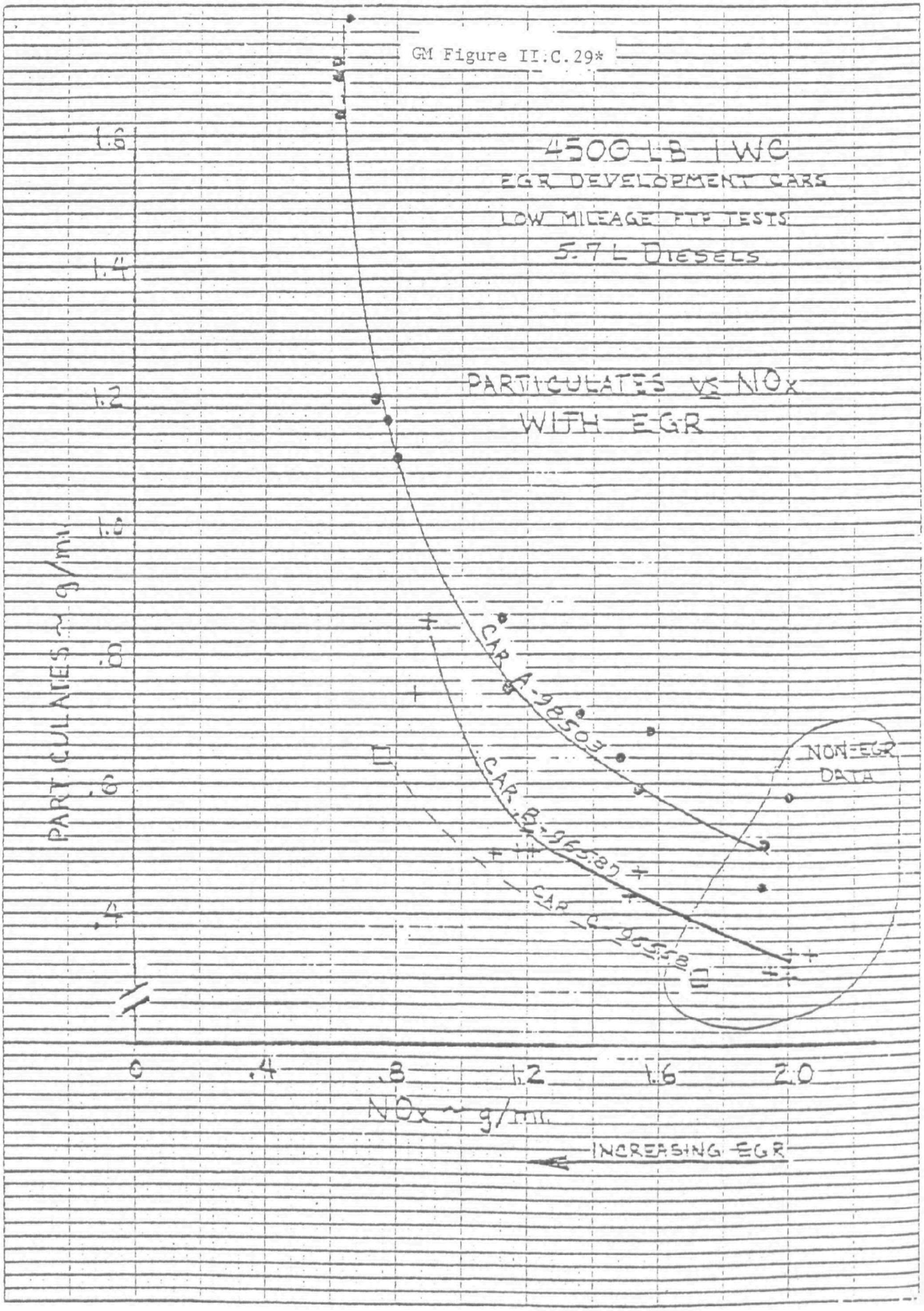
Volkswagen has admitted that their two most popular models, the Rabbit and the Dasher, would have no problem meeting the 0.60 g/mi (0.37 g/km) standard. VW intends to replace the 1.5-liter engine with a 1.6-liter engine in both the Rabbit and the Dasher in 1981. VW expects slightly higher emissions but not to the extent that either model would be in jeopardy of exceeding 0.60 g/mi (0.37 g/km) particulate. They claim that their Audi 5000D cannot meet 0.60 g/mi (0.37 g/km) until the 1982 model year.25/ As Table IV-3 shows, VW reported typical Audi 5000D emissions of 0.65 g/mi (0.40 g/km) particulate and 1.73 g/mi (1.08 g/km) NOx for naturally-aspirated production vehicles and 0.58 g/mi (0.36 g/km) particulate and 1.87 g/mi (1.16 g/km) NOx for turbocharged prototype vehicles. Thus, the Audi appears to have a NOx problem as well as a particulate problem. Because of its relatively small size (2.0-liter engine, 3,000-pound vehicle), we were surprised at VW's assertion that it could not meet 0.60 g/mi (0.37 g/km) particulate and 1.5 g/mi (0.93 g/km) NOx in 1981 and have examined the situation further. First of all,the 1979 Audi 5000D durability vehicle emitted 1.30 g/mi (0.81 g/km) NOx (the interpolated value at both 5000 and 50,000 miles) and thus we would not expect 1.5 g/mi (0.93 g/km) NOx in 1981 to be difficult to achieve. Secondly, since the data above are on production vehicles, we are confident that particulate and NOx improvements have been achieved through engine modifications since the data were collected. Thirdly, we have found that Volkswagen seems to get consistently higher particulate measurements at their German laboratory when compared to EPA test results in Ann Arbor. Table IV-5 gives the comparisons that have led us to this conclusion. In every case Volkswagen measured significantly higher particulate levels, from 25 to 43 percent higher. The EPA Audi value was based on two tests of one vehicle, while the VW Audi value was an average of eight production vehicles, yet the EPA value was lower than all eight of the VW values. Thus, based on its small size, the 1979 durability vehicle, the expected particulate and NOx reductions achieved through engine modifications, and the significantly lower particulate values that EPA has obtained for VW vehicles, it is anticipated that the Audi 5000D could meet a 0.60 g/mi (0.37 g/km) particulate standard in 1981 at a NOx level of 1.5 g/mi (0.93 g/km) or less. As VW itself has stated, the Audi should easily meet the standards in 1982.

Volkswagen's applications for NOx waivers were all denied by EPA due to insufficient emissions data. As mentioned above, Volkswagen is still eligible for NOx waivers if and when it provides sufficient data proving that they cannot meet 1.0 g/mi (0.62 g/km) NOx without significantly increasing particulate emissions.

General Motors is undeniably in a more difficult technical position, due to its larger engines (5.7 and 4.3 liters) and heavier vehicles (4,500 and 4,000 pounds). GM's particulate reduction program has produced promising results, however, and the data we received in its comment and in its NOx waiver request lead us to the conclusion that GM could meet 0.60 g/mi (0.37 g/km) particulate at a NOx level of 1.5 g/mi (0.93 g/km).

Table IV-3 gives the most promising particulate/NOx data for the GM 4,000 and 4,500-pound diesel vehicles. GM considers the 5.7-liter, 4,500-pound vehicle to be its worst-case vehicle for particulate and NOx emissions. As of June 19, GM still had not selected a "prime system" for its 1981 5.7-liter engine family. Prototype car 96558 was one design being considered.27/ GM reported only four particulate data points for car 96558, two tests without EGR (low particulate emissions) and two tests with a relatively high EGR rate (low NOx emissions); GM averaged each pair of tests and plotted the data in Figure IV-1 (Figure II.C.29 in GM's NOx Waiver Application). The parabola drawn by GM represents its best estimate of the particulate/NOx levels that would be expected for car 96558 at varying EGR rates. From Figure IV-1, it can be determined that car 96558 would emit approximately 0.43 g/mi (0.27 g/km) particulate with a NOx level of 1.2 g/mi (0.75 g/km). Also shown on Figure IV-1 are four tests on car 96589 at approximately 0.5 g/mi (0.31 g/km) particulate and 1.2 g/mi (0.75 g/km) NOx. Not shown on the GM graph, but reported on the individual

FIGURE IV-1




*From General Motors Application for Waiver of the 1981-1984 NOx Emission Standards for Light-Duty Diesel Engines, May 1979 data sheets in the GM NOx Waiver submissions, are two sets of baseline tests when car 96589 was being used for development work with EGR, a four-speed transmission, and a torque converter clutch (TCC). Three tests with 96589 in February, 1979, with a 3-speed transmission and without the TCC, resulted in average emissions of 0.36 g/mi (0.22 g/km) particulate and 1.15 g/mi (0.71 g/km) NOx. In June, 1979, two more baseline tests produced average emissions of 0.39 g/mi (0.24 g/km) particulate and 1.00 g/mi (0.62 g/km) NOx. The final 5.7-liter, 4,500-pound vehicle listed in Table IV-3 is car 86634. The only emissions results submitted to EPA for this vehicle were four tests performed after it had accumulated 8,000 miles. The two tests with EGR gave 0.56 g/mi (0.35 g/km) particulate and 1.10 g/mi (0.68 g/km) NOx. The non-EGR tests gave predictably higher NOx and lower particulate emissions. These data have convinced EPA that the GM 5.7-liter, 4,500-pound vehicle could meet the 0.60 g/mi (0.37 g/km) particulate standard in 1981, taking into account the necessary safety margin for variability and deterioration. In addition, it should be noted that all the particulate data above were at NOx levels of 1.0 to 1.2 g/mi (0.62 to 0.75 g/km) and thus the EGR rates could possibly be lessened, if necessary, to lower the particulate levels even more. Since diesel NOx deterioration factors are typically 1.0, this would be quite possible. GM has received the NOx waiver for 1981 and 1982 model years for the 5.7-liter engine.

Data from four 4.3-liter, 4,000-pound GM diesel prototypes are also shown in Table IV-3. Three of the four prototypes were of the very same design, with car 93514 a "slightly different technology." 28/ Car 72204 emitted just 0.27 g/mi (0.17 g/km) particulate and 1.01 g/mi (0.63 g/km) NOx (average of 3 tests), but GM stated that these very low emissions have not been repeatable. The two other prototypes of the same design also gave promising results. Car 93516 emitted 0.41 g/mi (0.25 g/km) particulate and 1.06 g/mi (0.66 g/km) NOx (average of 4 tests) and car 93513 emitted 0.50 g/mi (0.31 g/km) particulate and 1.29 g/mi (0.80 g/km) NOx (average of 2 tests). Car 93514 emitted 0.56 g/mi (0.35 g/km) particulate and 1.10 g/mi (0.68 g/km) NOx (average of 2 tests). Thus, we have three prototypes of the same design and one vehicle of a slightly different design which all meet the particulate standard at low NOx levels. We are convinced that the 4.3-liter, 4,000-pound GM vehicle could meet the 0.60 g/mi (0.37 g/km) particulate standard in 1981. GM's application for the NOx waiver for the 4.3-liter engine was denied due to insufficient data. GM may reapply for the waiver.

GM's primary concern with the design of these prototypes is the durability of the engines. This is because of the greater oil contamination apparently due to the greater EGR rates. As mentioned above, the EGR rates of these prototypes might be slightly higher than necessary, and might be lowered, thus lessening any durability concerns. In any case, EGR is used for NOx control, and will be utilized on GM's diesels regardless of the particulate standard. Thus, any durability problems will not be due to particulate control.

While GM was adamant in its comments to the particulate NPRM that it could only meet 1.0 g/mi (0.62 g/km) particulate and 1.5 g/mi (0.93 g/km) NOx in 1981, it did not make any such claim in its NOx waiver request. Of interest was a section on the effect of the NOx waiver on public health. In that section GM performed a "worst case" air quality analysis and had to select emission rates. To quote:

> "The emission rates assumed for this analysis are: 1.5 gpm NOx (20 percent of which is $NO_2$), 0.6 gpm particulate if the waiver is granted, and, 1.0 gpm NOx (10 percent of which is $NO_2$), 1.0 gpm particulate if EPA denies the waiver. These emission values agree with observed data discussed later in this section and also agree with comments by various manufacturers at the recent EPA hearing on particulate standards."29/

It is not clear what GM meant by this statement, but it does seem to support our conclusion that GM can meet the 0.60 g/mi (0.37 g/km) particulate standard in 1981. In any case, with the extra full year there should be no question that GM can meet 0.60 g/mi (0.37 g/km) particulate at 1.5 g/mi (0.93 g/km) NOx or less by 1982.

No other manufacturer reported particulate data from in-house diesel development programs. International Harvester currently markets a diesel Scout, a light-duty truck, but as Table IV-2 shows, it should easily comply with the 0.60 g/mi (0.37 g/km) standard. Testimony at the NOx Waiver Hearing confirmed that Volvo intends to introduce a 3500-pound light-duty vehicle powered by a 6-cylinder, 2.4-liter Volkswagen diesel engine in the U.S. in the 1980 model year. The only particulate data reported to EPA for this vehicle were very, very sketchy, ranging from 0.30 to 0.65 g/mi (0.19 to 0.40 g/km) on one 1979 European production vehicle. 30/ It is also quite possible that Chrysler, Ford, Toyota, AMC, and/or BMW (or others) might market light-duty diesels in the U.S. in the near future, but since these manufacturers did not provide EPA with any particulate data, we are unable to assess their technical positions. We can only conclude that these manufacturers will have to meet the particulate standards should they decide to market diesels in this country. Since these manufacturers' diesel designs are still in the developmental stages, particulate control should not be a great problem as it will simply be an additional design constraint that will have to be considered.

In summary, EPA's technical staff has concluded that every light-duty diesel vehicle manufacturer can meet a 1981 particulate standard of 0.60 g/mi (0.37 g/km) at NOx levels of 1.5 g/mi (0.93 g/km) or less, utilizing readily available technology. Because of insufficient certification leadtime, however, the particulate standard will not apply until the 1982 model year.

C. 1984 Standard

EPA had proposed that a 0.20 g/mi (0.12 g/km) particulate standard be set for the 1983 model year. EPA expected that most light-duty diesel vehicles would require an after-treatment device of approximately 67 percent efficiency to meet the 0.20 g/mi (0.12 g/km) particulate level. It was recognized that the proposed 1983 particulate standard was a technology-forcing standard, i.e., after-treatment devices were not then sufficiently developed to fulfill the basic criterion of 67 percent particulate reduction over the lifetime of a vehicle, but EPA postulated that there was sufficient lead time for after-treatment devices to be developed by the 1983 model year.

EPA's technical staff expects additional particulate reductions in the years 1981 to 1985 other than the reduction due to the addition of an after-treatment device. We expect that progress will continue in the area of engine modifications to reduce particulate emissions. Certainly there is a strong probability of additional reductions due to fuel injector and combustion chamber redesign (especially for those manufacturers which have not seriously investigated these areas), timing adjustments and controls, and engine derating. Should additional manufacturers turbocharge their engines, it would enable them to utilize smaller engines with reduced particulate levels, while retaining comparable performance. It is very unlikely that all of these parameters have been optimized in just two years of development work. There is also a high probability that other, as yet unforeseen, engine modifications will be found that will reduce particulate emissions. For example, in preliminary testing at the Ann Arbor laboratory, intake air throttling has been found to reduce particulate emissions.31/ It is hypothesized that this might be due to reduced quenching around the fuel droplets due to the lower air/fuel ratio of the throttled engine. Despite the fact that intake air throttling is a rather simple concept, and has been investigated in the past for other reasons, no comments were received with respect to its effect on particulate emissions. We consider it very likely that other possible engine modification control technologies will be discovered and investigated in the near future. Finally, with the Corporate Average Fuel Economy Standards increasing annually until 1985, and with other emissions standards decreasing, EPA expects that many manufacturers (especially those who produce larger vehicles) will continue to lighten their vehicles in order to facilitate compliance with the impending regulations. It is public knowledge that GM intends to downsize both their mid- and full-size cars a second time in the early

1980s;32/ the Department of Transportation has estimated these reductions to be in the 200 to 400 pound range.33/ Other manufacturers are also expected to make their vehicles lighter. All of these factors should contribute to lower particulate levels by 1985. In fact, EPA anticipates that a 15 to 20 percent particulate reduction will be achieved by the worst-case vehicles due to continued engine design optimization, derating, turbocharging, and downsizing. Thus we expect that all light-duty diesels could meet a 0.50 g/mi (0.31 g/km) particulate standard by 1984 or 1985 even without the application of an after-treatment device.

It is quite likely that one light-duty diesel, the VW Rabbit, will not even require an after-treatment device to meet the 0.20 g/mi (0.12 g/km) standard. The 1979 certification Rabbit that EPA tested as part of the particulate baseline emitted 0.23 g/mi (0.14 g/km) particulate and 0.87 g/mi (0.54 g/km) NOx while the DOT Special Build turbocharged Rabbit which EPA tested emitted just 0.20 g/mi (0.12 g/km) particulate and 0.93 g/mi (0.58 g/km) NOx 14/. These very low emissions and the expectation of further improvements indicate that by 1985 it is very unlikely that the Rabbit will need an aftertreatment device to meet the 0.20 g/mi (0.12 g/km) particulate standard.

Except for the VW Rabbit, EPA expects every other light-duty diesel vehicle to require after-treatment control to meet the 0.20 g/mi (0.12 g/km) standard in 1985. The after-treatment device will have to reliably remove particulate from the diesel exhaust gas stream with at least 60 percent efficiency (from 0.50 g/mi to 0.20 g/mi, from 0.31 g/km to 0.12 g/km) over the useful life of the vehicle. Three types of after-treatment devices are currently being developed by industry: catalytic converters, traps, and trap-oxidizers.

The catalytic converter can be considered to be a continuous-burn trap-oxidizer. As such, its successful application on light-duty diesels would remove many of the problems now associated with trap-oxidizer regeneration. The primary difficulty in utilizing catalytic converter technology to reduce diesel particulate is in continuously maintaining both the high temperatures and sufficient residence times that are necessary for oxidation of the particulate. Although it has been shown that catalytic converters can be effective in reducing the organic component of the particulate, they have not been as effective in reducing the less easily oxidized carbon (soot) component of the particulate.34/ Some investigations have also shown increased sulfate emissions with catalytic converters, but the selection of the proper catalyst might obviate that problem.35/,36/ While we consider it unlikely that converters will be a primary particulate after-treatment technology, it is quite possible that they will be used in the future for HC and organics control, with some resulting reduction in total particulate emissions.

The use of simple exhaust traps (or filters) has been investigated for many years, at one time primarily for removing lead from non-catalyst gasoline-powered vehicles. The particulate collection efficiencies of many trap materials, when new, are very good. Daimler-Benz reported initial efficiencies as high as 80 percent, and General Motors reported efficiencies for paper elements as high as 90 percent, and for alumina-coated metal mesh, metal wool, quadralobe catalyst beads, and alumina-fiber material of 60 to 65 percent. GM was the only commenter to provide a comprehensive evaluation of trap material efficiencies, a summary of their data is shown in Table IV-6. EPA expects that collection efficiencies of approximately 67 percent will be feasible on trap-oxidizers in the near future. Since a trap does not attempt to oxidize the particulate continuously, particulate matter builds up on the trap as mileage accumulates, resulting in decreasing trap collection efficiency and increasing exhaust gas backpressure which, in extreme cases, can affect engine performance and fuel economy. Because of the low bulk density of diesel particulate, an efficient trap might collect over a gallon of particulate every thousand miles.37/ Clearly a method is needed to periodically replace or regenerate the trap in order to maintain the collection efficiency and backpressure at acceptable levels. The two basic ways this could be done are external trap servicing and on-board incineration. The latter way of regenerating the trap is the distinguishing characteristic of the trap-oxidizer and will be discussed later in this section.

External trap restoration could take many forms. If paper trap elements were used, chemical dipping, backward pulsed air flow, or even low-cost changeable filters could be used. With permanent filter cartridges, high-temperature oven incineration, pressurized washing, chemical dipping, or sonic cleaning could be possible techniques. At this time, none of these techniques has fulfilled the basic criteria of restoring the collection efficiency and backpressure of any trap to desirable levels.

Another critical issue is the frequency of external servicing and the certainty that the vehicle owner would order the servicing. Since excessive backpressure levels can result in performance and/or fuel economy losses, the vehicle owner would certainly have some motivation to service his or her trap at regular intervals. GM has suggested the inclusion of a bypass valve in the trap to allow exhaust pressure to be partially relieved under certain conditions to protect the trap. The existence of such a valve might allow the vehicle owner to abdicate his or her responsibility to service the trap, while also avoiding excessive backpressure problems which would otherwise provide the motivation for servicing the trap. Also at issue is the magnitude and frequency of the possible inconvenience to the vehicle owner, and the effects that the perceived inconvenience may have on the public's acceptability of the diesel.

Table IV-6

General Motors' Summary of Trap Material Efficiencies 38/

Opel 2.1-Liter Engine

| Material | Efficiency, % |
|---|---|
| Corrugated Foil Fecralloy | 36 |
| Chopped Fecralloy | 29 |
| Chromium Alloy Ribbon | 37 |
| Glass Fiber Fabric | 34-65 |
| Fiberfrax Fiber Fabric | 46 |
| Alumina Fiber | 32-61 |
| Catalyst Beads | <10-62 |
| Ceramic Monolith Extruded | <10-52 |
| Ceramic - Torturous Path | 39-49 |
| Ceramic Bobbin | 42 |
| Alumina Coated Metal Mesh | 63 |
| Metal Mesh | 28-44 |

Olds 5.7-Liter Engine

| Material | Efficiency, % |
|---|---|
| Corrugated Fecralloy | 30 |
| Catalyst Beads | 56 |
| Ceramic Monolith Extruded | 30 |
| Alumina Coated Mesh | 65 |
| Metal Wool | 60 |
| Fiberglass | 76 |
| Paper Element | 90 |

Because of the above concerns about external trap servicing, it is likely that on-board incineration will be the preferred method of trap restoration. Nevertheless, should the trap-oxidizer be rejected on technical or economic grounds, traps with external restoration could be a feasible particulate control technology, presuming that extensive research continues.

A trap-oxidizer is simply a trap with a mechanism by which the collected particulate is periodically oxidized in order to restore the collection efficiency and exhaust gas backpressure to acceptable levels. Having this periodic, on-board regeneration avoids the necessity of either maintaining the conditions for continuous oxidation (catalytic converter) or of relying on the vehicle owner and/or service center to consistently and reliably replace or clean the trap. Research is continuing on regeneration initiation and control.

The general consensus is that the minimum temperature required for combustion of the particulate is approximately 450-500°C. Since the exhaust gas temperature of a diesel powered vehicle operated over the LA-4 driving cycle rarely exceeds 400°C, this raises the question of how to elevate the exhaust temperature to the requisite levels. GM suggested two approaches, air intake throttling and use of an external heat supply that both seem promising. GM reported that over a 1,000-mile load up and incineration test with throttling utilized to initiate incineration and 100-mile trapping periods, the collection efficiency actually improved slightly.39/ Further research needs to be done to examine the impact of throttling on emissions and fuel economy. It is quite possible that throttling might tend to reduce particulate formation in the combustion chamber. The use of an external heat supply to initiate incineration has been shown in preliminary testing to reduce collection efficiency only slightly.40/ With this technique, there is the possibility of a dual path trap, designed with dual heating elements and a valve which would route a small fraction of the exhaust flow to the trap that was being incinerated, and the rest to the trap that was not. The advantage of the dual path trap is that it would significantly reduce the necessary power requirement to initiate incineration. A third mechanism of raising the exhaust gas temperature would be to better insulate the exhaust system. Port liners, insulated exhaust manifolds, and an insulated exhaust pipe would all contribute to slightly higher exhaust temperatures. Finally, the temperature required for oxidation could be lowered through the use of a noble metal catalyst. The use of a noble metal catalyst could be sufficient in itself to initiate oxidation (which would then be, in effect, a catalytic converter) or could be used in conjunction with either throttling or an external heat supply.

Clearly, some form of controller unit would be an integral part of the regenerative process. It might suffice to have a relatively simple control system whereby (for example) the throttle actuator mechanism could be based on the odometer reading and rack position, throttling at periodic intervals, or it might be necessary to have a much more complex electronic control unit to monitor a large number of sensors and controllers. The latter might be necessary in order to coordinate backpressure levels with EGR, for example.

It is impossible at this time to delineate the exact design that will prove to be the appropriate trap-oxidizer for various manufacturers. At this time, throttling in conjunction with an insulated exhaust system, possibly with a noble metal catalyst, seems to be the most promising system. Either a simple mechanical control or a more complex electronic control unit would be necessary. Four different trap-oxidizer systems, all with a throttle and some degree of exhaust system insulation, but with varying control units and differences in the use of noble metals, are discussed in Chapter V of the Summary and Analysis of Comments.

Another critical area where improvements must be made is with the durability of the trapping material in the trap-oxidizer. It should last at least 100,000 miles. To date, the best durability of a trap reported to EPA was a metal mesh trap on an Opel vehicle, run on a modified AMA driving schedule with no hard accelerations, hills, or speeds above 45 mph. The trap survived 12,800 miles and at that time had a collection efficiency similar to its zero-mile efficiency of 55 percent. GM reported some particulate blow-off and self incineration.41/

Various other concerns have been expressed about trap-oxidizers. EPA agrees that the emissions characteristics of a diesel vehicle during the regeneration mode should be thoroughly investigated, both with respect to the regulated pollutants and particulate, and to any unregulated pollutants as well. There was major concern expressed by Daimler-Benz42/ over the effect of increased exhaust backpressure (due to the trap-oxidizer) on diesel performance and fuel economy. Certainly it is true that excessive backpressure can have a debilitating effect on the diesel engine. But assuming the optimization of on-board regeneration, such excessive backpressure should not occur. GM's 1,000-mile load up and incineration test, with 100-mile trapping periods, utilizing throttling to initiate incineration, showed backpressure to increase slightly with mileage, but clearly indicated a trend of flattening out with time. Daimler-Benz's second point, of the deleterious effect of variable backpressure on the effectiveness of EGR systems, is a very real concern. As discussed above, we expect that some form of control over the incineration process will be necessary, though it is not clear at this time how complex that control might have to be. Certainly EGR and backpressure could be accommodated within such a control system. The possibility that the trap-oxidizer could be a safety hazard (accidental ignition, uncontrolled oxidation, etc.) should also be investigated, though at this time EPA does not foresee this to be a major problem. We would expect the safety ramifications of trap-oxidizers to be similar to those of oxidation catalytic converters, which have not been significant. Finally, Ford's concern over the possibility that the regeneration mode might not occur during CVS testing is well taken.43/ It is recognized that the FTP may have to be modified in order to ensure that regeneration occurs.

Clearly, more basic research still needs to be done in the areas of regeneration initiation and control, and trap durability. Enough progress has been achieved to convince EPA that a successful trap-oxidizer can be developed, but as of this time, no design has proven to have the required collection efficiency over the desired length of time. With the research that has been, and is, going on with regards to trap-oxidizer development, and a determined broad-based effort by the manufacturers to comply with the final standards, EPA's technical staff has concluded that it is very likely that a successful trap-oxidizer design can be optimized within the next 1-1/2 to 2 years.

This brings us to the general issue of leadtime. The time needed from the end of the development phase for a design change to when that design change can be integrated into mass production can be dependent on many factors, such as the complexity of the change, the size of the manufacturer, whether the manufacturer has the capability to produce the new hardware, etc. We received differing estimates of production lead time requirements for trap-oxidizers. Volkswagen projected 1-1/2 to 2 years44/, while Daimler-Benz estimated 3 years (for major engine modifications in general).45/ General Motors appears to have given two different lead time estimates. In its prepared statement at the public hearing, it stated that 2-1/2 to 3 years production leadtime would be required "after an acceptable method is defined,"46/ while in its written comment GM claimed it needed 50 months from "system design selection."47/ In response to questions about leadtime at the public hearing, GM reaffirmed the 2-1/2 to 3 years estimate. Based on our own understanding of lead time requirements and the authority of the GM representatives at the public hearings, we accept the 2-1/2 to 3 years figure as GM's best estimate of the leadtime necessary for trap oxidizers, once a design is selected.

Based on the differing leadtime estimates from the manufacturers, and confident that the industry will maximize its efforts to achieve particulate reductions in the coming years, we have concluded that the manufacturers could integrate trap-oxidizers into mass production within 2 to 2-1/2 years after a design is selected. Thus, combining the 1-1/2 to 2 years development time and 2 to 2-1/2 years production leadtime that we expect to be necessary, we conclude that trap-oxidizers could be feasible on production vehicles within 4 years. Starting from late 1979 then, trap-oxidizers could be integrated into production by late 1983, or in time for the 1984 model year.

While our technical analysis concluded that there is a strong likelihood that trap-oxidizers will be feasible for vehicle application by 1984, the uncertainty that exists with regard to trap-oxidizer durability and vehicle application has convinced EPA to minimize the economic risk of this rulemaking by delaying the implementation of the 0.20 g/mi (0.12 g/km) standard until 1985. This extra year will have only a marginal effect on ambient suspended particulate levels yet will ensure that the manufacturers have enough time to optimize trap-oxidizer development.

It should be noted that while EPA expects trap-oxidizers to be approximately 67 percent efficient in reducing particulate emissions, the worst-case manufacturer is expected to need only a 60 percent reduction to meet the 1985 standard, and other manufacturers will need correspondingly less.

Another factor that must be considered is the statutory 1.0 g/mi (0.62 g/km) NOx standard in 1985. EPA does not expect the 0.20 g/mi (0.12 g/km) particulate and 1.0 g/mi (0.62 g/km) NOx standards to force any diesel models out of production. As has been discussed earlier in this chapter, the use of EGR, the primary NOx control technique at this time, significantly increases particulate emissions. But EPA is convinced that as the particulate/EGR relationship becomes better understood, the deleterious effect of EGR on particulate levels will be lessened. In addition, it is expected that other NOx control techniques will be implemented which will not necessarily increase particulate emissions; it is certainly possible that a NOx control technique might reduce particulate emissions.

In summary, EPA's technical staff has concluded that with the expected successful application of trap-oxidizer technology, every light-duty diesel vehicle manufacturer can meet a 0.20 g/mi (0.12 g/km) particulate standard in model year 1985. This is a delay of two years from the NPRM. EPA is also confident that the manufacturers can comply with the 0.20 g/mi (0.12 g/km) particulate and 1.0 g/mi (0.62 g/km) NOx standards in 1985.

### D. Light-Duty Trucks

The Code of Federal Regulations defines a light-duty truck (LDT) to be "any motor vehicle rated at 8,500 pounds gross vehicle weight rating or less which has a vehicle curb weight of 6,000 pounds or less and which has a basic vehicle frontal area of 46 square feet or less, which is: 1) designed primarily for the purposes of transportation of property or is a derivation of such a vehicle, or 2) designed primarily for transportation of persons and has a capacity of more than 12 persons, or 3) available with special features enabling off-street or off-highway operation and use."48/ Thus, light-duty trucks (LDT's) and light-duty vehicles (LDV's) are distinct classes of motor vehicles. The NPRM proposed that the LDT particulate standards be equal to the LDV standards. There were no data available to justify a separate LDT standard.

LDT's are typically tested at higher road load horsepower and inertia weight settings than are LDV's. Any increased particulate levels that would be justified by the unique uses of LDT's would be caused by these higher settings. In the comments to the NPRM, we received a small amount of data on the effects of higher road load and inertia weight settings on diesel particulate emission levels. All of the EPA and industry data are plotted in Figures IV-2 (road load) and IV-3 (inertia weight).

As can be seen in Figure IV-2, there is only a very, very slight effect of road load on particulate emissions. Only the Opel data indicated any significant effect, and that was mostly at unusually high inertia weight settings. At most, the higher road load settings of LDT's might account for a few percent increase in particulate levels.

From Figure IV-3, however, it is apparent that the inertia weight setting of a LDT does have a significant effect on its particulate emission level.

In setting the LDT gaseous standards for the 1979 model year, EPA extrapolated available data from 5,500 pounds inertia weight to represent the heaviest "typical" LDV test to 6,500 pounds inertia weight which represented the heaviest "typical" LDT test. Applying these same guidelines to the GM data (Vehicles #89589 and #78504) and the EPA data on a Dodge truck (shown in Figure IV-3) resulted in the following increases in particulate:

| Vehicle | Increase in Particulate from 5,500 Lbs. IW to 6,500 Lbs. IW |
|---|---|
| GM #89589 | 19% |
| GM #78504 | 10% |
| Dodge Truck | 18% |
| Average | 16% |

Recognizing that vehicle weights and hence test inertia weights are decreasing, and to be consistent with existing test inertia weights, a more current inertia weight comparison would be between 4,500 lbs. (current heaviest "typical" LDV) and 5,500 lbs. (current heaviest "typical" LDT). This analysis of the data in Figure IV-3 results in the following increases in particulate:

FIGURE IV-2

PARTICULATE EMISSIONS AS A FUNCTION OF ROADLOAD

FTP DRIVING CYCLE

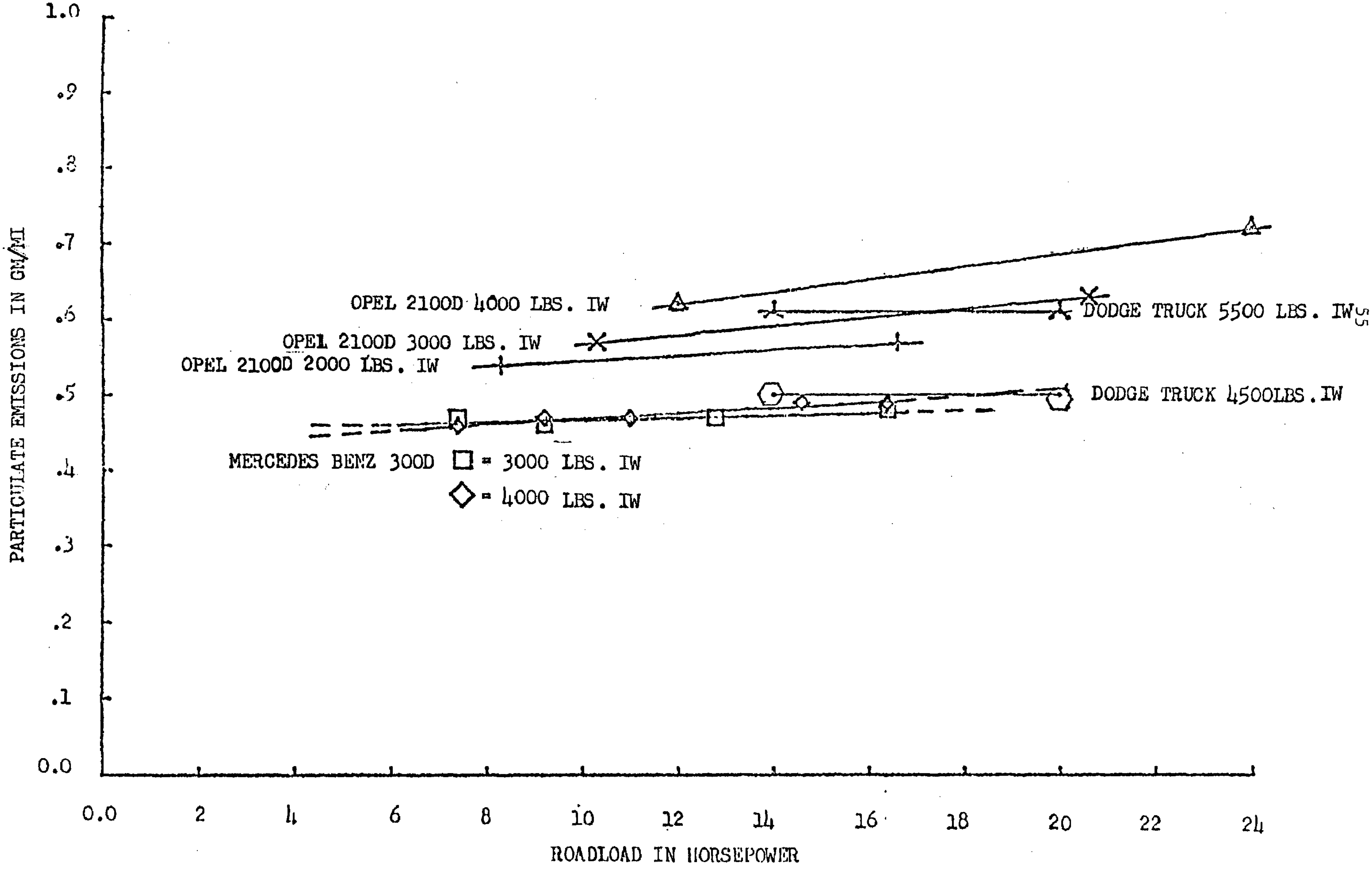
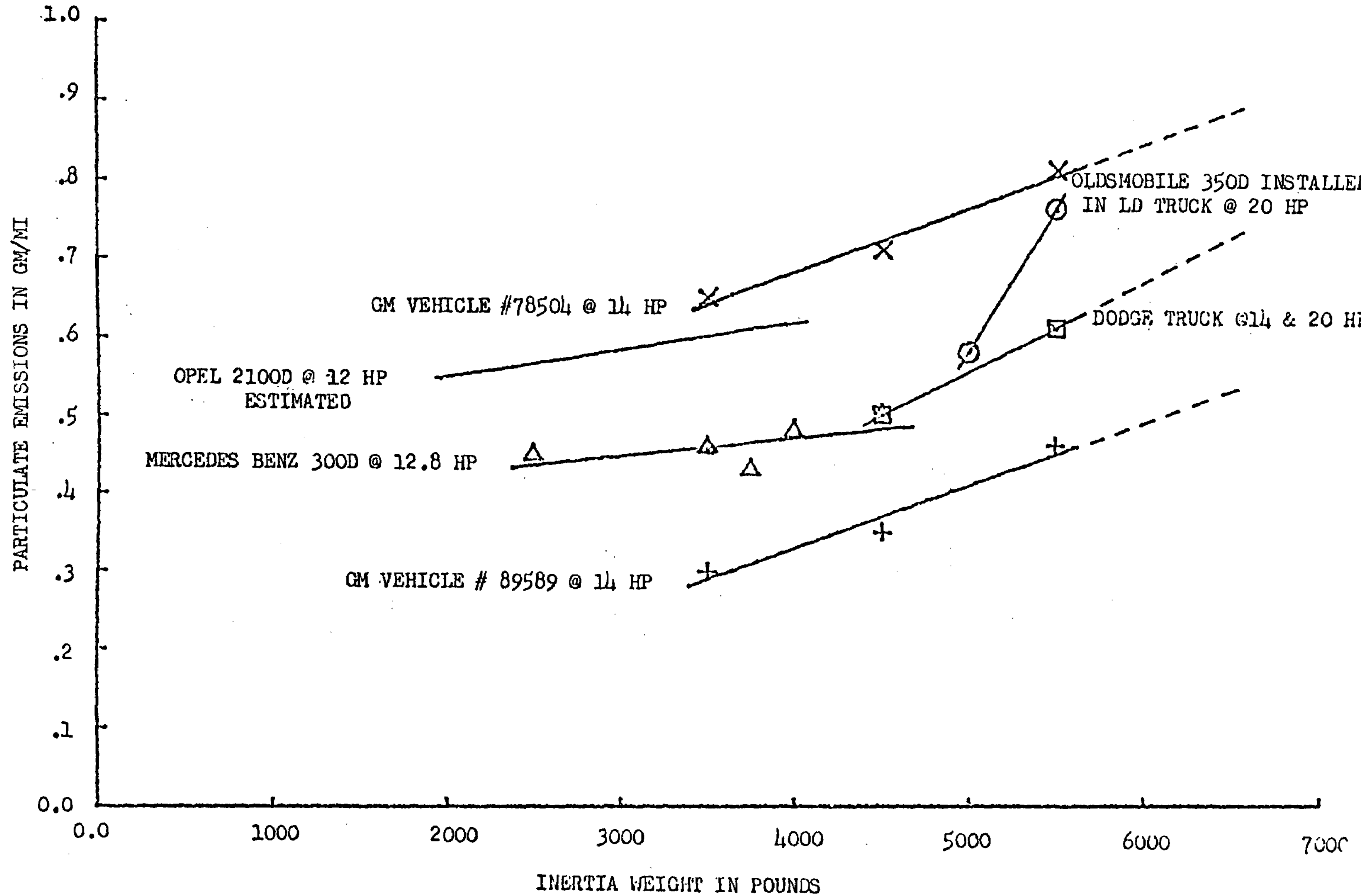


FIGURE IV-3

PARTICULATE EMISSIONS AS A FUNCTION OF INERTIA WEIGHT

FTP DRIVING CYCLE



| Vehicle | Increase in Particulate From 4,500 Lbs. IW to 5,500 Lbs. IW |
|---|---|
| GM #89589 | 22% |
| GM #78504 | 11% |
| Dodge Truck | 22% |
| Average | 18% |

In the above cases, the increases are 16 percent and 18 percent, respectively. These values are in very good agreement with Chrysler which claimed there was an approximate 17 percent increase in particulate emissions for a 1,000-pound inertia weight increase (or 33 percent for a 2,000-pound increase).

The GM Oldsmobile 350 data was considered to be non-typical because of the extreme slope as compared with the other data, and therefore was not analyzed. Furthermore, GM labeled this data as "fragmentary."49/ Similarly, the Opel (Ricardo) data and the Mercedes (Daimler-Benz) data were not considered because these did not represent the "worst case" situation.

Thus, the data clearly indicate the need to take the increased inertia weight settings of LDTs into consideration. The above data indicate that the combined effect of inertia weight and road load settings appears to be approximately 20 percent. If all other considerations were equal, EPA would promulgate LDT particulate standards that would be 20 percent greater than the corresponding LDV standards.

But one other factor must be considered. Diesel LDTs will only have to meet a NOx standard of 2.3 g/mi (1.43 g/km) until model year 1985 when a reduction is mandated by the Clean Air Act for trucks having GVWs over 6,000 pounds. Diesel LDVs will be required to meet a NOx level in the range of 1.0 to 1.5 g/mi (0.62 to 0.93 g/km), depending on the NOx waiver decisions, until 1985 when the Clean Air Act mandates a 1.0 g/mi (0.62 g/km) NOx standard. Even assuming the maximum NOx waiver for diesel LDVs to 1.5 g/mi (0.93 g/km), diesel LDTs will have a NOx standard 53 percent greater than the diesel LDV NOx standard for model years 1982 to 1984. Not only does this much larger NOx level account for the greater NOx emissions (approximately 20 to 30 percent) that would be expected from LDTs, but because of the relationship between NOx and particulate emissions due to EGR, it also can allow for the 20 percent higher particulate emissions than would otherwise be expected due to the greater inertia weights of LDTs. For example, it is unlikely that any diesel LDT would need very heavy EGR in order to meet a NOx standard of 2.3 g/mi (1.43 g/km). These trucks would emit less particulate than they would if greater amounts of EGR were required to meet a lower NOx level. For this reason, LDTs should be able to meet the 0.60 g/mi (0.37 g/km) level of control in 1982 through 1984. Since the particulate standards are technology based standards, EPA is promulgating the 1982 LDT particulate standard to be 0.60 g/mi (0.37 g/km).

An examination of the LDT data in Table IV-2 confirms our expectation that LDTs will be able to comply with the 0.60 g/mi (0.37 g/km) particulate standard in 1982. The Chevrolet and Dodge LDTs emitted 0.59 and 0.61 g/mi (0.37 and 0.38 g/km) particulate, respectively, and thus need just a small improvement to comfortably meet the 1982 standard. It should be noted that GM diesel LDTs utilize the same 5.7-liter diesel engines that are used in the GM 4,500-pound LDV's; their particulate reductions since the baseline data were taken were discussed earlier in this chapter. The International Harvester light-duty truck emitted 0.32 to 0.47 g/mi (0.20 to 0.29 g/km) particulate and thus it already meets the 1982 standard.

Two factors change this situation in 1985. First, as a result of the statutory requirement for a 75 percent NOx reduction, the LDT NOx standard is expected to drop to a stringency level much nearer to the LDV statutory NOx level of 1.0 g/mi (0.62 g/km). The "cushion" that now exists for LDT NOx control would disappear. Based on the analysis above, the particulate standard for LDTs should be 20 percent greater (all other things being equal) than the LDV standard due primarily to the greater inertia weight settings of LDTs. Second, the expected trends in downsizing and the use of smaller engines in LDVs will likely not take place as rapidly with LDTs. The EPA technical staff estimates that this discrepancy justifies an additional 10% particulate cushion for LDTs. Thus, the 1985 LDT particulate standard should be 30 percent greater than the 1985 LDV particulate standard and will be 0.26 g/mi (0.16 g/km).

Thus, the LDT diesel particulate standards are 0.60 g/mi (0.37 g/km) in 1982 and 0.26 g/mi (0.16 g/km) in 1985.

References

1/ Clean Air Act of 1963, Section 1(a)(1).

2/ Clean Air Act of 1963, Section 1(a)(2).

3/ Clean Air Act of 1963, Section 1(b)(1).

4/ Clean Air Act, Section 202 (a)(1).

5/ Clean Air Act, Section 202 (b)(1)(B).

6/ Clean Air Act, Section 202 (b)(6)(B).

7/ Federal Register, February 1, 1979, Volume 44, Number 23, p. 6650.

8/ "NOx Diesel Waiver Hearing" - General Motors Transcript, June 19, 1979, p. 58.

9/ "General Motors Response to EPA Notice of Proposed Rulemaking on Particulate Regulation for Light-Duty Diesel Vehicles," April 19, 1979, Attachment 1, p. 159.

10/ "Light-Duty Diesel Particulate Regulations Draft Regulatory Analysis," EPA, OMSAPC, ECTD, SDSB, December 22, 1978, p. 48.

11/ "General Motors Response...," Attachment 1, p. 148.

12/ "General Motors Application for Waiver of the 1981-1984 NOx Emission Standard for Light-Duty Diesel Engines," May 1979, Figure II.B.11.

13/ "General Motors Response...," Attachment 1, p. 157.

14/ Danielson, Eugene, "Particulate Measurement - Light-Duty Diesel Particulate Baseline Test Results," SDSB Technical Support Report 79-03, January 1979.

15/ "Draft Regulatory Analysis," p. 45.

16/ "Summary and Analysis of Comments on the Notice of Proposed Rulemaking for Light-Duty Diesel Particulate for 1981 and Later Model Year Vehicles," EPA, OANR, OMSAPC, ECTD, SDSB, October 1979.

17/ "Statement of Daimler-Benz AG on the Notice of Proposed Rulemaking Concerning Diesel Particulate Emissions," March 1979, p. 24.

18/ Personal communication with Mr. Trexl, Daimler-Benz, July 10, 1979.

19/ "Comments of P.S.A. Peugeot-Citroen on EPA Proposed Light-Duty Diesel Particulate Regulation," April 6, 1979, Chart 3.

20/ "Supplementary Information to the Record of the EPA Hearing on March 19, 1979 Concerning Proposed Particulate Emission Standards for Light-Duty Diesel Vehicles" - Volkswagen, April 1979, Section 1.

21/ "Comments of Fiat S.p.A., Italy on Proposed Particulate Regulation for Light-Duty Diesel Vehicle," March 19,1979, Table 1.

22/ "General Motors Response...," Attachment 1.

23/ "General Motors (NOx Waiver) Application...," Attachment II.B.1.

24/ Additional General Motors NOx Waiver Application Information submitted to EPA on July 18, 1979, Attachments.

25/ "Public Hearing on the Proposed Particulate Emission Standards for Light-Duty Diesel Vehicles" - Volkswagen Testimony, March 20, 1979, Volume 2, p. 40.

26/ Barth, Edward Anthony, "Audi 5000 Diesel Gaseous and Particulate Tests," EPA-TAEB Memorandum to Ralph Stahman, February 15, 1979.

27/ "NOx Diesel Waiver Hearing" - General Motors Transcript, June 19, 1979, p.33.

28/ "General Motors (NOx Waiver) Application...," p. II-30.

29/ Ibid,p. III-3.

30/ "NOx Diesel Waiver Hearing" - Volvo Transcript, June 21, 1979, p. 11.

31/ Penninga, T., "Second Interim Report on Status of Particulate Trap Study," EPA-TAEB Memorandum to R. Stahman, August 9, 1979.

32/ Ward's Engine Update, June 8, 1979, p. 6.

33/ Rulemaking Support Paper Concerning the 1981-1984 Passenger Auto Average Fuel Economy Standards, DOT-NHTSA, July 1977.

34/ "Notes on the Proposed Particulate Regulations for Light-Duty Diesel Vehicles," Ricardo Consulting Engineers, January 12, 1979, p. 5.

35/ "Comments of Fiat...," p.4.

36/ "Volkswagen Supplementary Information...," April 1979, Appendix 2.

37/ "General Motors Response...," Attachment 1, p. 98.

38/ Ibid, Attachment, pp. 86-90.

39/ Ibid, Attachment 1, Figure V-23, p. 111.

40/ Ibid, Attachment 1, p. 116.

41/ Ibid, Attachment 1, p. 94.

42/ "Statement of Daimler-Benz...," p. 16.

43/ "Public Hearing on the Proposed Particulate Emission Standards for Light-Duty Diesel Vehicles" - Ford Testimony, March 19, 1979, Volume 1, p. 249.

44/ "Public Hearing..." - Volkswagen Testimony, March 20, 1979, Volume 2, p. 36.

45/ "Statement of Daimler-Benz...," pp. 5-6.

46/ "Public Hearing..."- General Motors Testimony, March 19, 1979, Volume 1, p. 64.

47/ "General Motors Response...," Attachment 1, p. 175.

48/ Code of Federal Regulations, Title 40, Part 86.079-2.

49/ "General Motors Response...," Attachment 1, p. 44.

# CHAPTER V

# ENVIRONMENTAL IMPACT

## A. Health Effects of Total Suspended Particulate

Suspended particulate matter has long been recognized as a major pollutant of our nation's air. Of the greatest concern is the effect of total suspended particulate (TSP) matter on human health. Research has shown that TSP can be correlated with respiratory and pulmonary functions, and that effects of high TSP levels range from increased discomfort to healthy persons and aggravation of cardio-respiratory symptoms in elderly persons, to increased susceptibility to bronchitis, asthma, and pneumonia, to increased mortality. Some of the most important research on the health effects of TSP are listed in Tables V-1 and V-2. Table V-1 lists many of the major health effects studies examining relatively short exposure times (1 to 2 days) while Table V-2 shows the results of studies which utilized longer averaging times (1 to 2 years). When the Clean Air Act Amendments of 1970 mandated the establishment of National Ambient Air Quality Standards (NAAQS), TSP was among the first six pollutants for which a standard was promulgated. Many of the studies given in Tables V-1 and V-2 were utilized in the establishment of the NAAQS for TSP. The primary NAAQS for TSP, which are intended to provide protection to the public health, are 75 micrograms per cubic meter (annual geometric mean) and 260 micrograms per cubic meter (maximum 24-hour concentration, may be exceeded once per year). The secondary NAAQS for TSP, which is intended to protect the public welfare, is 150 micrograms per cubic meter (24-hour average to be exceeded only once per year).

The National Academy of Sciences has extensively reviewed all aspects of TSP, and for a detailed treatment of the health and welfare effects of TSP one should see their document.1/ EPA is currently conducting a review of the NAAQS for TSP. The scientific consensus that TSP levels impact on human health will be taken as given here. The emphasis of this section will be on the contribution of light-duty diesel particulate emissions to ambient TSP levels, and to any special health impacts that might result from diesel particulate matter.

## B. Health Effects of Diesel Particulate

This section will highlight only those aspects of the health effects of diesel particulate which differ from those of TSP in general. Much has been learned in the years since the NAAQS (based

* Bracketed numbers (1/) indicate references at the end of this chapter.

Table V-1

Research on Short-Term Health Effects of Total Suspended Particulate Matter

| | Adverse Health Effect | Concentration at Which Effect Was Observed<br>Concentration, μg/m$^3$ | Averaging Time | References |
|---|---|---|---|---|
| 1. | Increased mortality. | 750 or a rise of 200 | 24-48 Hours | Martin et al., 1960<br>Lawther, 1963 |
| 2. | Increased infant mortality and cancer mortality. | 200 | 2 Days | International Joint Commission, 1960 |
| 3. | Increased respiratory infection and cardiac morbidity. | 375 | 24 Hours | Martin et al., 1960<br>Lawther, 1963 |
| 4. | Excess bronchitis mortality. | 200 | 24 Hours | Buck et al., 1964 |
| 5. | Bronchitis symptoms. | 300 | Daily | Greenburg et al., 1962 |
| 6. | Cough, chest discomfort, restricted activity. | 100-269 | 24 Hours | Holland et al., 1965 |
| 7. | Cardio-respiratory symptoms in healthy persons. Asthma attacks in asthmatics. | 80-100 | 24 Hours | Douglas et al., 1966 |
| 8. | Aggravated symptoms in elderly with heart or chronic lung disease. | 76-260 | 24 Hours | Douglas et al., 1966 |

Source: Suspended Particulate Matter - A Report to Congress, Environmental Criteria and Assessment Office, ORD, EPA, October 1978.

Table V-2

Research on Longer-Term Health Effects Of Total Suspended Particulate

| | Adverse Health Effect | Concentration at Which Effect Was Observed: Concentration, μg/m³ | Averaging Time | References |
|---|---|---|---|---|
| 1. | Increased mortality (all causes). | 100 | 2 Years | Greenburg et al., 1962 |
| 2. | Increased respiratory disease (adults, children) and decreased pulmonary function (children). | 100-200 | Annual | Buck et al., 1964<br>Winkelstein, 1967 |
| 3. | Decreased pulmonary function in school children. | 110 | Annual | Lunn et al., 1967 |
| 4. | Increased frequency and severity of acute lower respiratory disease in school children. | 100 | Annual | French et al., 1973* |
| 5. | Increased chronic respiratory disease symptom prevalence in adults. | 100 | Annual | Chapman et al., 1973* |

* These two studies were part of the Community Health and Environmental Surveillance System (CHESS). For appropriate qualification with regards to the proper use and interpretation of CHESS studies in general, see 1) United States House of Representatives, 1976. The Environmental Protection Agency's Research Program with Primary Emphasis on the Community Health and Environmental Surveillance System (CHESS): An Investigative Report by the Committee on Science and Technology, Publication No. 77-590; 2) Research Outlook 1978, EPA 600/9-78-001, June 1978; or 3) Research Outlook 1979, EPA 600/9-79-005, February 1979.

Source: Suspended Particulate Matter - A Report to Congress, Environmental Criteria and Assessment Office, ORD, EPA, October 1978.

on total mass of parti ılate) was promulgated, and it is now accepted by most scientists that some particulate emissions are more deleterious than others, and that some sources necessitate priority control over others. There are two characteristics of diesel particulate matter which place it among the most harmful types of particulate matter. The first is size and the second is chemical composition. These will be discussed below.

1. Size-Related Effects

It is now generally accepted that size is one of the most critical characteristics of particulate matter. The size of a particle primarily affects three parameters which, in turn, help determine the health effect of that particle: total deposition, or how efficiently the particles are deposited in the respiratory tract; regional deposition, or where the particle is deposited in the respiratory tract; and clearance time, or how long it takes to remove the particle from the respiratory tract. When examining data presented, it will be important to note the differences in deposition between nose and mouth breathers. As the nasal passages are more efficient in capturing large particles than the mouth, the sizes of particles reaching various sections of the respiratory tract depend on how the air is being inhaled.

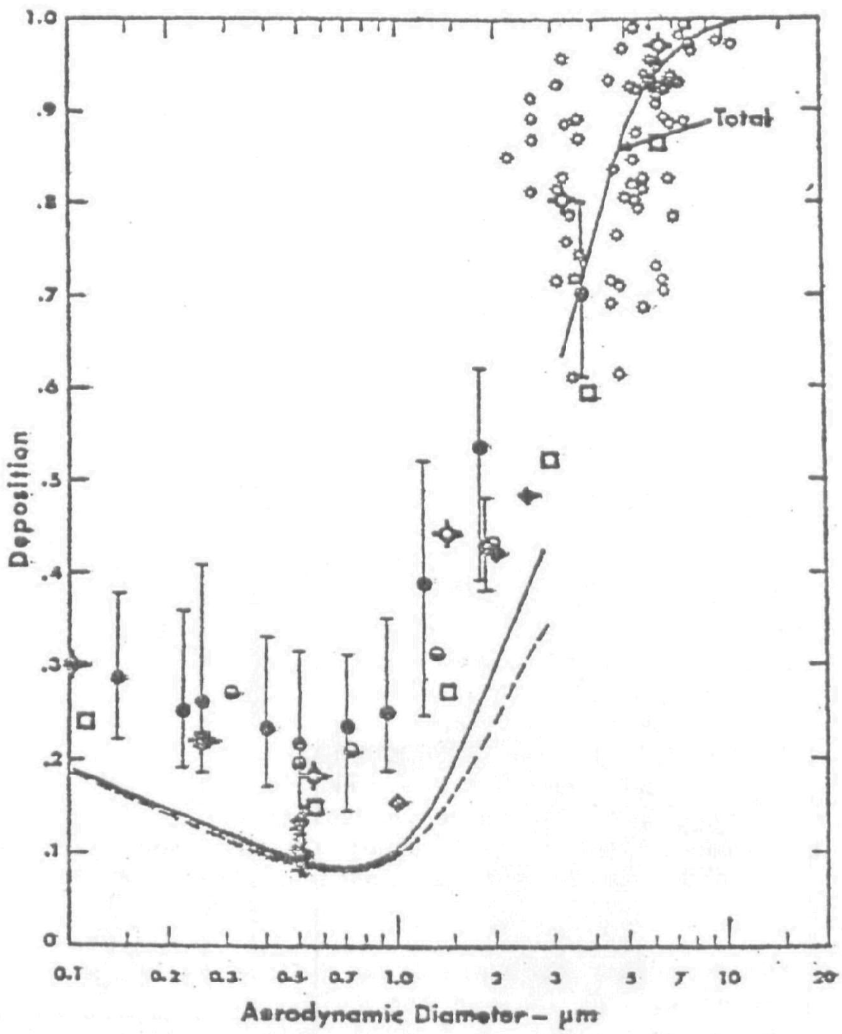
Total deposition by particle size for a mouth breather is shown in Figure V-1. As can be seen, the fraction decreases with particle diameter, until about 0.5-0.7 micrometers when the trend begins to reverse.

More important than total deposition, however, is the deposition occurring in selected regions of the respiratory tract, because the health effect of a particle is dependent on the region in which it is deposited. Deposition in three regions will be discussed, the head (nasal passages), the tracheo-bronchial zone and conducting airways, and the alveolar zone. These regions are depicted in Figure V-2.2/

Deposition in the head (for nose breathers) is highest for large particles and negligible for very small particles. Deposition is complete somewhere between ten and fifteen micrometers and higher, while deposition is less than 10% below one to two micrometers.1/ Fewer studies of this type have been performed with mouth breathing and the results have been highly variable.1/ However, it is clear that far less deposition occurs in the head during mouth breathing than for nose breathing for all particle sizes.

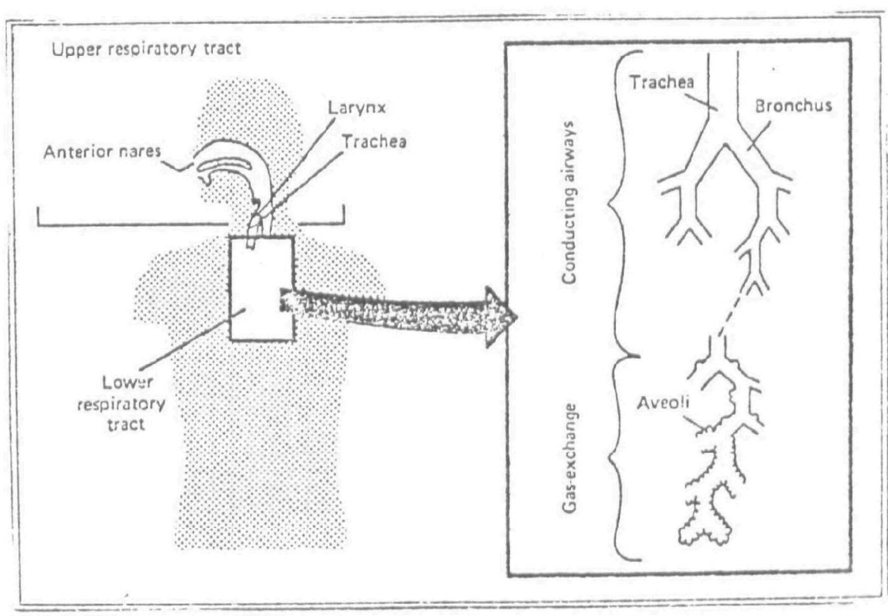
Deposition in the tracheo-bronchial region is very similar to that in the head(for both nose and mouth breathers), if deposition is determined as a fraction, or percent, of particles entering the tracheo-bronchial region. Deposition approaches 100% around eight

Figure V-1 1/




Total respiratory tract deposition during mouthpiece inhalations as a function of D (aerodynamic diameter in μm) except below 0.5 um, where deposition is plotted vs linear diameter.

Figure V-2 2/




Diagrammatic representation of the human upper and lower respiratory tract.

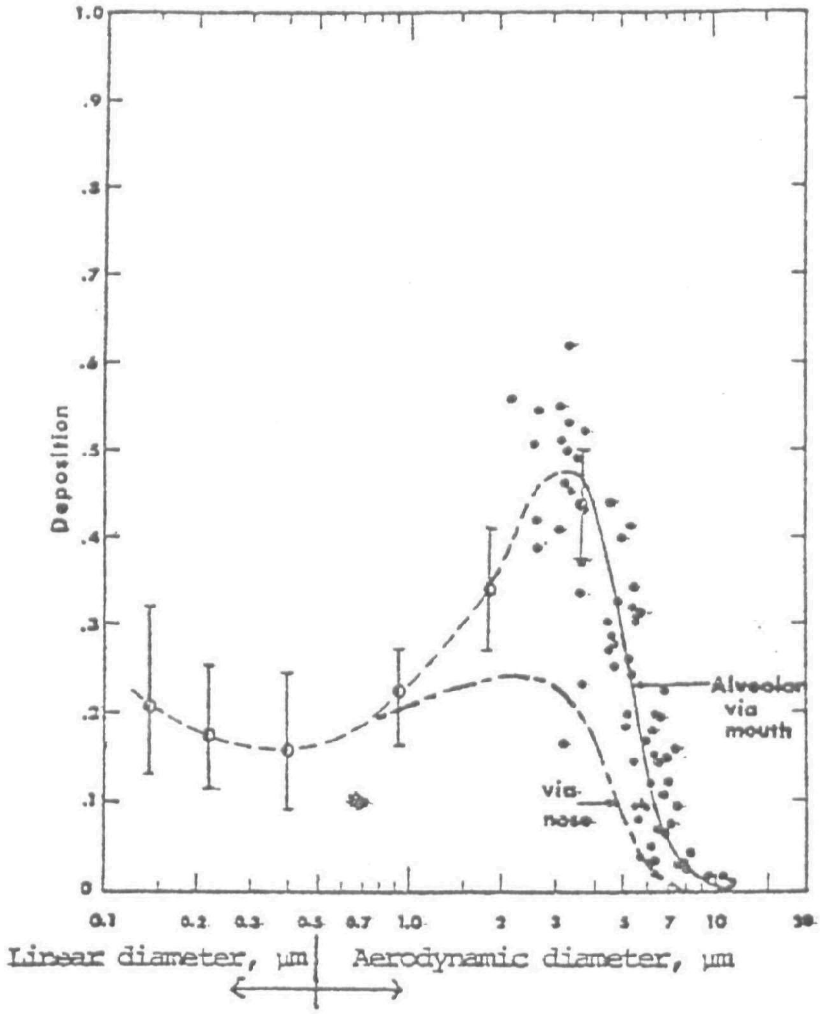
.o fifteen micrometers and approaches 10% around one to two micrometers.

Deposition in the alveolar region is shown in Figure V-3, based on the total number of particles entering the mouth or nose, not on the number of particles entering the alveolar region.1/ Deposition in this region is low above five to seven micrometers because the larger particles have already been captured by the nasal passages and the tracheo-bronchial region. Deposition reaches a relative peak around two to five micrometers. The level of the peak depends on whether the person is breathing through the mouth, when deposition reaches 40-50%, or the nose, 20%.

There are two primary reasons why particles deposited in the alveolar region can have the greatest impact on human health. First, the alveolar region (where gas-exchange takes place) is the most sensitive region of the respiratory tract. The second reason is the significantly longer clearance time required for particles in the alveolar region. Clearance time is the time it typically takes for a particle to be removed from the region in question. In healthy individuals, the clearance of particles deposited in the nasal passages and the tracheo-bronchial region is usually completed in less than one day.1/ Clearance can take somewhat longer for those people with respiratory ailments. In the alveolar region, clearance is measured in weeks unless the particle is very soluble in body fluid, which diesel particulate is not. While the results of studies on humans are variable, it appears that a half-time clearance for relatively insoluble particles is on the order of five to nine weeks.1/ Although particles distributed in other regions of the body can also affect health, it is those particles deposited in the alveolar region, which remain in contact with the most sensitive parts of the lung for the longest periods of time, which have the greatest potential for affecting human health.

As a result of a review of the available information on the effects of particle size on deposition and health, EPA is recommending that future health effects research be conducted on two size-specific fractions of TSP.2/ One fraction is labeled inhalable particulate (i.e., particles having a diameter equal to or less than fifteen micrometers). This fraction includes those particles which primarily deposit in the conducting airways and the gas-exchange portions of the respiratory tract. The second fraction is the fine particulate (i.e., particles having a diameter equal to or less than 2.5 micrometers). This second cutoff was chosen for two reasons; 1) this fraction includes those particles which primarily deposit in the gas exchange portion of the lung (alveolar), and 2) due to the breakdown of ambient particulate by size and chemical composition, there is a natural break between fine and coarse (diameter larger than 2.5 micrometers) particles at this size.

Figure V-3 1/




Deposition in the nonciliated alveolar region, by percent of aerosol entering the mouthpiece, as a function of diameter.

Diesel particulate is very small in size. Its mass mean diameter varies between 0.05 and 0.2 micrometers.3/4/ Essentially all diesel particles fall into the inhalable range and between 94% and 100% can be characterized as fine particulate.3/4/5/ Because of its small size, diesel particulate belongs to that category of particulate which is most likely to deposit in the alveolar region, thus remaining in contact with the most sensitive areas of the respiratory tract for comparatively long periods of time. Clearly, diesel particulate is of more concern than larger particles which deposit in the head or tracheo-bronchial regions and which have much shorter clearance times. Because of this, the control of diesel particulate and other fine and inhalable particulate is of high priority.

2. Chemical Composition-Related Effects

In addition to particle size, chemical composition is an important factor in determining the health effect of a particle. There are a wide variety of chemicals of particular concern, such as fibers (e.g., asbestos), toxic elements (e.g., Be, Cd, Pb), organic matter (e.g., benzo(a)pyrene), carbon, and sulfuric acid.

Diesel particulate is primarily carbonaceous, with between 10 and 50% of the particulate by weight being extractable organic matter.4/5/6/7/ This organic matter is definitely mutagenic in short-term bioassays,7/ and EPA is currently performing a health assessment to determine the carcinogenic risk of diesel particulate to humans.8/ Known human carcinogens are present in diesel particulate, such as benzo(a)pyrene, which comprises about 0.0001 to 0.007% by weight of diesel particulate.5/6/ However, most of the mutagenic response is being caused by substituted polycyclic organic matter, which does not require metabolic activation.7/ At this time, no definitive statement can be made concerning the complete effect of diesel particulate on human health. However, the data available is serious enough to merit caution and diesel particulate should definitely be numbered among those chemical types of particulate which require priority control.

C. Current Ambient Levels of TSP

The primary NAAQS for TSP of 75 micrograms per cubic meter (annual geometric mean) is currently being exceeded in many areas of the country. While relatively large reductions in ambient TSP levels occurred between 1971 and 1975,9/ particularly at those sites which showed high levels of TSP, the next two years have shown more of a holding pattern than a continued downward trend.10/ Figure V-4 shows the nationwide averages of ambient TSP levels from 1972 through 1977. The ambient TSP level exceeded by 25% of the sites decreased from 78 to 71 micrograms per cubic meter between 1971 and 1975, while in 1977 it was still 71 micrograms per cubic

Figure V-4 10/

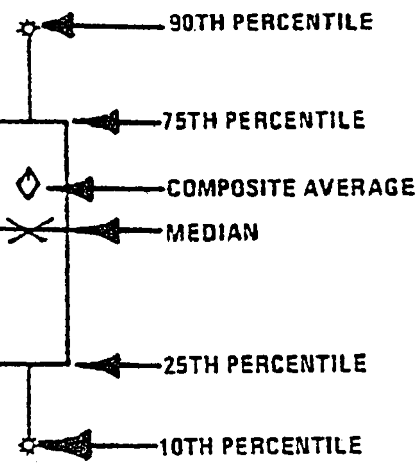
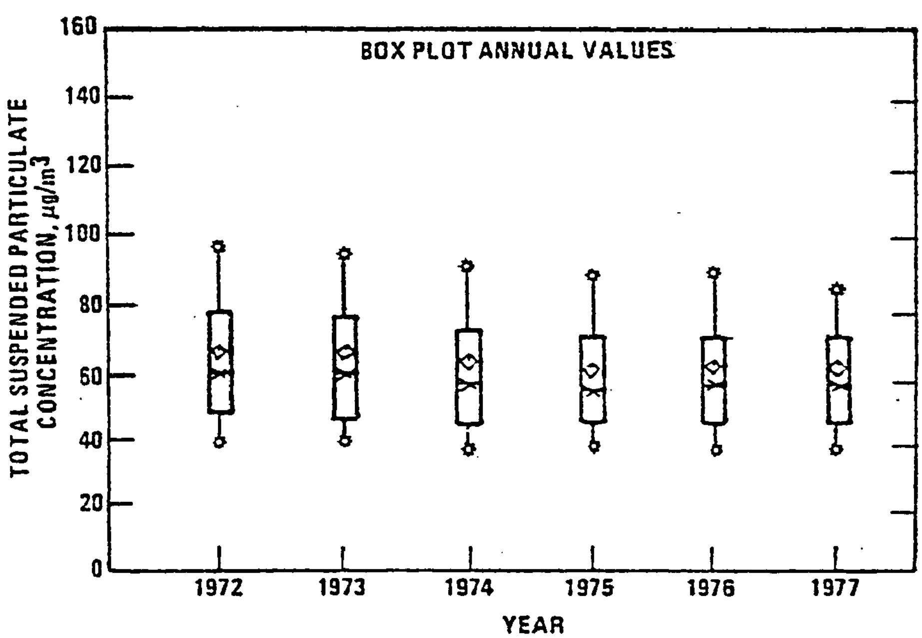



Figure 3-1. Sample illustration of plotting conventions for box plots.




Nationwide trends in annual mean total suspended particulate concentrations from 1972 to 1977 at 2,707 sampling sites.

meter. The TSP level exceeded by the worst 10% of the sites still managed to improve, however, through 1977. This level decreased from 97 to 88 micrograms per cubic meter between 1972 and 1975 and then decreased to 84 micrograms per cubic meter in 1977.

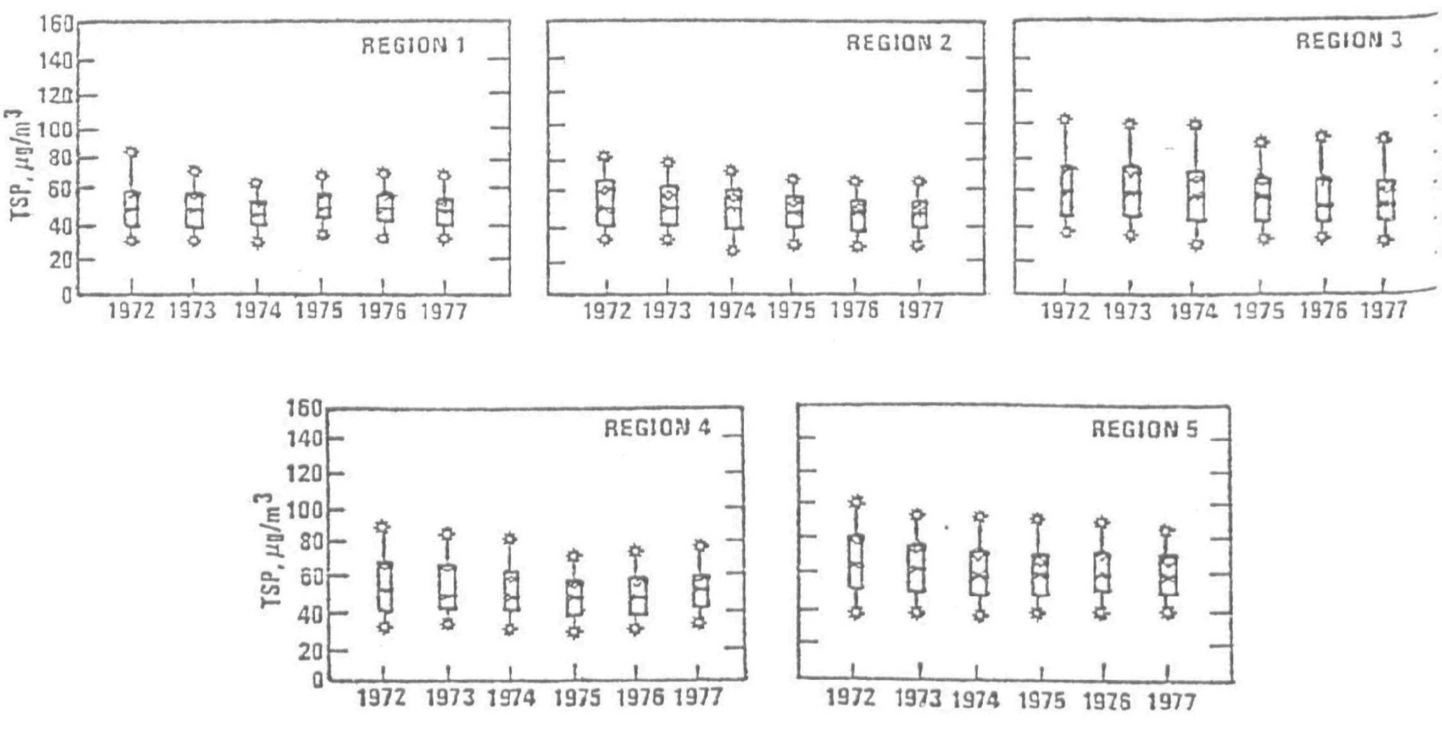
The high ambient levels of 1976 and 1977 were due at least partially to very dry weather.10/11/ In 1977, some sites recorded levels of 1000 micrograms per cubic meter for a day or two and this alone can cause the annual mean to increase 10%.10/ Figures V-5 and V-6 show the ambient TSP trends by region for 1972 through 1977. The dust storms of 1976 were primarily located in Regions 8, 9, and 10, while those of 1977 were primarily located in Region 6.

The fraction of the nation's population which is exposed to TSP levels exceeding the primary NAAQS is shown in Figure V-7.11/ While the number of people exposed to such levels dropped 9% between 1972 and 1975, this downward trend stopped in 1976 and 1977 when the number of people exposed remained constant at about 22% of the nation's population. An identical trend is present for the nation's metropolitan population. For the last three years (1975-1977), 27% of the nation's metropolitan population has been exposed to ambient TSP levels exceeding the primary NAAQS. These people are living in areas where the quality of the air they breathe could be harmful to their health.

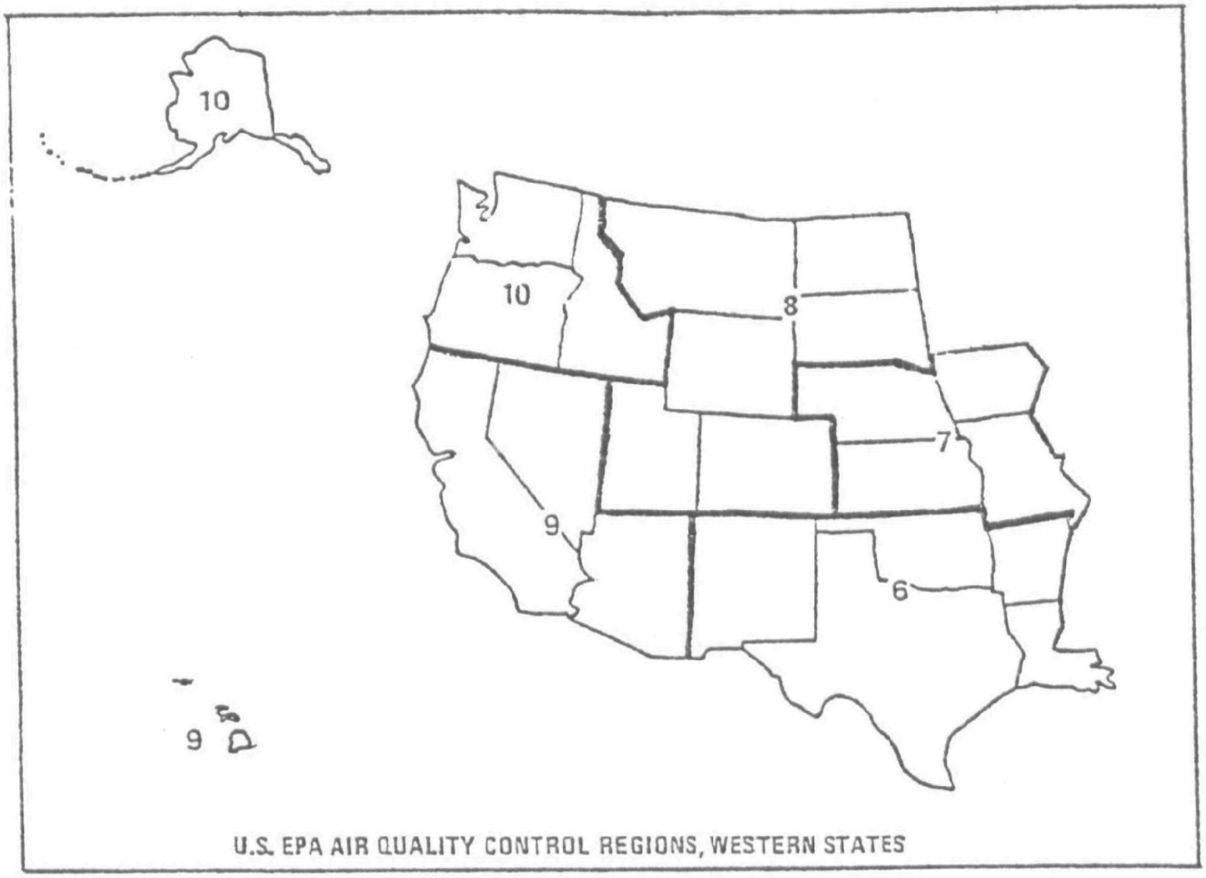
An even greater percentage of people are living in areas exceeding the secondary NAAQS for TSP. For example, in 1975 when 49 million people were living in areas exceeding the primary NAAQS; 89 million people were living in areas exceeding the secondary NAAQS. These people are living in areas where the air quality could be a hazard to their welfare (i.e., visibility, corrosion of materials, vegetation, etc.).

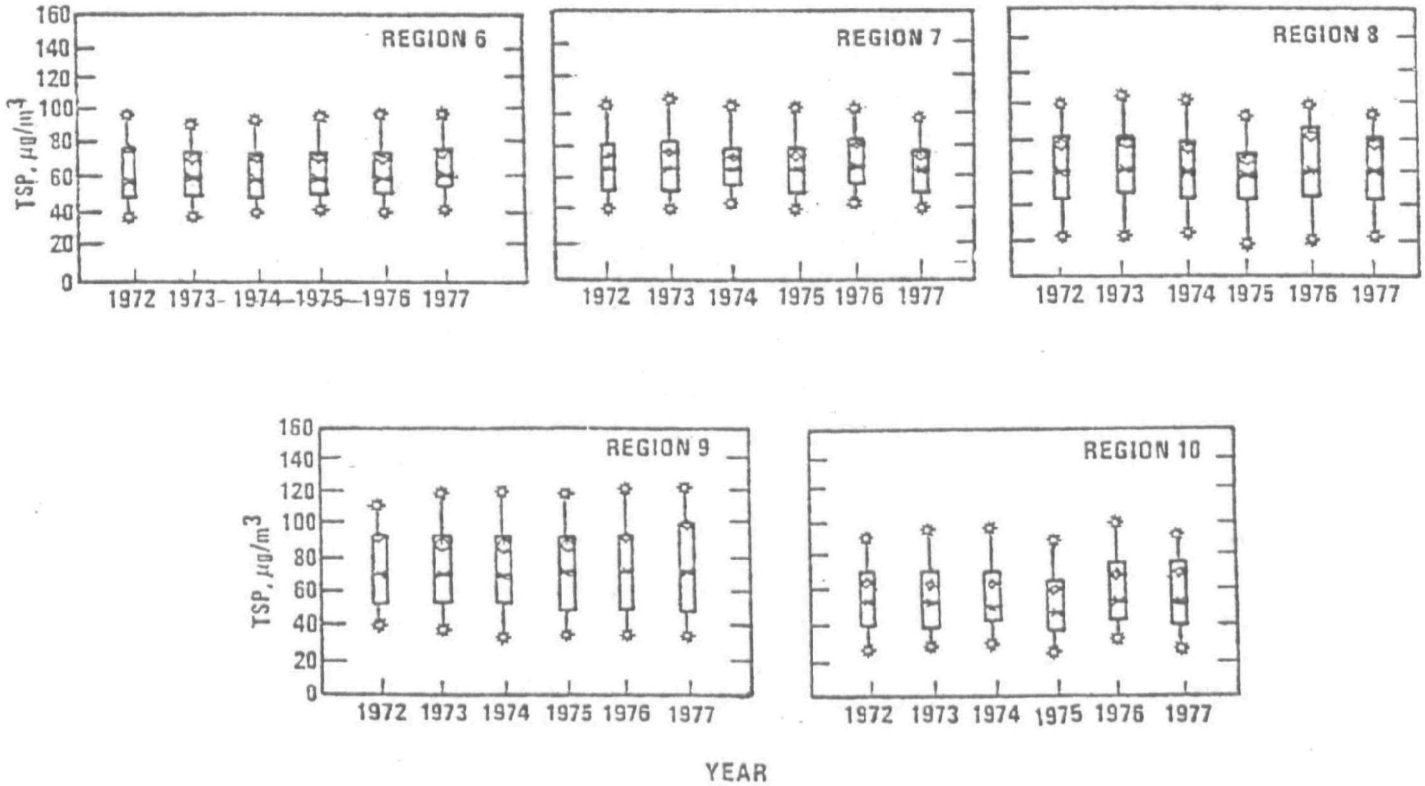
To examine the TSP problem in greater detail, ambient TSP trends are available for five large metropolitan areas.10/11/ These five cities, New York, Chicago, Denver, Cleveland, and St. Louis, were largely unaffected by the dry weather of 1976 and 1977 (except possibly St. Louis), so this bias should not be present. The populations exposed to TSP levels exceeding the primary NAAQS in these five metropolitan areas are shown in Table V-3. The most significant improvements occurred in the New York metropolitan area.11/ In 1970, 11.2 million people in metropolitan New York lived in areas where the annual primary NAAQS was being exceeded. By 1976, all TSP monitors had registered annual means below this level. Thus, no one was living in areas exceeding the primary NAAQS. The average TSP concentration in metropolitan New York dropped from 78 micrograms per cubic meter in 1970 to 55 micrograms per cubic meter in 1976.

The results for the other four cities were somewhat different. Improvements in the number of people exposed to ambient TSP levels

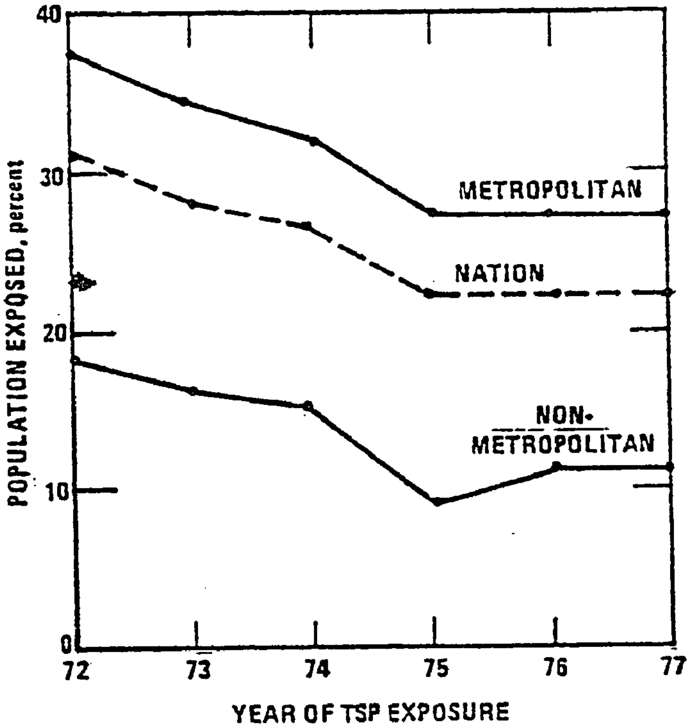

Regional trends of annual mean total suspended particulate concentrations, 1972 - 1977.




Regional trends of annual mean total suspended particulate concentrations, 1972 - 1977.

Figure V-7 10/




Population exposure to annual mean TSP in excess of NAAQS (75 μg/m3).

Table V-3

Population Exposure to TSP Levels in
Violation of the Primary NAAQS 10/,11/

| | New York | Chicago | Denver | Cleveland | St. Louis |
|---|---|---|---|---|---|
| Population (millions)* | 17 | 3.4 | 1.1 | 3.4 | 1.9 |
| | Percentage of Population Exposed to Levels Exceeding NAAQS | | | | |
| 1970 | 60% | 100% | 83% | | |
| 1972 | | | | 60% | 69% |
| 1973 | 12% | | | 50% | 46% |
| 1974 | | | | 37% | 48% |
| 1975 | | | 75% | 44% | 43% |
| 1976 | 0% | 64% | | 29% | 60% |
| 1977 | | | | 27% | 62% |

* 1970 Census data for the area studied, usually comprising the Air Quality Control Region.

in excess of the primary NAAQS have been made, but significant numbers are still exposed. Denver is probably in the worst situation.11/ While the percentage of people exposed to TSP levels exceeding the NAAQS has decreased 9%, a full three-fourths of the population are still exposed to these excessive levels. Likewise, for Chicago, 64% of the population are still living in areas where the TSP levels violate the primary NAAQS.11/ Cleveland has experienced a steady decrease in population exposure to excessive TSP levels since 1972, though 27% of the people in the air quality control region are still exposed.10/

St. Louis is the most interesting case. The population exposed to excessive TSP levels decreased steadily from 69% to 43% between 1972 and 1975. After that the exposed population increased back to nearly the 1972 level. Part of the reason for this increase, which first occurred in 1976, may have been the dry weather of that year. The precipitation around St. Louis was "slightly below normal" for 1976.11/ However, nothing is mentioned concerning the weather of 1977 and Region 7 (which includes St. Louis) in general showed no signs of exceptionally dry weather in 1977 (see Figure V-6). Thus, it would appear that at least some and perhaps most of the increase of 1977 is due to factors other than dry weather.

There are two primary reasons why ambient TSP levels have dropped significantly between 1971 and 1975. Both reasons concern stationary source particulate emissions. The first reason is the application of particulate control technology to the stationary sources of particulate emissions. Since 1970, many of the largest polluting industries have been required to control particulate emissions. This has occurred nationwide through attempts by states and localities to comply with the NAAQS for TSP (e.g., through equipping existing plants with particulate control devices as deemed necessary by local TSP levels). The second reason is that many combustion sources have switched to cleaner fuels which result in lower particulate emissions. The combustion of coal produces much more particulate emissions than the combustion of oil, and the combustion of natural gas produces even less particulate emissions than the combustion of oil. Thus, many sources in the early 1970's switched to oil and gas to reduce particulate emissions, as well as sulfur dioxide emissions.

While these methods have decreased ambient TSP levels over the last seven to eight years, there are some inherent problems associated with both of them which limit future reductions. First, most of the large reductions in particulate emissions possible from stationary sources have already been made.9/ The majority of the largest polluting plants have already come under state and federal standards, or are under compliance schedules soon to be completed. The potential for continued emission reductions has diminished, and future reductions will be even more costly. Since current NSPS are based on the best system of emission reduction which has been adequately demonstrated, while taking into account the cost of such a system, the advent of even greater control of currently controlled industries will not be widespread, barring major technological breakthroughs.

Second, the trend toward switching to oil and natural gas from coal has already stopped and even reversed itself due to the shortage of domestic oil and natural gas. Thus, any gains made in the past from switching to cleaner fuels will eventually disappear, and likely reverse themselves as coal usage becomes more and more prominent.

Finally, growth in production will enter into the situation. In any industry where emission standards stay at current levels, every new plant not replacing an obsolete plant will add to the overall emissions inventory. The ability of the air to clean itself does not increase with the nation's productive capabilities, so the end result is dirtier air.

In conclusion, while significant progress was made in the early 1970's in reducing ambient TSP levels, 22% of the national population is still exposed to ambient TSP levels in excess of the primary NAAQS of 75 micrograms per cubic meter (annual geometric mean). And the two strategies which contributed most to the TSP reductions of the early 1970's, application of emission controls to the stationary sources with the largest potential reductions and fuel-switching from coal to oil and natural gas, clearly will not be able to provide significant new reductions, expecially since the fuel-switching process will likely reverse itself and continued economic growth is expected to provide new sources of particulate matter. Therefore, heretofore uncontrolled particulate sources and new major particulate sources will need to be regulated if further TSP reductions are to be achieved. The next section will show the environmental benefits to be gained from the control of light-duty diesel particulate emissions.

## D. Impact of Diesel Particulate Emissions

The automotive diesel engine is currently an unregulated source of particulate in the atmosphere. Three different aspects of the diesel's environmental impact will be examined here. First, the amount of particulate emitted to the atmosphere will be determined. Second, the diesel's impact on large-scale TSP levels will be examined. Finally, the diesel's impact in localized areas where particularly high concentrations could occur will be examined. All of these impacts will be determined for 1990, as by that time the environmental benefits of the 1985 standard will be nearly complete. These environmental impacts in 1990 will be determined for both light-duty diesels and heavy-duty diesels, even though these regulations apply only to the former. Both sources emit in the same areas at the same time, and thus their impacts are typically combined. Of course, the combined impact cannot be used to justify control of only one of the sources.

1. Emissions

The determination of total particulate emissions from light- and heavy-duty diesels in 1990 requires three primary pieces of information: emission factors (in units of g/mi or g/km), sales (for each year until 1990), and a breakdown of vehicle miles travelled (VMT) for both light- and heavy-duty diesels.

The first step needed in this area is to determine the emission factors for light- and heavy-duty diesels. EPA has tested every light-duty diesel currently marketed in the U.S.12/ A current sales-weighted average of these emission levels (using Table III-6) is about 0.6 grams per mile (g/mi) or 0.37 grams per kilometer (g/km). However, the composition of the fleet could change considerably by 1990. From an analysis of the information available on future diesel sales,13/ General Motors, with its relatively high particulate emitters, is expected to retain a 55-65 percent share of the light-duty diesel market through 1990. Volkswagen, on the other hand, with its lower emitting diesels, is expected to lose much of its diesel market share, though increasing sales on an absolute basis. Ford and Chrysler are both expected to move toward diesels, together representing 28 percent of the diesel market in 1990, and nothing can be known about their emissions. Without the impetus of regulation, it is likely that these newer entrees to the market would be high emitters, not unlike the 1978-1979 Oldsmobiles.

To this is added the burden of strict NOx control (1.0 g/mi) by 1985. Up until that date, EPA may grant a waiver to 1.5 g/mi NOx and this waiver could prevent an increase in particulate emissions over current levels (see Chapter IV). However, beginning in 1985, Congress itself has set the NOx standard at 1.0 g/mi (0.62 g/km). Under this NOx standard, it is unlikely that uncontrolled particulate levels would be much under 1.0 g/mi (0.62 g/km). In fact, in their initial comments at the public hearing following the proposal of this regulation, some manufacturers wanted a 1.0 g/mi particulate standard even with a NOx waiver to 1.5 g/mi, especially General Motors which is presently the largest diesel manufacturer and which is expected to continue to account for a majority of the diesel market in the foreseeable future.13/,14/ Others thought lower levels were possible, but would require further effort. It is highly unlikely that any of this effort would occur without regulation. Thus, 1.0 g/mi (0.62 g/km) will be used as an uncontrolled particulate level for light-duty diesels.

The particulate emission factor for heavy-duty diesels will be estimated to be 2.0 g/mi (1.24 g/km). This factor is currently difficult to determine accurately since EPA has only recently developed a transient test for heavy-duty diesels.15/ A transient test appears necessary to accurately determine in-use particulate emissions. All historical data was obtained from steady-state tests and EPA is only now in the midst of its first transient testing of diesels. Thus, 2.0 g/mi (1.24 g/km), which is an accepted rough estimate of heavy-duty particulate emissions will be used.16/17/18/ It should be noted that in the past it has been believed that 2-stroke heavy-duty diesel engines had greater particulate emission factors than did 4-stroke engines; preliminary transient testing has indicated that 2.0 g/mi (1.24 g/km) is a good estimate for both 2-stroke and 4-stroke heavy-duty diesel particulate emission factors.

The next step is to determine the number of diesels which will be on the road in the future. This area has already been examined for light-duty diesels and the best estimate of future diesel sales is shown in Table V-4.13/ Diesel sales are expected to reach 11% of the light-duty market in 1985 and 20% in 1990 where they are expected to level off. As these projections could under or overestimate actual diesel sales, a range consisting of plus and minus 25% of the scenario in Table V-4 will be used for all subsequent analyses. If these scenarios are coupled with the standard EPA breakdown of annual vehicle miles travelled by model year,19/ the result is that 10.2-17.0% of light-duty travel in 1990 will be by diesel.

For heavy-duty diesels, the scenarios used here will be taken from the environmental impact analysis performed by PEDCo Environmental for EPA (based on projections made by Dr.John Johnson, Michigan Tech University).18/ These sales scenarios are shown in Table V-5. If the standard EPA breakdown of annual heavy-duty vehicle miles travelled by model year is used,19/ the result is that 59.7-83.9% of heavy-duty travel in 1990 will be diesel.

The final three items which are needed are an estimate of nationwide vehicle miles travelled (VMT), a breakdown of VMT by class, and an urban/rural breakdown of VMT by class. All of these will be taken from PEDCo (based on DOT data) and are shown in Table V-6.18/

Using all of these figures, the annual emissions of diesels can now be calculated. In 1990, uncontrolled particulate emissions from all diesels nationwide are expected to be 323,000 to 494,000 metric tons per year. Urban emissions would be slightly more than half this amount, 149,000 to 233,000 metric tons per year. Nationwide emissions from light-duty diesels in 1990 are expected to be 152,000 to 253,000 metric tons per year without control, while urban emissions would have been 84,000 to 141,000 metric tons per year. If no control is placed on heavy-duty diesel particulate emissions by 1990, they are expected to amount to 171,000 to

Table V-4

Year-by-Year Projections of the Diesel Fraction of Light-Duty Vehicle Sales 13/

| Model Year | Diesel Fraction (%) |
|---|---|
| 1981 | 4.7% |
| 1982 | 7.5% |
| 1983 | 8.9% |
| 1984 | 9.5% |
| 1985 | 11.4% |
| 1986 | 13.8% |
| 1987 | 16.5% |
| 1988 | 17.6% |
| 1989 | 18.7% |
| 1990 | 19.7% |
| 1991 | 20% |
| 1992 | 20% |
| 1993 | 20% |
| 1994 | 20% |
| 1995 | 20% |

Table V-5

Percentage of New Heavy-Duty Vehicle Sales Powered by Diesel Engines 18/

| Model Year | Heavy-Duty Vehicles | |
|---|---|---|
| | Low | High |
| 1977 | 28.0 | 28.0 |
| 1978 | 30.0 | 35.0 |
| 1979 | 31.0 | 36.0 |
| 1980 | 31.0 | 38.0 |
| 1981 | 31.0 | 40.0 |
| 1982 | 31.0 | 48.0 |
| 1983 | 31.0 | 57.0 |
| 1984 | 31.0 | 67.0 |
| 1985 | 33.0 | 78.0 |
| 1986 | 39.0 | 82.0 |
| 1987 | 45.0 | 86.0 |
| 1988 | 52.0 | 90.0 |
| 1989 | 58.0 | 94.0 |
| 1990 | 64.0 | 99.0 |

Table V-6

Nationwide and Urban VMT and Diesel
Particulate Emissions by Vehicle Class

| | |
|---|---|
| Nationwide VMT in 1974 18/ | 1.286 trillion miles |
| Annual Growth Rate | 1.5% per year |
| Urban/Rural Split | 54.1%/45.9% |

Breakdown of VMT by Class (1974) 18/

| | Nationwide | Urban |
|---|---|---|
| Light-Duty Vehicles | 0.788 | 0.830 |
| Light-Duty Trucks | 0.124 | 0.108 |
| Heavy-Duty Vehicles | 0.088 | 0.062 |
| | 1.000 | 1.000 |

Diesel Particulate Emissions (1990) (Metric tons per year)

| | Nationwide | Urban |
|---|---|---|
| Light-Duty Diesel | 152,000-253,000 | 84,000-141,000 |
| Heavy-Duty Diesel | 171,000-241,000 | 65,000-92,000 |
| Total | 323,000-494,000 | 149,000-233,000 |

241,000 metric tons per year, nationwide, and 65,000 to 92,000 metric tons in urban areas. These values are all shown in Table V-6. To put things into perspective, Table V-7 provides a comparison of current annual emissions from several major industrial source categories with estimates of uncontrolled diesel emissions in 1990. As can be seen, heavy-duty and light-duty diesels are projected to be significant sources of particulate emissions by 1990, if left uncontrolled.

During the next decade, as light-duty diesels become a major source of particulate emissions, there will be a significant decrease in lead particulate emissions from gasoline-powered light-duty vehicles and trucks. This trend has already begun and will continue as the gasoline-powered fleet becomes more and more dominated by vehicles equipped with catalysts, which require unleaded fuel and which thus emit little or no lead particulate. EPA estimates that gasoline-powered light-duty vehicles and trucks emitted approximately 250,000 metric tons of particulate matter in 1974 (1.173 trillion miles times a lead-salt emission factor of 0.213 g/mi), of which 107,000 metric tons would be classifiable as suspended particulate. By 1990, EPA expects gasoline-powered light-duty vehicles and trucks to emit only 16,000 metric tons of particulate matter, of which 7,000 metric tons would be classifiable as suspended particulate. Thus, EPA expects a reduction of 100,000 metric tons of suspended particulate from gasoline-powered light-duty vehicles and trucks by 1990 as compared to levels in 1974. With the expected increase in diesel particulate (from uncontrolled diesels) and the expected decrease in lead particulate (from gasoline-powered vehicles), then by 1990 EPA projects that total light-duty vehicle and truck particulate emissions will increase by 52,000 to 153,000 metric tons per year.

In summary, if left uncontrolled light-duty diesels will emit 152,000 to 253,000 metric tons of particulate per year by 1990, which EPA projects would make them one of the largest sources of particulate emissions. Lead particulate emissions from gasoline-powered light-duty vehicles will be reduced by 100,000 metric tons per year by 1990, thus the net increase of light-duty vehicle and truck particulate emissions will be 52,000 to 153,000 metric tons per year by 1990. These tonnage impacts are significant, both in terms of the diesel contribution and the overall light-duty contribution. The air quality impacts on various regions will now be examined in the next sections.

2. Regional Impact

The regional, or large-scale, impact of diesel particulate emissions is greatest in urban areas. This is no surprise since it is in urban areas where the greatest concentration of vehicles exist. As it is also in urban areas where most of the people of the nation live and where most of the violations of the NAAQS for TPS occur,10/ it is appropriate that this section concentrates

Table V-7

1975 Emissions from Selected Major Stationary Source Categories and Projected 1990 Emissions from Diesel Vehicles

| Stationary Sources | 1975 Emissions* (tons per year) |
|---|---|
| Electric Generation Plants | 3,000,000 |
| Industrial Boilers | 1,000,000 |
| Iron and Steel Industry | |
| Coke Ovens | <100,000 |
| Basic Oxygen Furnaces | 100,000 |
| Blast Furnaces | <100,000 |
| Kraft Pulp Mills | 200,000 |
| Aluminum Industry | 200,000 |
| **Diesel Vehicles** | **1990 Emissions (tons per year)** |
| Heavy-Duty | 171,000-241,000 |
| Light-Duty | 152,000-253,000 |

* Stationary source data extracted from National Emission Data System, 1975.

primarily on the impact of diesel particulate emissions in urban areas.

Three studies have attempted to determine the impact of diesel particulate emissions on urban air. The first was performed by PEDCo Environmental and focussed on Kansas City.18/ An air quality display model (AQDM) was used to predict ambient diesel particulate levels throughout the Kansas City metropolitan area within two-kilometer square grids. A total of 165 grids were modeled (660 square kilometers). The population residing in each grid was also determined so an estimate of the population exposed to various ambient levels could also be made.

The second study was also performed by PEDCo Environmental for EPA, but it used a different approach.20/ First, three larger cities were examined, New York, Los Angeles, and Chicago. Second, the study did not use a dispersion model to calculate ambient diesel particulate levels. Rather, ambient lead concentrations coupled with lead emission factors were used to determine the relationship between emissions and air quality for mobile sources. Then, ambient concentrations of diesel particulate could be calculated using this relationship and known diesel particulate emission factors. Ambient levels of diesel particulate were calculated at 15 actual TSP monitoring sites so the calculated levels could be directly compared to levels currently being measured at the same sites.

The third study was conducted by EPA and used essentially the same methodology as the second PEDCo report.21/ Ambient diesel particulate concentrations were estimated in over 35 cities ranging in population from less than 100,000 to over 5,000,000. The study also includes similar estimates of ambient diesel particulate levels in Chicago and Toledo which were submitted by General Motors during the comment period following the proposal of this regulation.22/

Each of these three studies used a different set of input data for emission factors, VMT growth, diesel penetration, etc. In order to be comparable, each had to be adjusted to a common set of input factors. This has already been done under separate cover for convenience.21/ The common set of input factors used was described in the previous subsection on emissions from uncontrolled diesels. The only difference was that growth in VMT was only assumed to be 1% per year in the central city areas being examined by the three studies.

One additional adjustment was also made to the results of the second PEDCo study. From the text of the PEDCo report, it was determined that an error was made concerning the automobile's contribution to ambient TSP levels in New York. A referenced study, which determined the auto's total contribution to ambient

TSP levels included reentrained dust, but was taken to refer only to automobile exhaust emissions. This error caused the New York results to be overestimated by a factor of 2.66. Due to the fact that the Chicago results were partially based on this erroneous factor, they were overestimated by a factor of 1.62. Any use of the PEDCo results here will be adjusted by these factors and a detailed discussion of the adjustments can be found under separate cover.21/

The results of the three studies are shown in Tables V-8, V-9, and V-10. Before drawing conclusions from any of them, it is helpful to discuss both similarities and differences among the results of the studies. The EPA study encompasses the cities contained in both the other two studies, so it can be used as common measure to compare the results of the two PEDCo methodologies, as well as for direct comparisons between EPA and PEDCo results.

First, it is evident that the expected Kansas City impact, as determined from ambient lead levels (Table V-10, EPA) is over twice that determined by the AQDM (Table V-8, PEDCo). On the other hand, the expected impacts in New York, Los Angeles and Chicago are about the same whether determined by EPA (Table V-10) or PEDCo (Table V-9). This latter finding is not surprising since both studies used ambient lead measurements as a basis, though slightly different methodologies were used to convert these ambient lead concentrations into diesel particulate concentrations. The level found at the first Chicago monitor modeled by PEDCo (Table V-9) appears quite out of line with all the others and will be excluded from further reference. It is known that PEDCo assumed that automotive exhaust particulate was a constant fraction of TSP throughout the city. If this particular monitor was in a heavily industrial area showing a very high TSP level due to industrial sources, of which Chicago has quite a few,11/ then the automotive portion could be overestimated.

Using the EPA study as a common yardstick, the methodology applied in the second PEDCo study (Table V-9) yielded higher diesel particulate impacts than the AQDM even after taking into account differences in the cities examined. There is independent reason to believe that the AQDM underestimated the mobile source impact in Kansas City. A study has been performed which calculates ambient carbon monoxide (CO) levels using the PEDCo Kansas City results, and CO emission factors.24/ The model appears to estimate ambient CO levels a factor of four below those determined by monitors located within the city. This comparison was performed using CO, because current ambient levels of diesel particulate are difficult to distinguish from other combustion particles. Also, intuitively, there should be less error involved in ambient pollutant measurements and emission factors than that involved in regional dispersion modeling. From this section it would appear that the greater

Table V-8

Results of PEDCo Environmental's Kansas City Study 21/

| | |
|---|---|
| Total Number of Grids (2 x 2km) | 165 |
| Total Population (1970) | 756,000 |

| Ambient Diesel Particulate Level (micrograms per cubic meter ) | | Percentage of Population Exposed to at Least the Indicated Level of Diesel Particulate |
|---|---|---|
| Light-Duty | Heavy-Duty | |
| 0.7 - 1.2 | 0.6 - 0.8 | 2.1% |
| 0.7 - 1.1 | 0.5 - 0.8 | 5.9% |
| 0.6 - 1.0 | 0.5 - 0.7 | 13.2% |
| 0.6 - 1.0 | 0.4 - 0.6 | 17.8% |
| 0.5 - 0.9 | 0.4 - 0.6 | 28.6% |
| 0.5 - 0.8 | 0.4 - 0.6 | 32.8% |

Table V-9

Estimated Ambient Levels of Diesel Particulate at 15 TSP Monitoring Sites in Three Cities 21/

| City | Height (meters) | Distance from Road (meters) | Average Daily Traffic | Diesel Particulate Levels (micrograms per cubic meter) Light-Duty | Heavy-Duty |
|---|---|---|---|---|---|
| New York* | 22.9 | 91.5 | 12,100 | 2.1 - 3.5 | 1.6 - 2.3 |
| | 22.9 | 30.5 | 16,500 | 2.2 - 3.6 | 1.7 - 2.4 |
| | 18.3 | 15.25 | 26,600 | 2.6 - 4.3 | 2.0 - 2.8 |
| | 13.7 | 30.5 | 17,900 | 2.0 - 3.3 | 1.5 - 2.2 |
| | 7.6 | 91.5 | 16,800 | 2.5 - 4.2 | 1.9 - 2.7 |
| Los Angeles | 1.2 | N/A | 15,000 | 5.4 - 9.1 | 4.2 - 5.9 |
| | 7.6 | 1.8 | 15,000 | 5.6 - 9.4 | 4.3 - 6.1 |
| | 27.4 | 5.0 | 13,500 | 6.8 - 11.3 | 5.2 - 7.3 |
| | 5.5 | 17.0 | 18,000 | 5.7 - 9.5 | 4.4 - 6.2 |
| | 18.3 | N/A | N/A | 6.2 - 10.3 | 4.8 - 6.7 |
| Chicago* | 9.5 | 24.4 | N/A | 9.8 - 16.3 | 7.5 - 10.6 |
| | 4.6 | 30.5 | 4,700 | 4.8 - 8.0 | 3.7 - 5.2 |
| | 4.9 | 21.3 | 9,400 | 5.2 - 8.7 | 4.0 - 5.7 |
| | 39.9 | 9.15 | 11,600 | 5.0 - 8.3 | 3.8 - 5.4 |
| | 19.2 | 3.6 | 25,100 | 4.1 - 6.9 | 3.1 - 4.4 |

* The levels shown include a reduction by a factor of 2.66 (New York) and 1.62 (Chicago) to account for an error in the original PEDCo analysis. See text for further description.

Table V-10

Estimated Regional Ambient Levels of Diesel Particulate in 39 Cities in 1990 21/*

| Population Category | City | Particulate Level (micrograms per cubic meter) Light-Duty | Heavy-Duty |
|---|---|---|---|
| Over 1 million | Chicago | 3.0 - 5.1 | 2.3 - 3.3 |
| | | 6.3 - 10.7 | 4.9 - 7.0 |
| | Detroit | 2.1 - 3.5 | 1.6 - 2.3 |
| | Houston | 4.4 - 7.5 | 3.4 - 4.9 |
| | Los Angeles | 5.7 - 9.6 | 4.3 - 6.2 |
| | New York | 2.2 - 3.8 | 1.7 - 2.4 |
| | | 2.8 - 4.8 | 2.2 - 3.1 |
| | Philadelphia | 2.6 - 4.4 | 2.0 - 2.9 |
| | Average | 3.6 - 6.2 | 2.8 - 4.0 |
| 500,000 to 1,000,000 | Boston | 1.9 - 3.3 | 1.5 - 2.1 |
| | Dallas | 6.4 - 10.8 | 4.9 - 7.0 |
| | Denver | 2.0 - 3.4 | 1.5 - 2.2 |
| | Kansas City, MO | 1.5 - 2.5 | 1.1 - 1.6 |
| | New Orleans | 2.2 - 3.8 | 1.7 - 2.5 |
| | Phoenix | 4.4 - 7.5 | 3.4 - 4.9 |
| | Pittsburgh | 1.8 - 3.0 | 1.4 - 2.0 |
| | San Diego | 2.4 - 4.0 | 1.8 - 2.6 |
| | St. Louis | 2.5 - 4.2 | 1.9 - 2.7 |
| | Average | 2.8 - 4.7 | 2.2 - 3.1 |
| 250,000 to 500,000 | Atlanta | 2.2 - 3.7 | 1.7 - 2.4 |
| | Birmingham, AL | 2.6 - 4.4 | 2.0 - 2.8 |
| | Cincinnati | 1.7 - 2.9 | 1.3 - 1.9 |
| | Jersey City | 2.2 - 3.7 | 1.7 - 2.4 |
| | Louisville | 2.0 - 3.4 | 1.5 - 2.2 |
| | Oklahoma City | 3.5 - 5.9 | 2.7 - 3.9 |
| | | 2.1 - 3.6 | 1.6 - 2.4 |
| | Portland | 1.7 - 2.9 | 1.3 - 1.9 |
| | Sacramento | 2.2 - 3.8 | 1.7 - 2.4 |
| | Tucson | 1.6 - 2.7 | 1.2 - 1.7 |
| | Yonkers, NY | 2.4 - 4.1 | 1.9 - 2.7 |
| | Average | 2.2 - 3.7 | 1.7 - 2.3 |
| 100,000 to 250,000 | Baton Rouge | 2.0 - 3.3 | 1.5 - 2.2 |
| | Jackson, MS | 1.7 - 2.9 | 1.3 - 1.9 |
| | Kansas City, KA | 0.9 - 1.5 | 0.7 - 1.0 |
| | | 1.3 - 2.1 | 1.0 - 1.4 |
| | Mobile, AL | 2.0 - 3.4 | 1.5 - 2.2 |
| | New Haven | 2.4 - 4.1 | 1.9 - 2.7 |
| | Salt Lake City | 2.1 - 3.5 | 1.6 - 2.3 |
| | Spokane | 1.2 - 2.1 | 0.9 - 1.3 |
| | Torrance, CA | 5.0 - 8.4 | 3.8 - 5.5 |
| | Trenton, NJ | 1.9 - 3.1 | 1.4 - 2.0 |
| | Waterbury, CT | 3.8 - 6.7 | 2.9 - 4.4 |
| | Average | 2.2 - 3.7 | 1.7 - 2.4 |
| Under 100,000 | Anchorage | 2.1 - 2.7 | 1.6 - 1.7 |
| | Helena, MN | 0.6 - 0.8 | 0.5 - 0.5 |
| | Jackson Co., MS | 0.9 - 1.7 | 0.7 - 1.1 |
| | Average | 1.2 - 1.7 | 0.9 - 1.1 |

* Based on data from National Air Surveillance Network (NASN)

emphasis should be placed on the studies based on ambient CO and lead levels than those using regional dispersion modeling, particularly when the number of ambient pollutant measurements is large.

Given this emphasis, the regional impact of uncontrolled diesel particulate emissions in 1990 would be 2-11 micrograms per cubic meter (light-duty), and 2-7 micrograms per cubic meter (heavy-duty) in the nation's three largest cities. Together, these levels represent 5-24% of the NAAQS for TSP. The levels for other cities are somewhat lower and these levels tend to decrease with decreasing population, as shown in Table V-10. There are exceptions in each population category, such as Dallas and Kansas City. The impact of all diesel particulate emissions in Dallas is projected to be 6-11 micrograms per cubic meter from light-duty diesels and 5-7 micrograms per cubic meter from heavy-duty diesels. The impact in Kansas City is only projected to be 1.5-2.5 micrograms per cubic meter from light-duty diesels and 1.1-1.6 micrograms per cubic meter from heavy-duty diesels. It should be noted that the regional impacts in Table V-10 are based on National Air Surveillance Network (NASN) data, which typically involve only one or two monitors per city. Certainly the small number of monitors might explain some of the variability between cities. However, being a part of the NASN system, these monitors have a much greater likelihood of representing areas at least as large as a neighborhood and not be overly influenced by nearby sources. National Aerometric Data Bank (NADB) data was not used because these monitors are more likely to be located near large sources of lead and may not represent larger-scale impacts. Thus, the presence of a large nearby source should not be a cause of the variability.

Levels such as these would have a significant impact on the ability of these cities to meet the primary NAAQS for TSP. For example, in 1976, 64% of the population in the Chicago air quality control region lived in areas exceeding the primary NAAQS for TSP. Table V-9 projects the total diesel particulate impact to be 7-14 micrograms per cubic meter, with well over half due to light-duty diesels, even ignoring the one very high monitoring site. This is 5-12 micrograms per cubic meter higher than the diesel impact in 1976 which was estimated to be 2 micrograms per cubic meter at that time.20/ Ambient lead concentrations in 1975 were approximately 17-27 percent of the diesel particulate impact in 1990, or about 2.4 micrograms per cubic meter.21/ Since lead comprises about 52 percent of lead-containing particulate,21/ this translates into about 5 micrograms per cubic meter of leaded particulate. Since use of leaded gasoline should greatly decrease by 1990, a reduction of about 4 micrograms per cubic meter should occur. The net mobile source impact would then be 1-8 micrograms per cubic meter citywide. If stationary source and fugitive emissions did not decrease, then a total of 67-83 percent of the population would live in areas exceeding the standards, rather than only 64%.11/ In order to comply with the primary NAAQS for TSP with uncontrolled diesel emissions, an additional 1-7 micrograms per cubic meter of control would be necessary. This is a large amount of control for an area already having difficulty meeting the standards for TSP. The projected impacts of uncontrolled diesels in cities such as St. Louis, Denver, Dallas, and Los Angeles are similar to those in Chicago (see Table V-10).

In summary, EPA finds that the original PEDCo Environmental analysis (utilizing an air quality display model in Kansas City) was weak in certain aspects, and that the more recent PEDCo Environmental and EPA analyses (based on ambient lead levels and lead and diesel particulate emission factors) more accurately reflect the regional impacts to be expected from light-duty diesel particulate emissions. These studies show the regional impacts expected in 1990 from uncontrolled light-duty diesels to be very significant. Moderate increases in mobile source particulate levels (2-10 micrograms per cubic meter) will add to already excessive levels of TSP and increase the difficulty of complying with the primary NAAQS for TSP for practically all of the regions which have the very worst TSP violations. As discussed in the section on health effects, all of this additional particulate burden will involve particles which are inhalable, and nearly all will involve particles with diameters less than 2.5 micrometers, which are thought to be the most harmful to human health.

3. Localized Levels

Approximately six studies are available which examine the localized air quality impact of diesel particulate emissions. Here localized is defined to include areas on an expressway, beside an expressway at distances up to approximately 91 meters from its edge, and in a street canyon. These scenarios represent exposure to: people while commuting to and from work; persons employed by roadside businesses such as gasoline stations; families residing near major thoroughfares; pedestrians on busy streets; and occupants of offices, apartments, etc. which flank busy streets. As a survey and analysis of these studies has already been performed, only the pertinent results along with short descriptions shall be discussed here.25/

Since each study utilized different diesel penetration rates and emission factors, these variables were factored from their respective results and replaced by the standard set of conditions, described earlier, in order to be comparable. For light-duty vehicles and trucks, these conditions consist of a diesel emission factor of 1.0 gram/mile, a low estimate of dieselization equal to 10.2 percent of all light-duty vehicles in 1990, and a high estimate of dieselization corresponding to 17 percent of the light-duty fleet in 1990. For heavy-duty vehicles, the diesel emission factor is 2.0 grams/mile. The low and high diesel penetration estimates are 60 percent and 84 percent of urban miles traveled by heavy-duty vehicles, respectively. An analysis of urban traffic characteristics reveals that 93.8 percent of accumulated miles are from light-duty vehicles and trucks, the remainder are, for the purposes of this study, attributable to heavy-duty vehicles (based on DOT data, PEDCo).18/

A Southwest Research Institute study evaluated the on-expressway scenario.16/ Positive aspects of this report include: the choice of dispersion model, GM's line source model 26/, which yielded good correlation with tracer gas experiments 28/; the study site, a portion of I-45 at Joplin (Houston), where the wind is oriented roughly parallel to the roadway approximately 15 percent of the time (from 2.75°-25.25° relative to the road at 2.06-8.3 meters/ second); and the traffic count was well documented at 1494 vehicles/ hour for each of 6 lanes. The results, modified to comply with the aforementioned standard emission factors and dieselization rates, can be found in Table V-11.

From this study it can be seen that commuters on an expressway with a traffic volume of approximately 9000 vehicles per hour may expect exposure to diesel particulate at concentrations above regional levels of diesel particulate ranging from 13.7-65.1 micrograms per cubic meter. These values reflect the low estimate of dieselization and represent the contribution from both light-duty, approximately 56% of the total, and heavy-duty diesels. The high estimate of dieselization yields concentrations ranging from 21.3-100.9 micrograms per cubic meter; 61% of which is from light-duty vehicles. The wide range in expected levels reflects the important role of the wind. Higher on-expressway concentrations result when lower velocity wind approaches a trajectory parallel to the road. This condition allows cumulative dispersion towards receptors (people in cars) rather than away from them as would be the case for steeper road-wind angles.

To characterize the off-expressway impact, the Aerospace Corporation utilized a number of studies which used monitors to construct roadside spatial distributions of carbon monoxide and tracer gases.17/ Carbon monoxide is an especially good surrogate for ambient diesel particulate level projections, since motor vehicles are the predominant contributors to ambient CO levels and diesel particulate disperses more like a gas than a typical large particle. Their approach involved developing a pollutant concentration index by subtracting background concentration from measured roadside values and dividing the resulting difference by the appropriate source term. This process was repeated for various distances from the roadway. A roadside diesel particulate concentration profile was developed by multiplying the index values for specific locations by the desired particulate source term. The 7850 vehicle per hour traffic count was based on a 24-hour integration of actual traffic flow on an 8 lane urban freeway in Los Angeles.

This approach should be superior to mathematical modeling

Table V-11

Expected On-Expressway Concentrations
(micrograms per cubic meter)

| | 2.06 m/sec at 2.75°* | 2.06 m/sec at 25.25° | 8.3 m/sec at 2.75° | 8.3 m/sec at 25.25° |
|---|---|---|---|---|
| Light-Duty | 36.7 - 61.1 | 23.2 - 38.8 | 26.5 - 44.2 | 7.7 - 12.9 |
| Heavy-Duty | 28.4 - 39.8 | 18.0 - 25.3 | 20.6 - 28.8 | 6.0 - 8.4 |

* Wind speed and orientation with road.

Table V-12

Expected Off-Expressway Concentrations
(micrograms per cubic meter)

| | | 24-Hour Maximum | Annual Geometric Mean |
|---|---|---|---|
| 30 Meters from Road | Light-Duty | 24.2 - 40.3 | 8.1 - 13.4 |
| | Heavy-Duty | 18.7 - 26.3 | 6.2 - 8.8 |
| 91 Meters from Road | Light-Duty | 15.8 - 26.3 | 5.3 - 8.7 |
| | Heavy-Duty | 12.2 - 17.1 | 4.1 - 5.7 |

efforts because it is based on measured trends and characteristics while avoiding such assumptions as constant wind speed and atmospheric stability. The results, found in Table V-12, are given in terms of a 24-hour maximum concentration during one year and the corresponding annual geometric mean. In order to obtain 24-hour maximums, Aerospace chose values of the concentration index which corresponded to the 99.73 percentile ((1 - 1/365) x 100%). Annual geometric means were then calculated by dividing the 24-hour maximum values by 3.

To confirm this relationship between the two sampling times, the carbon monoxide records of the 8 cities listed in Table 6-1 of Air Quality Criteria for Carbon Monoxide were examined.27/ A slightly different divisor of 3.16 was obtained when the geometric mean of the ratio of 24-hour maximums to annual geometric means was calculated. Since the range of individual ratios is 2.44 (Chicago) to 5.0 (Washington D.C.), it is concluded that the factor used by Aerospace is reasonable and well within the scatter of the data.

Following this methodology, persons approximately 30 meters from a roadway carrying 7850 vehicles per hour could be exposed to annual mean diesel particulate concentrations of 14.3-22.2 micrograms per cubic meter from both light and heavy-duty vehicles. Roughly 58 percent of this is the light-duty contribution. Similarly, concentrations at a distance of about 91 meters from the roadway fall in the 9.4-14.7 microgram per cubic meter range. As mentioned above, annual geometric mean values are roughly one-third of the 24-hour maximum values.

It is important to remember that all these local impacts consider only one source. The total concentration that people would be exposed to would, therefore, be the predicted localized value plus the regional or background value coming from other roadways nearby which was discussed in the previous section. It is also important to note that the 91 meter distance used above to characterize a localized effect is further from the road than many of the "regional" monitors used to develop the regional impacts shown in Tables V-9 and V-10. This does not mean that the regional impacts described in Tables V-9 and V-10 are instead localized impacts. The regional monitors are located near roadways, but most are elevated and the roads are not heavily travelled relative to the expressway examined above. Rather, the large distances (91 meters) at which one can still find single source effects (busy expressway) is simply an example of the extent of potential localized effects.

Aerospace used the same methodology employed in the off-expressway study to characterize the street canyon impact.17/ Data collected from carbon monoxide monitors at various heights above the street were used to determine the pollutant concentration indices. Although it is recognized that mathematical models are valuable tools when trying to analyze pollutant dispersion, the Aerospace approach is more appropriate when trying to study general trends and situations. By not relying on such assumptions as constant building height and wind velocity this study relates more directly to everyday conditions. Their results, modified to reflect the standardizing assumptions mentioned earlier, 25/ are in Table V-13. The traffic count for the street canyon scenario was 936 vehicles per hour.

A special worst case scenario was evaluated to augment the street canyon study. For this analysis, it was postulated that 100 percent of the taxis in Manhattan (responsible for 40 percent of the midtown vehicle miles traveled) 29/ together with 25 percent of the remaining light-duty vehicles were powered by diesel engines emitting particulate at the rate of 1.0 grams per mile. A rush hour traffic density of 2,400 vehicles per hour was assumed.

Using these inputs to the Aerospace street canyon study, a predicted yearly 24-hour maximum concentration of 250 micrograms per cubic meter is obtained for a height of 1.8 meters above the street. The corresponding annual geometric mean under these conditions is 83 micrograms per cubic meter. No heavy-duty vehicles were considered in obtaining these concentrations.

General Motors performed a similar Manhattan analysis using a mathematical simulation of street canyon dispersion. 24/ They assumed a traffic density of 3,000 vehicles per hour, 60 percent of which were light-duty diesels emitting 1.0 grams per mile. An expected 1-hour concentration of 127 micrograms per cubic meter and a 24-hour average of 71 micrograms per cubic meter were reported.

When determining the potential impact of a particular concentration, it is important to consider the length of time people will be exposed to that level of pollutant. People who live and work in downtown areas (characterized by the 9.1 and 27.4 meter receptor heights) will be exposed for longer periods of time than those who are merely shopping (pedestrians). The impact to those living and working in the downtown area is, therefore, greater than the pedestrian impact under the conditions of this study.

In assessing the localized impact from diesels, it is beneficial to compare predicted concentrations to the National Ambient Air Quality Standards for particulate. The primary standards are 75 micrograms per cubic meter for an annual geometric mean and 260 micrograms per cubic meter for a maximum 24-hour concentration not to be exceeded more than once a year.

Due to the highly-specialized nature of the on-expressway study (designed to represent a worst case meteorology), no comparisons of its maximum 65.1-100.9 microgram per cubic meter diesel particulate levels to the standards will be made. Conditions

Table V-13

Expected Street Canyon Concentrations
(micrograms per cubic meter)

| | | 24-hour Max | Annual Geo. Mean |
|---|---|---|---|
| 1.8 Meters | Light-Duty | 17.3 - 28.7 | 5.7 - 9.6 |
| Above Street | Heavy-Duty | 13.3 - 18.7 | 4.4 - 6.2 |
| 9.1 Meters | Light-Duty | 13.9 - 23.2 | 4.6 - 7.7 |
| Above Street | Heavy-Duty | 10.7 - 15.1 | 3.6 - 5.0 |
| 27.4 Meters | Light-Duty | 8.3 - 13.9 | 2.8 - 4.6 |
| Above Street | Heavy-Duty | 6.4 - 9.0 | 2.1 - 3.0 |

favorable for such levels will occur less than 15% of the time. However, it would be useful to note that commuters could be exposed to these levels for 2 hours per day or more.

Approximately 30 meters from the roadway, diesel particulate will constitute 16.5-25.6% of the 24-hour standard and 19.1-29.6% of the annual standard. At the 91 meter distance, diesel contributions represent 10.8-16.7% of the 24-hour standard and 12.5-19.2% of the annual standard. It is important to remember that these numbers reflect the contribution from a single roadway and, therefore, do not consider background levels from other nearby streets and highways.

In the street canyon, at the 1.8 meter height, diesels are responsible for 11.8-18.2% of the 24-hour maximum and 13.5-21.1% of the annual standard. At a height of 9.1 meters the percentages are 9.5-14.7% for the 24-hour case and 10.9-16.9% for the annual case. The worst case Manhattan street canyon projected concentrations for light-duty diesels exceed the annual geometric mean standard by 11 percent and account for 96 percent of the maximum 24-hour standard.

These analyses clearly indicate that uncontrolled light-duty diesel particulate emission levels would have significant air quality impacts on areas surrounding busy streets and expressways. These localized impacts would be in addition to the regional impacts analyzed in the previous section and would make it extremely difficult for some such areas to comply with the NAAQS standards for TSP. The health effects consequences on persons who live, work, and travel in such areas would be even greater than those expected based on TSP impacts, since the small size of diesel particulate makes it especially hazardous to human health.

## E. Air Quality Impact of Regulation

The promulgation of a 0.6 g/mi (0.37 g/km) light-duty diesel particulate standard in 1982 and the lowering of this standard to 0.2 g/mi (0.12 g/km) in 1985 will markedly reduce both emissions from these vehicles and their impact on air quality. Beginning in 1982, particulate emissions from new light-duty diesels will decrease 40% from what would have been the uncontrolled level of 1.0 g/mi (0.62 g/km). Beginning in 1985, emissions from new diesels will be reduced 80% from uncontrolled levels. However even after implementation of the 1985 standard, diesel-powered vehicles will still be emitting approximately 15 times the amount of particulate emitted by gasoline-powered vehicles equipped with catalysts. Thus, even though the proposed reductions are significant, they do not require the diesel to perform as well as the catalyst-equipped gasoline engine with respect to particulate emissions.

These reductions are from new vehicles only. Those sold before 1982 and 1985 that are still operating will continue to emit particulate at their previous level. Thus, because this regulation only affects new vehicles, some time is needed for the in-use fleet to change over before the impact of the regulation can reach its full potential. By 1990, particulate emissions from light-duty diesels will be reduced 74%, from 152,000-253,000 metric tons per year nationwide to 40,000-66,000 metric tons per year nationwide. Urban emissions will similarly be reduced by 74%, from 84,000-141,000 metric tons per year to 22,000-37,000 metric tons per year.

As was mentioned earlier, uncontrolled light-duty diesels are projected to be a significant source of particulate emissions by 1990. In terms of projected reduction potential, however, light-duty diesels may be even more significant. The annual particulate emission reductions available from light-duty diesels are actually close to the total annual emissions from some entire industries, such as the iron and steel industry (see Table V-7). Also, while further reductions in stationary source emissions can be expected to mitigate future increases in emissions due to industrial growth, they cannot be expected to significantly reduce total emissions from current levels, making reductions from light-duty diesels even more necessary.

More importantly, the air quality impact of light-duty diesel particulate emissions will also be reduced by 74% in 1990. Table V-14 shows the ambient levels both before and after regulation of 15 cities having a population of over 500,000 people. The data have been taken from Tables V-9 and V-10 and the full range has been used when more than one estimate is available. These impacts should be indicative of neighborhood or larger scale impacts in the cities mentioned. Any monitors modeled by PEDCo (Table V-9) which did not meet EPA's criteria for the minimum distance from the roadway were excluded from Table V-14. As can be seen, ambient particulate levels from light-duty diesels will be reduced by 1.1-1.9 micrograms per cubic meter in Kansas City to 4.0-8.4 micrograms per cubic meter in Los Angeles and Dallas. This reduction should aid the majority of these cities in meeting the primary NAAQS for TSP.

The impact of this regulation on particulate levels in localized areas of particularly high concentrations is also significant. Table V-15 presents an overview of this impact. (All concentrations refer to light-duty diesel contributions only.) On the expressway the diesel particulate level will drop from 36.7-61.1 micrograms per cubic meter to 9.5-15.9 micrograms per cubic meter for the 2.06 meter per second wind speed - 2.75° worst case scenario. At a distance of approximately 30 meters from the roadway, the maximum 24-hour particulate levels are reduced from 24.2-40.3 to 6.3-10.5 micrograms per cubic meter. This reduction in the light-duty diesel particulate levels will benefit such people as service station operators who spend large amounts of time near roadways. People residing approximately 9 meters above the

Table V-14

Large-Scale Air Quality Impact on Regulation of Light-Duty Diesel Particulate Emissions

| Population Category | City | Light-Duty Diesel Ambient Particulate Level micrograms per cubic meter Uncontrolled | Regulated |
|---|---|---|---|
| Over 1 Million | New York | 2.0 - 4.8 | 0.5 - 1.2 |
| | Los Angeles | 5.4 - 11.3 | 1.4 - 2.9 |
| | Chicago | 3.0 - 10.7 | 0.8 - 2.8 |
| | Philadelphia | 2.6 - 4.4 | 0.7 - 1.1 |
| | Houston | 4.4 - 7.5 | 1.1 - 1.9 |
| | Detroit | 2.1 - 3.5 | 0.5 - 0.9 |
| 500,000 to 1,000,000 | Dallas | 6.4 - 10.8 | 1.7 - 2.8 |
| | New Orleans | 2.2 - 3.8 | 0.6 - 1.0 |
| | Boston | 1.9 - 3.3 | 0.5 - 0.9 |
| | Denver | 2.0 - 3.4 | 0.5 - 0.9 |
| | Pittsburgh | 1.8 - 3.0 | 0.5 - 0.8 |
| | San Diego | 2.4 - 4.0 | 0.6 - 1.0 |
| | Phoenix | 4.4 - 7.5 | 1.1 - 1.9 |
| | St. Louis | 2.5 - 4.2 | 0.6 - 1.1 |
| | Kansas City, MO | 1.5 - 2.5 | 0.4 - 0.6 |

Table V-15

Light-Duty Diesel Particulate Levels With and Without Regulation (micrograms per cubic meter)

On-Expressway

| | 2.06 m/sec wind speed at 2.75°* | 2.06 m/sec at 25.25° | 8.3 m/sec at 2.75° | 8.3 m/sec at 25.25° |
|---|---|---|---|---|
| Without Control | 36.7 - 61.1 | 23.3 - 38.8 | 26.5 - 44.2 | 7.7 - 12.9 |
| With Control | 9.5 - 15.9 | 6.1 - 10.1 | 6.9 - 11.5 | 2.0 - 3.4 |

Off-Expressway

| | 30 Meters from Road | | 91 Meters from Road | |
|---|---|---|---|---|
| | 24-Hour Max. | Annual Geo. Mean | 24-Hour Max. | Annual Geo. Mean |
| Without Control | 24.2 - 40.3 | 8.1 - 13.4 | 15.8 - 26.3 | 5.3 - 8.7 |
| With Control | 6.3 -10.5 | 2.1 - 3.5 | 4.1 - 6.8 | 1.4 - 2.3 |

Street Canyon

| | 1-8 Meters Above Street | | 9.1 Meters Above Street | | 27.4 Meters Above Street | |
|---|---|---|---|---|---|---|
| | 24-Hour Max. | Annual Geo. Mean | 24-Hour Max. | Annual Geo. Mean | 24-Hour Max. | Annual Geo. Mean |
| Without Control | 17.3-28.7 | 5.7-9.6 | 13.9-23.2 | 4.6-7.7 | 8.3-13.9 | 2.8-4.6 |
| With Control | 4.5- 7.5 | 1.5-2.5 | 3.6- 6.0 | 1.2-2.0 | 2.2- 3.6 | 0.7-1.2 |

Worst Case Manhattan Street Canyon**
1.8 Meters Above Street

| | 24-Hour Max. | Annual Geo. Mean |
|---|---|---|
| Without Control | 250 | 83 |
| With Control | 65 | 22 |

---

* Wind road angle.

** Diesels comprise 100 percent of the taxi fleet (40 percent of the total VMT) and comprise 25 percent of the remaining light-duty VMT.

street will witness reductions in the 24-hour maximum diesel particulate concentration from 13.9-23.2 micrograms per cubic meter to 3.6-6.0 micrograms per cubic meter. The worst case Manhattan street canyon scenario concentration will be reduced from 83 to 22 micrograms per cubic meter for the 1.8-meter height on an annual geometric mean basis. The corresponding 24-hour maximum will be reduced from 250 to 65 micrograms per cubic meter.

In summary, particulate emissions from light-duty diesels will be reduced by 74% by 1990, from 152,000-253,000 metric tons per year to 40,000-66,000 metric tons per year. The air quality impacts will also be reduced by 74% in 1990, with regional reductions in large metropolitan areas varying between 1.1 and 8.4 micrograms per cubic meter, and localized reductions near busy streets and expressways varying between 3.9-6.4 micrograms per cubic meter (91 meters from expressway, annual geometric mean) to 27.2-45.2 micrograms per cubic meter (on expressway, 2.06 meters per second wind speed at an angle of 2.75 degrees from the road). Clearly these reductions are very significant and would greatly increase the chances of urban air quality regions to comply with the NAAQS for total suspended particulate.

## F. Secondary Environmental Impacts of Regulations

Five potential secondary areas of impact will be discussed: energy, noise, safety, waste, and water pollution. No significant impact is expected in any of these areas.

The control technology expected to be used to meet both the 1982 and 1985 standards does not appear to affect fuel economy, either positively or negatively. Thus, there should be no impact on the nation's energy resources. Similarly, this control technology should not significantly affect engine noise.

There are potential safety implications connected with the use of a trap-oxidizer. It is possible that the trap-oxidizer could be damaged by extreme temperatures if too much particulate was capture before burn off. Any design of a device like this will have to adequately ensure that an accidental occurrence such as this would not affect vehicle safety.

It is also possible that these regulations could have an impact on solid waste and water pollution. While disposable traps are not envisioned as a likely control technology, if they were used to collect the particulate emissions, these traps would need to be discarded into the garbage, or burned. If discarded into the garbage and used as land fill, some of the chemical compounds present in diesel particulate could seep into the ground and pollute the ground water. This should not be more difficult to solve than the current problem of disposing of used engine lubricating oil. Assuming a typical diesel engine oil replacement period of 3,000 miles, (4800 km), a 4-liter engine capacity and an oil having a specific gravity of 0.9, 3.6 kilograms (kg) of oil must be disposed of every 3000 miles. If a trap collected 0.4 g/mi (0.25 g/km), this would produce 1.2 kg of particulate plus the trap every 3000 miles. Since the engine oil actually contains some particulate from the cylinder and is essentially all organic matter, while the majority of the particulate matter is carbon, the traps should be less of an environmental problem than the existing oil disposal problem.

References

1/ "Airborne Particles," National Academy of Sciences, November 1977, EPA-600/1-77-053.

2/ Miller, Frederick J., et. al., "Size Considerations for Establishing a Standard for Inhalable Particles," JAPCA, Vol. 29, No. 6, June 1979, pp. 610-615.

3/ Groblicki, P.J., and C.R. Begeman, "Particle Size Variation in Diesel Car Exhaust," SAE 790421.

4/ Schreck, Richard M., et.al., "Characterization of Diesel Exhaust Particulate Under Different Engine Load Conditions," Presented at 71st Annual Meeting of APCA, June 25-30, 1978.

5/ Hare, Charles T. and Thomas M. Baines, "Characterization of Particulate and Gaseous Emissions from Two Diesel Automobiles as Functions of Fuel and Driving Cycle," SAE 790424.

6/ Braddock, James N. and Peter A. Gabele, "Emission Patterns of Diesel-Powered Passenger Cars - Part II," SAE 770168.

7/ Huisingh, J., et.al., "Application of Bioassay to the Characterization of Diesel Particulate Emissions," presented at the Symposium on Application of Short-Term Bioassays in the Fractionation and Analysis of Complex Environmental Mixtures, Williamsburg, VA, February 21-23, 1978.

8/ Barth, D. S., and Blacker, S. M., "EPA's Program to Assess the Public Health Significance of Diesel Emissions," Presented at the APCA National Meeting, June 28, 1979.

9/ "National Air Quality and Emissions Trends Report, 1975," OAQPS, OAWM, EPA, November 1976, EPA-450/1-76-002.

10/ "National Air Quality, Monitoring, and Emissions Trends Report, 1977" OAQPS, OAWM, EPA, December 1978, EPA-450/2-78-052.

11/ "National Air Quality and Emissions Trends Report, 1976," OAQPS, OAWM, EPA, December 1977, EPA-450/1-77-002.

12/ Danielson, Eugene, "Particulate Measurement - Light-Duty Diesel Particulate Baseline Test Results," Technical Support Report, EPA, January 1979, SDSB 79-03.

13/ "Summary and Analysis of Comments, Light-Duty Diesel Particulate Regulations," OMSAPC, EPA, October 1979.

14/ Transcript of the Public Hearing on Proposed Particulate Emission Standards for Light-Duty Diesel Vehicles, EPA, March 19-20, 1979.

15/ "Proposed Gaseous Emission Regulations for 1983 and Later Model Year Heavy-Duty Engines: Draft Regulatory Analysis," OMSAPC, EPA, December 8, 1978.

16/ "Study of Particulate Emissions from Motor Vehicles," Report to Congress.

17/ "Assessment of Environmental Impacts of Light-Duty Vehicle Dieselization," Aerospace Corp. for DOT, March 1979.

18/ "Air Quality Assessment of Particulate Emissions from Diesel-Powered Vehicles," PEDCo Environmental Inc. for EPA, March 1978, Contract #68-02-2515, Task #17.

19/ "Mobile Source Emission Factors," EPA, March 1978, EPA-400/9-78-005.

20/ "The Impact of Future Diesel Emissions on the Air Quality of Large Cities," PEDCo Environmental for the EPA, Contract No. 68-02-2585, February 1979.

21/ Heiser, Daniel, "Regional Air Quality Impacts of Diesel Particulate Emissions," EPA, November 1979, SDSB 79-30.

22/ "General Motors' Response to EPA NPRM on Particulate Regulation for Light-Duty Diesel Vehicles," April 19, 1979.

23/ 40 CFR, Part 60, "Standards of Performance for New Stationary Sources," Appendix C (FRL 907-11).

24/ Rykowski, Richard A., "Relative Impact of CO and Particulate on Air Quality," EPA Memorandum to Robert E. Maxwell, Chief, SDSB, November 5, 1979.

25/ Atkinson, R. Dwight, "Localized Air Quality Impacts of Diesel Particulate Emissions," EPA, November 1979, SDSB 79-31.

26/ Chock, David P., "A Simple Line-Source Model for Dispersion Near Roadways," Atmospheric Environment, Vol. 12, pp. 823-829, 1979.

27/ "Air Quality Criteria for Carbon Monoxide," Environmental Health Service, Public Health Service, Dept. of HEW, March 1970, AP-62.

28/ "Dispersion of Pollutants Near Highways - Data Analysis and Model Evaluation," Environmental Sciences Research Laboratory, U.S. EPA, EPA-600/4-79-011, Feb. 1979.

29/ Schwartz, Sam, Manhattan Transporation Department, Personal Communication with R. Dwight Atkinson, ECTD-EPA, September 10, 1979.

# CHAPTER VI

# ECONOMIC IMPACT

There is associated with nearly all emission standards a cost of compliance. In this chapter, the costs necessary for compliance with these regulations are examined and analyzed. The primary cost involves the development and installation of emission control technology and hardware on the diesel vehicles. Lesser costs are incurred by the emissions testing required for EPA certification, which include the purchase of new instrumentation and equipment required for the measurement of particulate emissions. All of these costs are borne by the manufacturer, who, in turn, passes them on to the consumer. The manufacturer will also attempt to make a profit on his investment and this will also be passed on to the consumer. A return on the manufacturer's investment is necessary, even if the investment is for pollution control equipment. Finally, the consumer also must bear any additional operating costs that may result from the proposed standards. All costs presented in the following sections will be in terms of 1979 dollars.

## A. Cost to Vehicle Manufacturers

### 1. Emission Control System Costs

The technology expected to be used to meet the 1982 and 1985 particulate emission standards was discussed in Chapter IV. Contrary to EPA's projections in the draft Regulatory Analysis,1/ vehicle manufacturers are no longer expected to use turbocharging to meet the 1982 standard. Instead, it appears that only minor combustion chamber modifications will be needed to meet this initial standard. To meet the 1985 standard, all vehicles except the Volkswagen Rabbit are expected to require trap-oxidizers. It is possible that some of these vehicles will be able to use other techniques to meet the final standard, such as turbocharging or other engine modifications, but to be conservative, this economic analysis will assume that all except the Rabbit will require trap-oxidizers.

The actual combustion chamber modifications that will be used to meet the 1982 standard are difficult to identify. The light-duty diesel manufacturers have been attempting to reduce the particulate emissions from their vehicles since it became evident that EPA was serious about controlling particulate emissions from light-duty diesels. Some of the resulting modifications will be introduced in 1980 with others being introduced in 1981 and 1982. Complicating matters is the fact that engine modifications have also been introduced to reduce hydrocarbon and nitrogen oxide emissions. Some of these modifications have improved particulate emissions while other have increased particulate emissions.

To simplify matters, the uncontrolled baseline will be taken to be the 1978-1979 model years, which followed so closely after the Clean Air Act Amendments of 1977 that no modifications to reduce particulate emissions could have been made. From that time to the 1982 model year, no manufacturer is expected to add any control hardware to reduce particulate emissions. All that should be required are modifications to the existing designs of the engine. As such, the only costs resulting should be those related to research, development, and retooling. These costs have been estimated to be $10 per vehicle averaged over all light-duty diesel sales between 1981 and 1983.2/ Due to delaying the standards to 1982 and 1985, the appropriate averaging period would be the 1982-1984 model years. As three model years are involved in both cases, the $10 per vehicle cost should be appropriate in either case.

Beginning in 1985, EPA estimates (for economic purposes) that all vehicles except the Volkswagen Rabbit will require a trap-oxidizer. The expected costs of trap-oxidizer systems for various engine sizes are shown in Table VI-1.2/ The costs decrease with time because the accumulated production volumes are increasing with time. A 12 percent learning curve was assumed to apply for the first five years of trap-oxidizer production, which means that the cost was reduced by 12 percent each time the accumulated production doubled. The fleet-wide average costs include the sales-weighted effect of small producers, whose small production volumes can lead to very high costs. It was conservatively assumed that each manufacturer would manufacture its own trap-oxidizers. As can be seen from Table VI-1, the costs for the smallest manufacturer of light-duty diesels could be over two and a half times the fleet-average cost. With these kinds of economics, it would seem likely that these small manufacturers would purchase their trap-oxidizers from an outside supplier to take advantage of lower production costs. Therefore, these high costs should never occur. However, they are shown here to indicate what would happen if these small manufacturers were forced to produce their own control systems.

The average costs for each year are also shown in Table VI-1. They were calculated by simply taking the arithmetic mean of the costs for the three engine sizes. It was assumed that in the timeframe in question, the production of 4-, 6-, and 8-cylinder engines would be roughly equal and that this simple averaging would suffice.2/ As can be seen, the fleet-wide average cost is expected to be $189-$224 per vehicle in 1985 and drop to $128-$152 per vehicle by 1989.

The original calculation of these costs assumed that the second standard would be implemented for the 1984 model year and covered the five-year period between 1984 and 1988.2/ As we are now interested in the period 1985 tnrough 1989, the original

Table VI-1

Estimated Costs of Trap-Oxidizer Systems at Predicted Production Volumes 2/

| | # of Engine Cylinders | Fleetwide Average | Largest Manufacturer (GM) | Smallest Manufacturer (IHC) |
|---|---|---|---|---|
| 1985 | 4 | 153-190 | 133-165 | --- |
| | 6 | 184-220 | 160-191 | --- |
| | 8 | 229-263 | 199-228 | 469-556 |
| | Ave. | 189-224 | 164-195 | --- |
| 1986 | 4 | 132-164 | 115-142 | --- |
| | 6 | 159-189 | 139-165 | --- |
| | 8 | 197-227 | 171-197 | 413-490 |
| | Ave. | 163-193 | 142-168 | --- |
| 1987 | 4 | 119-147 | 104-129 | --- |
| | 6 | 144-170 | 125-149 | --- |
| | 8 | 178-204 | 156-179 | 375-444 |
| | Ave. | 147-174 | 128-152 | --- |
| 1988 | 4 | 110-136 | 96-118 | --- |
| | 6 | 131-157 | 115-138 | --- |
| | 8 | 164-188 | 144-165 | 348-413 |
| | Ave. | 135-160 | 118-140 | -- |
| 1989 | 4 | 104-128 | 90-111 | --- |
| | 6 | 125-149 | 109-130 | --- |
| | 8 | 155-179 | 136-155 | 326-387 |
| | Ave. | 128-152 | 112-132 | --- |

costs have been simply delayed one year. For example, what was originally the fleet-wide average cost in 1984, $189-224, is now taken to be the same cost in 1985. This is an approximation which results in marginally higher costs, since the production in every subsequent year is higher than the preceding year and costs decrease with increasing production. However, because production is only increasing 10-25 percent per year during this period, the costs shown in Table VI-1 should only be around 2-4 percent high, which is within the general error of cost estimating.

A range of costs is shown in Table VI-1 because the actual components which will comprise a trap-oxidizer can be variable. The cost of two different systems have been included in the above range. The simpler system includes a trap, exhaust insulating features and a throttle with simple electro-mechanical control to periodically raise the exhaust temperature. The more complex system consists of a trap, exhaust insulating features and a complex electronic-control unit using a number of sensors to control a throttle on the intake air. A more detailed discussion of both the systems involved can be found elsewhere.2/

The Volkswagen Rabbits are expected to meet the final standard with further modifications to the engine at a similar cost to that of meeting the 1985 standard, $10 per vehicle. All light-duty diesels built after 1985 are expected to retain the engine modifications of the earlier years. However, these modifications shall carry no cost since the research, development, and retooling costs shall have been paid for during the two previous years.

2. Certification Costs

Certification is the process that a vehicle manufacturer must go through to demonstrate to EPA that its vehicles are designed to meet emission standards over a predetermined useful life. A manufacturer must first submit an application for certification to EPA. Then the vehicle in question undergoes two types of testing. The first type of testing is a durability test. This test covers 50,000 miles (80,500 km) of driving during which the vehicle is tested for emissions every 5,000 miles (8,050 km). The durability test is used to determine the function between emission levels and accumulated mileage. The data from a durability test of a single vehicle type may then be used to characterize the durability of other slightly different vehicles within that engine family expected to have similar emission deterioration.

The second type of test, an emission-data test, is performed to determine the level of emissions from the various vehicles in each family. This test is performed after each vehicle has been driven 4,000 miles (6440 km). The emission level at 50,000 miles is then determined by multiplying the emission-data test results by the deterioration factor derived from the durability test vehicle. There will typically be three to five emission-data tests run for every durability test performed. This allows the emissions of up to five different vehicles to be determined without the cost of running five durability tests.

If a manufacturer does not change its engine or vehicle design significantly from one year to the next, it may request that EPA "carryover" the emission test results from the year before to the current year. In this way, the manufacturer can obtain certification without repeating the process needlessly, assuming that the emission standards have not been reduced to a level below the past year's emission results.

In the case of these particulate regulations the standard will become effective in the 1982 model year. Normally, this would prevent any carryover of the previous year's testing because particulate emissions were not being measured in the previous year. However, in this case, the option is being made available to measure particulate emissions during 1981 certification so that carryover can be a possibility. As the standard for NOx is being reduced in 1981, most vehicles are expected to have to recertify in 1981. Certification to the 1982 particulate standard in 1981 is a real possibility since all manufacturers were expected to be able to meet the 0.6 g/mi (0.37 g/km) standard in 1981. A one-year delay was made because the promulgation date of the standard was too late to require all manufacturers to certify all of their vehicles in time for the start of the 1981 model year. However, there should be time for manufacturers to certify most of their vehicles for particulate emissions in 1981, if they so choose. It is possible that this regulation will require very few additional certification tests in 1982, or that it will require all that normally would be required by a new standard, because no one was able to take advantage of the option of certifying in 1981. The first situation would result in nearly no 1982 certification costs being due to this regulation. The second would result in nearly all 1982 certification costs of light-duty diesels being due to this regulation. However, there are always new models being introduced and significant changes occurring with others that require recertification regardless of emission standards changing. This will be particularly true for light-duty diesels, because the growth in sales expected during this timeframe will include many new models. Thus, it will be estimated that 30 percent of the 1982 certification costs will result from new or modified models and at most 70 percent will be due to this regulation.

It is estimated that a durability test will cost about $168,000 to perform while an emission-data test will cost $23,000. 3/ Of these costs, 3.5% result from actual testing while the rest is due to vehicle use and mileage accumulation. Table VI-2 shows the number of successful tests each manufacturer is expected

Table VI-2

Light-Duty Diesel Certification
Test Costs for MY 1982

| Manufacturer | Estimated Number of Durability Vehicles 1/ | Estimated Number of Emission Data Vehicles |
|---|---|---|
| General Motors | 6 | 18 |
| Volkswagen | 3 | 8 |
| Daimler-Benz | 3 | 9 |
| Peugeot | 1 | 3 |
| International Harvester | 1 | 3 |
| Others | 8 | 23 |
| | 22 | 64 |
| Cost per Vehicle Tested 2/ | $ 169,000 | $ 23,000 |
| Total Cost 3/ | $3,790,000 | $1,500,000 |
| Cost Due to Particulate Regulation | | |
| Maximum 4/ | $2,653,000 | $1,050,000 |
| Minimum 5/ | $0 | $0 |

---

1/ Approximately equal to number of Engine Families.

2/ Hardin, Daniel P., Jr., "Light-Duty Vehicle Certification Cost", EPA Memorandum to Edmund J. Brune, March 13, 1975. Adjusted to 1979 dollars using an annual inflation rate of 8%.

3/ A factor of 1.55 has been applied to 3.5% of the test costs, which is due to actual emission testing, to account for voided tests and retests.

4/ Includes a factor of 0.7 to account for those tests which would have occurred without these regulations on new models and models which were significantly modified.

5/ Assumes all vehicles were able to certify in 1981 and obtain carryover.

to perfor on light-duty diesels and the associated costs. All of the costs in this section are stated in 1979 dollars. Based on current EPA experience in testing light-duty diesels for gaseous emissions, a void rate of 20% on such tests is typical. This rate is expected to decrease in the future as experience with the diesel procedure increases. When other disqualifiers are included (e.g., manufacturer and administrative errors, lack of correlation with previous tests, etc.), the overall retest rate becomes about 50%. The addition of a particulate measurement system is expected to increase this retest rate by 5%, or to an overall rate of 55%. This factor has been included in calculating the total costs shown in Table VI-2.

The total cost of 1982 certification due to these regulations is estimated to be $0-3.7 million. No additional costs due to an inability to carryover should occur in 1983 and 1984 because the particulate standard will not change. Certification costs in 1983 and 1984 will increase slightly, though, due to the need for increased personnel requirements and the increased number of void tests due to particulate testing. It is estimated that the additional requirement of particulate measurement will require one additional technician to be present for three hours per test. This time period includes the weighing of the particulate filter. Assuming the number of tests decreases 30%, due to a carryover of 50% of the 1982 models plus 20% additional new engines and model lines, and a cost of $25 per hour for technicians, the additional cost in 1983 and 1984 is $23,000 per year for the entire industry. The 5% increase in retest rate amounts to about 15 extra emission tests per year or about $6,000 per year.3/ Thus, the total cost of 1983 and 1984 certification due to these regulations is $29,000 per year.

The result for the 1985 standard is slightly different than that for the 1982 standard. The presence of a reduced particulate standard will prevent carryover for most light-duty diesels where it might have taken place since federal gaseous standards are not expected to change in 1985 for these vehicles. It would be reasonable to expect the number of engine families and models to increase about 30% between 1982 and 1985, since total diesel production is expected to increase in that timeframe. One-third of these new models should arrive in 1983, one-third in 1984, and one-third in 1985. Those that arrive in 1985 would not have been able to carryover from 1984, even without particulate regulations, because they will be brand new models. Thus, the cost of 1985 certification of the new models in 1985 should not be counted against these regulations. To account for the new models of 1983 and 1984, the maximum 1982 certification costs should be increased by 20%. It is also expected that with increased experience, the basic void rate of light-duty diesel emissions testing (before particulate testing) should decrease. This decrease is assumed to be about 10%, reducing the overall retest rate to 45% from 55%. It is assumed that this will occur in time for 1984 testing. Taking these factors into account, 1985 certification costs due to these regulations will be about $4.4 million. The additional costs of certification in future years due to the 1985 standard should be about $34,000 per year.

The addition of particulate standards is not expected to increase the number of Selective Enforcement Audit (SEA) tests performed on light-duty diesels. These vehicles can already be audited for compliance with gaseous emission standards. There will be an increase in the cost of these tests, however, due to both an increase in the number of voided tests and an increase in number of personnel needed to perform each test. Currently about 40 light-duty engine families are audited each year, with about ten vehicles being tested in each audit.4/ Each test is expected to cost about $400 (1979).3/ Roughly assuming that 10% of these engine families will be diesels and using the above estimates for the increase in voided tests and test personnel due to particulate measurement, the increased cost of SEA testing due to diesels will be $4,000 per year.

### 3. Test Facility Modifications

The light-duty diesel particulate regulations will require that manufacturers purchase new equipment to modify existing emission test cells to allow the measurement of particulate emissions. EPA estimates that it will cost approximately $55,000 plus $30,000 for a filter weighing system to modify each test cell.2/ A breakdown of this cost is shown in Table VI-3. Using this estimate, the total cost to industry will be $4,065,000. The distribution of this cost among the various manufacturers is shown in Table VI-4. The estimated number of test cells and facilities includes those required for SEA testing.

## B. Costs to Users of Light-Duty Diesels

Purchasers of light-duty diesels initially will have to pay for the costs of any emission control equipment used to meet the particulate emission standards plus the cost of certification and SEA which includes the cost of new particulate measurement equipment. The vehicle manufacturers pass on these costs to the purchaser by increasing the "first cost" or sticker price of the vehicle.

To calculate these costs, an estimate of the number of light-duty diesels which will be sold each year is needed. EPA's best estimate of diesel penetration can be found in the Summary and Analysis of Comments to the proposed regulation.2/ This estimate is reproduced here in Table VI-5. The estimates of total light-duty sales were determined by taking 1978 sales of light-duty vehicles and light-duty trucks, and using a 2% per year growth

Table VI-3

Costs of Modifying an Emissions Test Cell for the Measurement of Particulate Emissions

| Item | | Cost |
|---|---|---|
| 600 CFM PDP-CVS | | $38,000 |
| 18" Dilution Tunnel | | 10,000 |
| Particulate Sample System | | 7,000 |
| | Cost Per Cell: | $55,000 |
| Microgram Balance | | $10,000 |
| Weighing Chamber | | 20,000 |
| | Additional Cost Per Test Facility: | $30,000 |

Table VI-4

Certification and SEA Test-Equipment Modification Costs by Manufacturer

| Manufacturer | Estimated Number of Modified Cells | Estimated Number of Facilities | Total Cost 1/ |
|---|---|---|---|
| General Motors | 24 | 13 | $1,710,000 |
| Volkswagen | 8 | 4 | 560,000 |
| Daimler-Benz | 6 | 3 | 420,000 |
| Peugeot | 2 | 2 | 170,000 |
| International Harvester | 2 | 1 | 140,000 |
| Others | 15 | 8 | 1,065,000 |
| Total: | 57 | 31 | $4,065,000 |

1/ Based on $55,000 per cell modification and $30,000 per laboratory.

Table VI-5

Year-by-Year Projections of the Diesel Fraction of Light-Duty Vehicle Sales 2/

| Model Year | Diesel Fraction (%) | Total Light-Duty Diesel Sales |
|---|---|---|
| 1981 | 4.7% | 732,000 |
| 1982 | 7.5% | 1,192,000 |
| 1983 | 8.9% | 1,443,000 |
| 1984 | 9.5% | 1,571,000 |
| 1985 | 11.4% | 1,923,000 |
| 1986 | 13.8% | 2,374,000 |
| 1987 | 16.5% | 2,895,000 |
| 1988 | 17.6% | 3,150,000 |
| 1989 | 18.7% | 3,414,000 |
| 1990 | 19.7% | 3,668,000 |
| 1991 | 20% | 3,799,000 |
| 1992 | 20% | 3,874,000 |
| 1993 | 20% | 3,952,000 |
| 1994 | 20% | 4,031,000 |
| 1995 | 20% | 4,112,000 |

rate. The 1978 breakdown sales by manufacturer was assumed to stay constant through 1990. Diesel penetration rates were then estimated for each manufacturer and combined to yield the diesel fraction of total sales.

The costs of this regulation to users of light-duty diesels can now be calculated and are shown in Table VI-6. The cost of test equipment modifications were assumed to occur in 1981 and all certification costs were assumed to occur during the year prior to that model year. A 10 percent discount rate was used to determine the present value of all expenditures in 1979. These costs were then amortized over future diesel production to yield a constant cost per vehicle (again using a 10 percent discount rate). All costs incurred through 1983 were amortized over 1982-1984 production, which are the model years for which the first standard is effective. All later costs were amortized over the next five years of production (1985-1989).

The costs of vehicle modifications are shown next in Table VI-6; for 1982-1984 ($10 per vehicle) and for 1985 and on ($138-$164 per vehicle). The latter value is a sales-weighted average of the cost for Volkswagen Rabbits ($10 per vehicle) and the cost for all other vehicles ($147-$174 per vehicle averaged over 1985-1989).

The users of light-duty diesels will also have to pay for any increases in the costs of maintenance or fuel that occur because of this regulation. No increases in maintenance or fuel costs are expected due to the engine modifications occuring in 1982. The trap-oxidizer is expected to require about $30 worth of maintenance after the vehicle is 5 years old.2/ The addition of a trap-oxidizer system is also expected to reduce maintenance in two ways. One, the system will include a stainless steel exhaust pipe which will eliminate the normal need to replace it.2/ This is expected to save an average of $36 once during the life of the vehicle (at five years). Two, the trap itself should eliminate the need for either the muffler or the resonator.2/ This also eliminates the need to replace the muffler or resonator, which again occurs once when the vehicle is five years old and typically costs $44. Altogether, the addition of a trap-oxidizer should reduce operating costs by $50, which would typically have occurred in the fifth year of operation. Discounting back to the year of purchase reduces this savings to $31 per vehicle. No fuel penalty is expected from the use of a trap-oxidizer.

The total cost to the consumer can now be simply added up. For the 1982-1984 models, the users' cost should increase $11-$12 per vehicle. For the 1985 models, the cost of owning and using a light-duty diesel should increase $107-$133 per vehicle. The range of the latter cost is due to the possibility of different trap-oxidizer systems being used on different models. The actual cost paid by consumers will fall somewhere between these two costs, depending

Table VI-6

Cost to the Consumer of Light-Duty Diesel Particulate Regulations

| | | |
|---|---|---|
| **Pre-Manufacturing Costs** | | |
| Test Equipment - 1981 | | $4,065,000 |
| Certification and SEA - 1981 | | $0 - 3,707,000 |
| - 1982-1983 | | $33,000 |
| - 1984 | | $4,400,000 |
| - 1985 and on | | $38,000 |
| Total 1981-1983 1/ | | $3,407,000 - 6,471,000 |
| Amortized over 1982-1984 Production 2/ | | $1 - 2 per vehicle |
| Total 1984-1988 1/ | | $2,807,000 |
| Amortized over 1985-1989 Production 2/ | | $0 per vehicle 3/ |
| **Control Hardware Costs** | | |
| 1982-1984 | | $10 per vehicle |
| 1985 and on (VW Rabbit) | | $10 per vehicle |
| (All others) | 1985 | $189-224 per vehicle |
| | 1986 | $163-193 per vehicle |
| | 1987 | $147-174 per vehicle |
| | 1988 | $135-160 per vehicle |
| | 1989 | $128-152 per vehicle |
| | (Sales-weighted average) | $147-174 per vehicle |
| (Sales-weighted average 1984-88) | | $138-164 per vehicle 4/ |
| **Operating Costs** | | |
| 1982-1984 | | $0 |
| 1985 and on | | -$50 |
| (discounted to year of model) | | -$31 |
| **Net Cost to Consumer** | | |
| 1982-1984 | | $11-$12 per vehicle |
| 1985 and on | | $107-133 per vehicle |

1/ Discount rate of 10%, present value in 1979 dollars.

2/ Amortization weighted to result in an equal cost per vehicle over the years of production cited. Discount rate assumed to be 10%. Expenses are assumed to occur on January 1 of the given year and revenues are assumed to be received on December 31 of the given year.

3/ Less than $0.45 per vehicle.

4/ Based on 80% of VW's diesel production being Rabbits, 42% of VW's production being diesel, 11.4% of fleet sales being diesels (1985), VW representing 2.1% of light-duty sales and he total diesel sales projections for 1985-89 shown in Table VI-5.

on the complexity of the trap-oxidizer system used on a given model.

## C. Aggregate Costs--1982-1989

The aggregate cost to the nation of complying with the 1982 and 1985 light-duty diesel particulate standards consists of the sum of increased costs for new emission control devices, new test equipment, additional certification costs, and changes in vehicle fuel consumption and maintenance requirements. These costs will be calculated for two periods. First, the aggregate cost of the 1982 standard will be calculated for the years for which that standard will be effective, 1982-1984. Second, the cost of the 1985 standard will be calculated over a period of five years, 1985-1989. Both aggregate costs will be presented in terms of 1979 dollars, present value in 1985. The year 1985 was chosen as the present value reference point to coincide with the implementation date of the second standard, since most of the costs of the regulation are associated with this standard. The aggregate cost of the 1982 standard was also calculated using 1985 as the present value reference point so that the two costs could be additive.

The aggregate cost to the nation is dependent on the number of light-duty diesels sold during these time periods. Any projection of this type will by nature be rough, due to the many social and economic factors involved. The sales projections used will be those shown in Table VI-5, plus and minus 25%. The aggregate cost to the nation based on these sales projections are shown in Table VI-7. The per vehicle costs of the two emission standards were taken from Table VI-6.

As shown in Table VI-7, the aggregate cost of the 1982 standard between 1982 and 1984 will be $42-76 million (present value in 1985, 1979 dollars). The five-year aggregate cost of the 1985 standard will be $897-1857 million (present value in 1985, 1979 dollars) between 1985 and 1989.

## D. Socio-Economic Impact

### 1. Impact on Light-Duty Vehicle Manufacturers

These regulations will affect diesel manufacturers in two ways. First, the manufacturers will be required to modify their current test cells to allow for particulate measurements and to certify their vehicles in 1982 and 1985 when otherwise they would have been able to obtain carryover. Secondly, the addition of particulate control hardware including R & D expense will raise the initial price of the vehicle and may affect sales.

Overall, diesel manufacturers may have to spend $7.7 million (1979 dollars) by 1982 to modify their emission test cells and

Table VI-7

Aggregate Cost to the Nation of Light-Duty Diesel Particulate Regulations

| | Per Vehicle Cost | Sales | Aggregate Cost 1/ |
|---|---|---|---|
| 1982 Standard 1982-1984 Model Years | $11-12 | 3.2-5.3 million | $42 to 76 million |
| 1985 Standard 1985-1989 Model Years | $107-133 | 10.3-17.2 million | $897 to 1857 million |
| 1982-1989 Total: | | | $939 to 1933 million |

1/ Present value in 1985, 1979 dollars, 10% discount rate used.

certify 1982 model year vehicles. A breakdown of these costs by manufacturer is shown in Table VI-8 (taken from Tables VI-2 and VI-4). General Motors could bear the largest portion of this, $2.7 million. This should not prove to be a problem for a company with over $35 billion in annual sales and $2.2 billion in capital expenditures (1975).5/ Volkswagen may have to spend $1.0 million, which again is not troublesome for a manufacturer of 2.1 million vehicles worldwide (1976).5/ Daimler-Benz may have to spend $0.9 million in 1981, but even if all of this was added to the price of their 1982 U.S. diesel models, it would only amount to $32 per vehicle, which is only about 0.2% of their sticker price (10% discount rate). If Daimler-Benz would spread the cost over 5 years, the per vehicle cost including 1985 certification would only be $10. Peugeot and International Harvester may have to spend more than the others, when compared on a per vehicle basis, because of their relatively small sales. On an absolute basis, though, neither would be expected to have a problem raising the capital involved. Thus, while there is a real cost involved in this area, no manufacturer is expected to be adversely affected.

The second area of impact of these regulations on manufacturers occurs in the area of increased vehicle prices due to emission control hardware. Cash flow problems should not be significant since the money invested in control devices is recovered soon after from the sale of controlled vehicles. The sticker price increase due to these devices, though, could potentially affect sales. In 1982, sticker prices of light-duty diesels are expected to increase $11-$12 per vehicle. With current vehicle prices ranging between $5,000 and $23,000, this increase represents less than 0.3% of the initial vehicle price and sales should not be affected.

Between 1985 and 1989 projected price increases are expected to average between $138 and $164 per vehicle. This represents about 1-6% of initial vehicle prices. This real price increase could affect sales in two ways. Purchasers of diesel-powered vehicles might switch to gasoline-powered vehicles. Or some purchasers may decide to wait an additional year before buying a new diesel.

It should be realized that the price of a gasoline-powered vehicle will also increase by 1985 due in part to the new gaseous emission standards being implemented in 1980 and 1981. Using the same cost methodology as that used for trap-oxidizers, a three-way catalyst system with its larger production volumes is expected to cost $226.2/ This, plus the cost of exhaust gas recirculation (EGR) and evaporative hydrocarbon control would place the total cost of pollution control equipment on gasoline-fueled vehicles around $240. The cost for a diesel to meet these gaseous emission standards should be less than $30 per vehicle based on current designs of exhaust gas recirculation systems. Even with the

Table VI-8

Initial Investment Required by
Light-Duty Diesel Particulate Regulation

| Manufacturer | Cost for Test Cell Modification and 1981 Certification 1/ |
| --- | --- |
| General Motors | $2,710,000 |
| Volkswagen | 1,044,000 |
| Daimler-Benz | 920,000 |
| Peugeot | 337,000 |
| International Harvester | 307,000 |
| Others 2/ | 2,450,000 |
| TOTAL: | $7,768,000 |

1/ Present value in 1981, 1979 dollars.

2/ Could include Ford, Chrysler, AMC, BMW, Volvo, Fiat, etc.

particulate regulations, the overall cost of pollution control from diesels should be less than that from gasoline engines. It is true that between now and 1985, the price of light-duty diesels will rise more than that of gasoline-fueled vehicles, but this is only because gasoline-fueled vehicles are currently paying a larger price for pollution control than diesels. Light-duty diesels will lose most of their advantage (with respect to the cost of pollution control) in 1985 due to this regulation, but it will be an advantage that was gained from previous environmental regulation. Gaseous pollutants such as hydrocarbons, carbon monoxide, and oxides of nitrogen simply came under control before particulate emissions. It appears, then, that diesel sales should not decrease at the expense of gasoline sales due to aggregate emissions regulations. Second, any absolute decrease in diesel sales should be less than any decrease in sales of gasoline-powered vehicles and this particulate standard should be no less acceptable than the Congressionally-mandated gaseous emission standards from this standpoint.

Thus, these regulations should not adversely affect the light-duty diesel industry, either through employment or productivity. Though a small decrease in diesel sales may occur due to the 1985 standard, this decrease should not be greater than any experienced by the gasoline-powered vehicle industry due to gaseous emission standards.

2. Impact on Users of Light-Duty Diesels

Users of light-duty diesels will be affected through higher initial vehicle costs averaging $11-$12 for 1982-84 and $138-$164 for 1985 and on. The average retail price of a new car in 1978 was estimated to be $6,940 or $7,495 in 1979 using an 8 percent inflation rate.6/ This means that the average vehicle sticker price will increase 0.2 percent between 1982 and 1984 and 1.9-2.2 percent in 1985 and beyond. Users of light-duty diesels will actually save $50 through reduced maintenance costs beginning in 1985. The lifetime cost of owning a vehicle was $12,600-17,900 in 1976 (undiscounted).7/ Inflating this to 1979 prices using an 8 percent inflation rate yields $15,900-22,500. When the increased cost of this regulation are compared to lifetime vehicle costs, the increases represent only 0.1 percent (1982-84) and 0.5-0.9 percent (1985 on) (undiscounted) of lifetime vehicle costs. Thus, this regulation should not have an adverse impact on the users of light-duty diesels.

## References


1/ "Draft Regulatory Analysis - Light-Duty Diesel Particulate Regulations," MSAPC, OANR, EPA, December 22, 1978.

2/ "Summary and Analysis of Comments - Light-Duty Diesel Particulate Regulations," MSAPC, OANR, EPA, October 1979.

3/ Hardin, Daniel P., Jr., "Light-Duty Vehicle Certification Cost," EPA Memorandum to Edmund J. Brune, March 13, 1975.

4/ Personal communication with Frank Slaveter, Mobile Source Enforcement Division, EPA, July 10, 1979.

5/ Automotive News - 1977 Market Data Book Issue, April 27, 1977.

6/ Personal communication with Tom Alexander, Economic Analysis Division, OPE, EPA, August 21, 1976.

7/ "Cost of Owning and Operating an Automobile - 1976," FHA, DOT, 1977.

# CHAPTER VII

## COST EFFECTIVENESS

Intuitively, cost effectiveness is a measure of the economic efficiency of an action towards achieving a goal. Historically however, the cost effectiveness of emission control regulations has been expressed in such terms as "dollars per ton of pollutant controlled." This expression is a measure of the cost of the regulation, not necessarily its efficiency. The presence of this conflict makes it awkward to speak in relative terms about cost effectiveness since a low cost-effectiveness value implies a highly effective regulation. To escape this conflict here, and still follow the precedent of placing cost in the numerator, the measure of cost effectiveness will be referred to as the cost-effectiveness ratio, or C/E ratio.

Furthermore, air pollution control regulations have multiple and frequently differing goals and, therefore, do not easily lend themselves to direct comparison of C/E measures. In the past, the principal application of comparing C/E measures has been the evaluation of alternative control strategies applicable to the same source, in the same time frame, and with the same objective. This markedly simplifies the analysis and, as will be seen below, avoids many problems. Nevertheless, a rough measure of one aspect of the relative merit of the light-duty diesel rules can be achieved by comparing the C/E measures of alternative diesel standards with other strategies designed to control particulate emissions. One area where EPA has adopted regulations to limit particulate emissions is the New Source Performance Standards (NSPS) for Stationary Sources called for by Section 111 of the Clean Air Act. While the statutory purposes and tests in Section 111 are different from those applicable to this diesel particulate standard, a rough comparison has been made which indicates that this decision is not inconsistent with other decisions the Agency has made to control particulate emissions.

In this chapter, the C/E measures for the two levels of diesel particulate control will be calculated and compared to those from other control strategies. As will be seen, it is not possible to take into account all of the environmental factors such as meteorological conditions, location, population exposures, etc., due to a lack of data. However, as many of the factors for which data are available will be incorporated.

### A. 1982 Light-Duty Diesel Particulate Standard

The calculation of the C/E ratio for light-duty diesel particulate control can be performed using input data already presented in past chapters. The uncontrolled emission level is 1.0 g/mi (0.62 g/km), and the standard is 0.6 g/mi (0.37 g/km). If these levels are assumed to occur over the entire life of the vehicle, the improvement due to regulation is 0.4 g/mi (0.25 g/km). If the life of a light-duty diesel is taken to be 100,000 miles (160,900 km), then the lifetime emission reduction is 0.04 metric tons. The cost of control has been calculated in Chapter VI to be $11-12 per vehicle. Thus, the C/E ratio is $11-12 divided by 0.04 metric tons, or $275-300 per metric ton of particulate controlled. This procedure of dividing lifetime costs by lifetime emission reduction does have the effect of underestimating the C/E ratio somewhat compared to the C/E ratios of stationary source controls to be presented later. However, as this procedure has been used for all past mobile source regulations, its use will be continued here.

## B. 1985 Light-Duty Diesel Particulate Standard

For this standard, two C/E ratios should be calculated. The first is an overall C/E ratio which represents the cost of the 1985 standard compared to no control. The second is the incremental C/E ratio which expresses the cost of the 1985 standard over that of the 1982 standard. It is this latter ratio which should be compared to the C/E ratios of other control strategies.

The overall cost per vehicle of the 1985 standard is $107-133 (Chapter VI, Section B). The overall emission reduction is 0.8 g/mi or 0.08 metric tons over the life of the vehicle. The overall C/E ratio is then $1,337-1,662 per metric ton of particulate controlled.

To determine the incremental C/E ratio, both the incremental cost and the incremental effect of the 1985 standard, over that of the 1982 standard, must be determined. The incremental cost is $107-133 minus $11-12, or $96-121. The incremental control is 0.08 minus 0.04 metric tons, or 0.04 metric tons of particulate controlled. The incremental C/E ratio is then $2,400-3,025 per metric ton of particulate controlled.

## C. Comparison of Strategies

The purpose of this section is to determine the C/E ratios of other particulate control strategies and demonstrate that the C/E ratio of the light-duty diesel regulations is not inconsistent with those of past strategies. All comparisons will be made against the higher incremental C/E ratio of the 1985 standard. If the 1985 standard is consistent with the incremental C/E ratios of other strategies, then the 1982 standard will also be consistent. All of the C/E ratios examined should be marginal in nature. This is necessary because the comparison must be made between the cost of the last level of control and cannot be influenced by the costs at less stringent control levels.

The incremental C/E ratios for several stationary sources are shown in Table VII-1. Except for the industrial boiler category, all of the C/E measures shown represent the costs and emission reductions of a Federal New Source Performance Standard over the less stringent alternative rejected by the Agency in selecting the level of the standard. The C/E ratio for the industrial boiler category represents the costs and effectiveness of two alternative control devices which are available.

As mentioned earlier, the most direct and easiest use of a cost-effectiveness measure is to compare various levels of control of a single source. In this case, most of the factors pertinent to the environmental impact, such as source location, dispersion characteristics, and pollutant characteristics, are the same for all the levels considered and the 'dollar per ton' measure is a good relative measure of the cost effectivenesss of the various strategies. Given enough knowledge and data, there is no reason that this same kind of analysis cannot be used to compare various strategies for controlling different sources. The problem is, of course, that the necessary data is usually very difficult to obtain and not available. The comparisons being made in this section are not true comparisons of the cost effectiveness of any of the strategies being examined. The necessary data is simply not available. However, comparisons such as these are being made elsewhere and will be made in the future. The goal here will be to make the comparisons, while at the same time stating clearly the limitations involved, insuring that any use of the results of this section is accompanied by full knowledge of their meaning.

The strategies being examined here all address particulate emissions on a nationwide scale. The light-duty diesel regulations will apply to every new light-duty diesel sold in the U.S. beginning in 1982, regardless of where the vehicle is bought or used. Likewise, the New Source Performance Standards (NSPS) for stationary sources also apply to all new or significantly modified plants of a certain type nationwide. No comparison of the diesel regulations will be made to other mobile source strategies because these diesel regulations are the first to control the emission of particulate matter from motor vehicles.

While both the mobile source and stationary source strategies being examined control particulate emissions into the atmosphere, there are differences in their primary purposes. An examination of Title II of the Clean Air Act, particularly section 202, shows that the primary purpose of mobile source regulations is to protect the public health and welfare. The primary purpose of the NSPS's, on the other hand, is to reduce inequities in interstate competition for economic growth, while minimizing emissions through the nationwide use of the best available control technology. A nationwide NSPS prevents those states and localities without severe air pollution problems from having an unreasonable advantage in drawing new plants from areas where strict controls are required.

Table VII-1

Incremental Cost Per Ton of Particulate Removed for Selected New Stationary Sources (1979 Dollars)

| Source | Cost-$/Metric Ton for Particulate Collected in Incremental Range | Reference |
|---|---|---|
| Medium Sized Industrial Boilers1/ | $900 | 1 |
| Electric Utility Coal-Fired Steam Generator2/ | $800-$900 | 2 |
| Kraft Recovery Furnace3/ | $1300-$1700 | 3 |
| Kraft Smelt Tank4/ | $150-$200 | 3 |
| Rotary Lime Kiln5/ | $1100-$1200 | 4,5 |
| Electric Arc Furnaces - Steel6/ | $600 | 6 |

1/ Baghouse (0.03 lb/$10^6$BTU) versus cyclone (0.3 lb/$10^6$BTU).

2/ High efficiency ESP (0.03 lb/$10^6$BTU) versus lower efficiency ESP (0.1 lb/$10^6$ BTU).

3/ High efficiency ESP (99.5 percent) versus lower efficiency ESP (99.0 percent).

4/ Venturi scrubber versus Demister (80 percent efficiency).

5/ High efficiency ESP (0.3 lb/ton limestone) versus lower efficiency ESP (0.6 lb/ton limestone) for 500 TPD plant; baghouse (0.3 lb/ton) versus lower efficiency ESP for 125 TPD plant.

6/ Direct evacuation with 90 percent efficient canopy hood versus direct evacuation with open roof.

While the primary purposes of the two types of strategies differ, the levels of control they represent do have a common purpose, that of protecting the public health and welfare. The NSPS's exist because some states and localities require at least this level of control to protect the public health and welfare in their areas. There are factors that affect the relative stringency of the two types of standards. For example, economics may be a more critical parameter for NSPS's than mobile source standards and the requirements for the demonstration of technology are stricter for NSPS's than mobile source standards. In a rough sense, however, both represent control levels implemented to protect the public health and welfare.

To take one rough step toward making the measure of cost effectiveness more relevant to health and welfare impacts, the basis of the previously cited 'dollar per ton' figures shall be modified to reflect the cost of controlling inhalable and fine particulate. In Chapter V, it was shown that it is these particles that have the greatest potential for adverse health impact. Thus, it is appropriate to emphasize the control of these particles. Also, it is these smaller particles (inhalable particles have diameters of less than 15 micrometers and fine particles have diameters of less than 2.5 micrometers) which have the greatest effect on visibility, which is likely one of the largest welfare effects of diesel particulate emissions.

Particle size data currently available for these sources are limited and the figures presented below should only be considered to be rough approximations. The size of diesel particulate has already been discussed in Chapter V. All of the uncontrolled diesel particulate is inhalable (diameter less than 15 micrometers) and between 94 and 100% is fine (less than 2.5 micrometers). It will be assumed that these size fractions will remain constant after the first level of particulate control in 1981 and the necessary levels of NOx control needed to meet the 1981-1984 NOx standards. This is a reasonable assumption since there is no reason to believe that the size should change drastically with the addition of EGR. The trap oxidizer, however, may be more efficient in trapping large particles than small ones. To be conservative, it will be assumed that all coarse particles (diameter greater than 2.5 micrometers) are captured and burned and that only that amount of fine particles necessary to meet the 1985 standard are also captured and burned. Using these assumptions, the result is that 100% (by weight) of the additional particulate controlled by the 1985 standard is inhalable and 91-100% is fine. An average value of 96 percent will be used for the latter figure.

Power plants (large steam generators) tend to emit larger particles than diesel engines. EPA has measured the particle size distribution of electrostatic precipitator effluent at both the previous emission standard of 0.1 pounds per million BTU (43 nanograms per joule) and the revised standard of 0.03 pounds per million BTU (13 nanograms per joule). Of the additional particulate collected at the revised standard, 90-100 percent (by weight) is inhalable and 20-40 percent is fine.6/

Medium sized boilers are commonly spreader stoker-type boilers which emit coarser particles than pulverized coal-fired boilers. As an approximation, it is estimated that 70 percent of the particulate collected in the incremental range between a cyclone and baghouse is inhalable and 25 percent is fine. For electric arc furnaces, the particulate removed by a baghouse installed with a canopy hood is about 90 percent inhalable and 60 percent fine.6/ For a kraft recovery furnace the incremental particulate collected by an ESP in the range from 99.5 to 99.0 percent is about 100 percent inhalable and 70 percent fine. The differential quantity of entrainment collected by a venturi scrubber in comparison with a demister on a kraft mill smelt tank is about 85 percent inhalable and 55 percent fine. High efficiency collection versus medium efficiency collection of particulate from a rotary lime kiln captures particulate that is about 80 percent inhalable and 50 percent fine.

Using these approximations, the C/E ratios for these six sources can now be placed on an inhalable and a fine particulate basis. The results are shown in Table VII-2. As can be seen, the cost effectiveness of the 1985 light-duty diesel standard is not inconsistent with those of past Agency actions or with a possible future Agency action (medium-size industrial boilers).

It is important to emphasize a point made earlier, i.e., that in some respects the mobile and stationary source strategies for particulate control have certain differences in their primary purposes. Therefore, selection of a measure of effectiveness for comparison purposes has inherent limitations. In spite of these, however, a comparison may still be useful to the degree that it focuses on one of their common purposes, protection of public health and welfare.

Up to this point, however, we have only incorporated one factor which may improve the comparability of the cost-effectiveness measures for different source strategies. There are many other factors which would need to be accounted for before a truly valid comparison could be made, such as emission dispersion characteristics, source location, chemical composition (and resulting health effects) of the particulate, etc. As these factors cannot be incorporated at this time due to lack of data, even the comparison performed in Table VII-2 must be taken cautiously. The incorporation of the factors mentioned above could change the results drastically.

To indicate this possibility, one rough calculation will be

Table VII-2

Incremental Cost-Effectiveness Ratios of Particulate Control Strategies Using Three Measures of Effectiveness (1979 Dollars per Metric Ton)

| Controlled Source | Total Particulate Basis | Inhalable Particulate Basis | Fine Particulate Basis |
|---|---|---|---|
| Light-Duty Diesel 1982 Standard | 275-300 | 275-300 | 286-312 |
| Light-Duty Diesel - 1985 Standard | 2400-3025 | 2400-3025 | 2500-3150 |
| Utility Steam Generators | 800-900 | 800-1000 | 2000-4500 |
| Medium-Size Industrial Boilers | 900 | 1300 | 3800 |
| Electric Arc Furnaces | | | |
| Steel | 600 | 700 | 1000 |
| Lime Kilns | 1100-1200 | 1400-1500 | 2200-2300 |
| Kraft Pump Mills | | | |
| Recovery Furnaces | 1300-1700 | 1300-1700 | 1900-2400 |
| Smelt Tank | 150-200 | 180-240 | 270-360 |

made comparing the air quality impact of a given rate of emission for both diesels and power plants. Only rough large-scale impacts will be considered, so this will not be an exhaustive comparison by any measure. However, it will serve to highlight the possible effects that these missing factors may have on any comparison of the cost effectiveness of different strategies.

As a rough approximation of the relationship of ambient impact to emission rate, the ratio of the maximum ground level concentration to the annual emission rate will be used. The maximum ground level concentration was chosen as an indicator of air quality impact because: 1) it was available for both sources, and 2) particulate levels near this maximum should occur over large areas for both sources. From 2), no localized concentrations of diesel particulate will be used in this analysis, only regional concentrations, nor will unusually high impacts from power plants due to unique topography or poor design be used. The annual emission rate was chosen as the indicator of emission levels because it is a good indicator of long-term emission impact.

EPA has already analyzed the air quality impact of power plants and it will only be summarized here.1/ Three sizes of steam generators were examined along with stack heights typical for those plants. The dispersion of emissions were then modeled to determine the maximum downwind concentration at ground level. The results are shown in Table VII-3. As can be seen, the ratio of the maximum ground level concentration to the annual emission rate is larger for the smaller plants. This is primarily due to shorter stacks.

The same calculation for light-duty diesels is slightly more complicated in that there are many individual diesels in close proximity to each other at various concentrations. No one source can be modeled and at the same time, no one source has a very large impact on air quality. With light-duty diesels, then, a geographical area must be examined rather than a single vehicle.

A metropolitan area would be appropriate since it represents a large area (on the order of that affected by a large power plant, though possibly smaller) and it contains areas of high concentrations (downtown) and low concentrations (semi-rural areas). Kansas City will be chosen for this task even though it appears to have a smaller diesel impact relative to other cities its size. The necessary data is available for Kansas City, and the metropolitan area does contain both urban and semi-rural areas.

The Kansas City area examined here will be that examined by PEDCo.7/ It comprises 660 square kilometers. Total vehicle travel in 1974 was $2.85 \times 10^9$ miles per year. Using the 1% per year growth rate used in Chapter V, total vehicle travel in 1990 will be $3.34 \times 10^9$ miles per year. If the low estimate of dieselization is examined here, 9.57% of total vehicle travel will

Table VII-3

Air Quality Impact of Three Steam Generators at Ground Level 4/*

| | Plant Size (Megawatts) | | |
| --- | --- | --- | --- |
| | 25 | 300 | 1000 |
| Annual Emission Rate (metric tons per year) | 71 | 854 | 2847 |
| Typical Stack Height (meters) | 75 | 175 | 275 |
| Maximum Ground Level Concentration (micrograms per cubic meter): | | | |
| Annual Mean | 0.1 | 0.1 | <0.1 |
| 24-Hour Maximum | 1.3 | 1.3 | 1.3 |
| Ratio of Maximum Ground Level Concentration to Annual Emission Rate (micrograms per cubic meter/metric tons per year) | | | |
| Annual | .0014 | 0.00011 | <0.000035 |
| 24-Hour Maximum | .0183 | 0.0015 | 0.00046 |

* Numbers bracketed (_/) indicate references at the end of this chapter.

be by light-duty diesel in 1990. At a particulate emission rate of 1.0 gram per mile, light-duty diesels would emit 321 metric tons per year. Using this scenario, the ambient concentration at a typical TSP monitor would be 1.5 micrograms per cubic meter (Table V-7). The ratio of ambient concentration to the annual emission rate would be 0.0047 microgram per cubic meter (per) metric ton per year. The maximum 24-hour impact for light-duty diesels is about 3.16 times the annual geometric mean (see Chapter V). Thus, the ratio of the 24-hour ambient concentration to annual emission rate would be 0.0149 microgram per cubic meter (per) metric ton per year. These results are summarized in Table VII-4. A comparison of these values with those in Table VII-3 shows that the ambient concentrations per unit emission rate of light-duty diesels is 3.4 and 134 times that for small and large steam generators on an annual basis, respectively. On a 24-hour basis, the ambient concentration per unit emission rate for small power plants is actually 1.2 times larger than that for light-duty diesels. For the large plants, however, light-duty diesels still have the larger relative impact by a factor of 32.

As mentioned earlier, the above ratios are only an extremely rough estimate of the relative air quality impacts of diesels and power plants. Many simplifications were necessary to be able to make this comparison at all. However, the results do indicate the size of the factors which may occur if an extensive analysis were performed and how the results of Table VII-2 might change if other factors were incorporated. Finally, the results also indicate clearly that the control of diesel particulate is no less cost effective than certain other cost-effective control measures adopted by EPA using the measures of effectiveness discussed above.

Table VII-4

Air Quality Impact of Light-Duty Diesels in the Kansas City Metropolitan Area - 1990

| | |
|---|---|
| Total vehicle miles traveled in area | $3.34 \times 10^9$ miles per year |
| Fraction of travel by light-duty diesel (low estimate of dieselization) | 0.094 |
| Emission factor | 1.0 gram per mile |
| Annual emissions | 314 metric tons per year |
| Maximum regional air quality impact (micrograms per cubic meter) | 1.5 |
| Maximum 24-hour average per year (micrograms per cubic meter) | 4.7 |
| Ratio of maximum ground level concentration to annual emission rate (micrograms per cubic meter (per) metric tons per year): | |
| Annual | 0.0047 |
| 24-Hour | 0.0149 |

## References


1/ "Particulate Emission Control Costs for Intermediate-Sized Boilers," Industrial Cleaning Institute for EPA, February 1977.

2/ "Electric Utility Steam Generating Units - Background Information for Proposed Particulate Matter Emission Standards," OAQPS, EPA, July 1978, EPA 450/2-78-006a.

3/ "Standards Support and Environmental Impact Statement, Volume 1: Proposed Standards of Performance for Kraft Pulp Mills," OAQPS OAWM, EPA, September 1976.

4/ "Standards Support and Environmental Impact Statement, Volume 1: Proposed Standards of Performance for Lime Manufacturing Plants," OAQPS, OAWM, EPA, April 1977, EPA 450/2-77-007a.

5/ Compilation of Air Pollutant Emission Factors, AP-42, Supplement No. 7, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, April, 1977.

6/ "Background Information for Standards of Performance: Electric Arc Furnaces in the Steel Industry Volume 1: Proposed Standards," OAQPS, OAWM, EPA, October 1974, EPA-450/2-74-017a.

7/ Personal communication with Jim Abbot, Industrial Emissions Research Laboratory Studies, ORD, EPA, January 10, 1980, unpublished emission control test results.

8/ "Air Quality Assessment of Particulate Emissions from Diesel-Powered Vehicles," PEDCo Environmental for EPA, March 1978, EPA-450/3-78-038.

# CHAPTER VIII

## ALTERNATIVE ACTIONS

These particulate regulations for light-duty diesels were required by Congress in the 1977 Amendments to the Clean Air Act. Nonetheless, possible control of other sources of particulate emissions were examined to ensure that these regulations were consistent with EPA's program to improve the nation's air quality. Also, Congress left it to EPA to determine the actual level of the emission standard, so many alternatives were available in this area. In the following chapter these alternative actions will be presented and discussed. In the first two sections, those actions which would preclude control of light-duty diesels will be presented. These would include 1) further control of stationary sources, and 2) the control of mobile sources other than light-duty diesels. Strategies for controlling fugitive dust or reentrained dust have been discussed previously and will not be repeated here.1/* Next, alternatives to the traditional individual vehicle emission standards will be presented and discussed. These alternative approaches include averaging the emission standard over all corporate sales, or over all corporate diesel sales. Finally, specific alternative emission standards to the 0.6 g/mi (0.37 g/km) standards for 1982 and the 0.2 g/mi (0.12 g/km) and 0.26 g/mi (0.16 g/km) standards for 1985 will be presented and discussed.

### A. Control of Stationary Sources

The majority of major urban areas have severe particulate non-attainment problems. The need for reductions in particulate emissions from some source or sources is clear. However, these areas have also demonstrated that attainment is not feasible even after adoption of all reasonable stationary source controls. While new source performance standards can definitely help to mitigate increased emissions and ambient impacts due to industrial growth, they cannot be expected to reduce TSP concentrations in urban areas from current levels. (See Chapter V,1/2/) Thus, it is concluded that further control of stationary sources is not a viable alternative to these light-duty diesel regulations.

### B. Control of Other Mobile Sources

In addition to considering further control of stationary sources of particulate emissions as an alternative to controlling light-duty diesels, the control of other mobile sources was also considered. These alternative mobile sources include gasoline-powered light- and heavy-duty vehicles, diesel-powered heavy-duty vehicles, locomotives and aircraft.

Light-duty vehicles and trucks powered by the gasoline engine and using leaded fuel were once a very significant source of particulate emissions. In 1974, it is estimated that exhaust emissions from these vehicles totalled 250,000 metric tons of particulate, with 107,000 metric tons classifiable as suspended particulate.3/ The great majority of this particulate matter consisted of particles related to the lead and lead scavengers used in the fuel. Since 1975 though, the majority of new vehicles have required the use of unleaded fuel in order to prevent premature catalyst degradation. With unleaded fuel and catalysts, these vehicles produce less than 3% of the particulate emissions of a diesel-powered vehicle. By 1981, when more stringent gaseous emission standards for light-duty vehicles will have come into effect, it is expected that almost all manufacturers will require the use of unleaded fuel in their vehicles. Thus, by 1982, when these light-duty diesel particulate regulations come into effect, new gasoline-powered light-duty vehicles and trucks will be producing very low levels of particulate emissions. Thus, control of these vehicles does not present an alternative to controlling light-duty diesel particulate emissions.

Heavy-duty diesel vehicles, like their light-duty counterparts, are a significant source of particulate emissions. It is estimated that by 1990, particulate emissions from uncontrolled heavy-duty diesels will reach 171,000-241,000 metric tons per year (Chapter V). This emission level is as large as the estimated emissions from uncontrolled light-duty diesels mentioned earlier. Also, much of the control technology available to light-duty diesels should be equally applicable to heavy-duty diesels. The Clean Air Act requires heavy-duty diesel particulate regulations and EPA is in the process of formulating an NPRM in this area. The control of heavy-duty diesel emissions does not reduce the need for regulations for light-duty diesels. The rationale for the level of the proposed light-duty standards has been based only on the projected impact of light-duty emissions. The light-duty standards have not been set at a level to alleviate the total diesel contribution to ambient TSP levels. Reductions will be required from heavy-duty diesels and have been assumed in the process of determining the light-duty standards. Also, these reductions from heavy-duty diesels are necessary from an air quality standpoint if the contribution of diesel particulate to ambient TSP levels is to be reduced as far as technology and economics permit. Thus, controlling particulate emissions from heavy-duty diesels is not an alternative to these light-duty regulations, but is a necessary complement to the overall mobile source scheme for reducing particulate emissions.

New regulations for heavy-duty diesel particulate emissions have not yet been proposed because of changes currently planned for the standards and test procedures for heavy-duty diesel gaseous emissions. The current heavy-duty diesel gaseous emission test procedure is a 13-mode steady-state test. There is an additional transient test to measure smoke, since smoke levels typical of in-use driving do not appear during the 13-mode cycle. A new transient test procedure, which will replace the steady-state test procedure, is being developed for use beginning in 1985. It has been determined that this new transient test procedure is necessary to adequately measure particulate emissions from heavy-duty diesels. Thus, regulations governing particulate emissions from heavy-duty diesels are currently being planned to come into effect in 1985 when the transient test procedure becomes available for diesels.

The contribution of heavy-duty vehicles powered by gasoline engines to total particulate emissions was also examined. In 1975, heavy-duty vehicles (gasoline) emitted about 51,000 metric tons of particulate.4/ Because today's heavy-duty trucks (gasoline) are still being built for operation on leaded fuel, this figure would still be a rough estimate of emissions in 1978. While the particulate emission level of heavy-duty vehicles (gasoline) does not compare with the particulate emission level of light- and heavy-duty diesels, it is still significant. By 1984 though, it is predicted that most new heavy-duty vehicles (gasoline) will be equipped with catalysts due to new emission standards which will come into effect that year. This will require unleaded fuel, and the particulate emissions from these vehicles will decrease drastically, as in the light-duty case. Thus, it appears that particulate emissions will be low from the new vehicles of this class by 1984, and no further control will be required.

Locomotives are another source of particulate emissions in the U.S. In 1975, locomotives emitted nearly 45,000 metric tons of particulate.4/ While this is not insignificant, a complete removal of all locomotive particulate emissions would only be a fraction of the necessary reductions of emissions from light-duty diesels. Also, reductions in locomotive emissions will not decrease the effect of automotive diesels near the roadway, where the largest impacts will occur. Thus, while locomotive particulate emissions may merit control at some time in the future, such control is not a feasible alternative to the proposed light-duty diesel regulations, either in magnitude or locality of emissions.

Finally, the control of particulate emissions from aircraft was examined as a possible alternative to the proposed regulations. In 1975, civil and commercial aircraft emitted 18,000 metric tons of particulate.4/ This emission level is even less than that from locomotives and amounts to only 7-12% of the projected light-duty diesel emissions in 1990. Thus, control of aircraft particulate emissions is not a viable alternative to the proposed standards for light-duty diesels.

## C. Averaging Approaches

In the Notice of Proposed Rulemaking (NPRM), EPA invited interested parties to comment on alternative regulatory approaches. One alternative approach generated considerable discussion during the public hearing and comment period--the development of an average particulate standard. Presently, all motor vehicle emissions standards are per vehicle standards, that is, each manufacturer is required to certify every engine family at or below each emission standard to receive certificates of conformity for every engine family. Under an average emission standard, each manufacturer would only have to insure that its average, fleet-wide emission level was at or below the appropriate emission standard. There are two primary advantages of an average emission standard as opposed to a per vehicle emission standard. The first is the increased flexibility that a manufacturer has in determining how it is going to comply with the emission standard. Instead of being required to design each engine family such that it can certify at or below the emission standard, the manufacturer has more flexibility as it must only conform to the requirement that its sales-weighted average emission level be equal to or less than the emission standard. The second advantage of an averaging approach, a result of the added flexibility, is that the manufacturer is better able to optimize its control technology strategies with respect to economics. It may quite likely be more cost-effective for a manufacturer to control one engine family to a very low emission level and a second engine family correspondingly less, than to control every engine family to the very same level. Two distinct averaging approaches were proposed during the comment period. General Motors (GM) proposed a plan whereby the sales-weighted average particulate level of a manufacturer's entire light-duty vehicle fleet would have to be equal to or less than the Corporate Average Particulate Standard (CAPS). Volkswagen (VW) suggested that the particulate emission levels from diesel vehicles only be averaged, and that each manufacturer's sales-weighted average be required to comply with the Diesel Average Particulate Standard (DAPS). Both of these proposals have been evaluated by the technical staff and will be discussed below, not only in the specific terms as proposed by GM and VW, but also with modifications that have been suggested by the technical staff to make the proposals more acceptable to EPA.

1. Corporate Average Particulate Standard (CAPS)

The following is an abbreviated description by GM of their CAPS proposal:

"[I]n response to the EPA invitation to address alternate particulate standard concepts, General Motors has developed a Corporate Average Particulate Standard (CAPS) concept. We believe this concept has the potential for providing the benefits of the diesel engine, reasonably controlling diesel particulate emissions, and being responsive to the legislative and regulatory requirements while properly considering technological feasibility and manufacturer capabilities. This CAPS results in a sequence of particulate standards based on the average level of particulate emissions of a manufacturer's total--both gasoline and diesel-powered--light-duty car and truck production. Although this standard-setting concept is markedly different than that proposed by EPA, such a concept is currently used in establishing fuel economy standards, so it is not new to government regulation... [T]he basic objective of the particulate standards is to prevent any deterioration in the mobile source contribution to total suspended particulates... The resulting CAPS levels are shown below:

| Year | CAPS Level |
|---|---|
| 1981 | 0.2 gpm |
| 1983 | 0.1 gpm |
| 1985 | 0.07 gpm |
| 1987 | 0.05 gpm |

In addition to these CAPS levels, a maximum permissible particulate emission level of 1 gpm from any individual diesel engine was also made a part of the CAPS requirements. In summary, the CAPS concept provides a number of major benefits. First, the air quality impacts would be reliably controlled, since the CAPS level would limit the total particulate emission levels to the atmosphere. This is a distinct improvement in long-term performance of the standard over the individual engine standards proposed by EPA. Second, CAPS would provide each manufacturer flexibility in determining what mix of diesel engine sizes can be produced, as well as what percentage of total production can be diesel engines....Third, CAPS provides a strong incentive for diesel manufacturers to develop better particulate emission controls, since successful development would allow increased sales of diesels with the resulting increase in fuel efficiency. Fourth, the CAPS concept is enforceable utilizing the basic structure of EPA enforcement regulations now in place. Only minor administrative modifications would be required to perform the enforcement operations in an effective manner."5/

As was mentioned earlier in this chapter, we agree with GM that the promulgation of an average particulate standard would provide more flexibility to the manufacturers. We also agree with GM that CAPS would put a "lid" on diesel particulate emissions. Once a manufacturer reached approximate equilibrium with the CAPS level, any increase in the number of diesels sold by that manufacturer would have to be accompanied by a corresponding reduction in particulate levels (assuming constant total sales by the manufacturer). Thus, the total diesel particulate loading to the atmosphere would be relatively constant, except for small increases due to increasing total sales by the industry. While we agree with GM that CAPS provides these two benefits, we take issue with the remaining two benefits which GM claims, and extensive analysis has found many problems which have compelled EPA to reject both GM's specific proposal and the CAPS concept in general. These issues will be examined in detail.

One basic tenet of EPA's motor vehicle emissions program has been to utilize uniform individual vehicle standards within a class of vehicles, i.e., to promulgate uniform standards within each class of vehicles that each individual vehicle must comply with. There are two primary reasons for this policy. One is simply the structure of Title II of the Clean Air Act, which assumes individual vehicle standards (see, for example, Sections 202 and 207). It is true that the current SEA assembly-line program is based on a quasi-averaging approach, but this was implemented so as not to be "unreasonably burdensome to the auto companies" in the short-term, and may be only temporary.6/ EPA's position is that the Clean Air Act requires every vehicle to meet the emission standards.7/ Certification averaging would clearly be inconsistent with this position. The second reason for individual vehicle standards concerns vehicle/vehicle equity. It has been determined that vehicles of the same general utility should be required to comply with the same emissions standards; that it would be inequitable to legally allow vehicle A to emit more than vehicle B is allowed to, when both vehicles perform the same general function. CAPS, and any other averaging approach, is inconsistent with both the Clean Air Act and the vehicle/vehicle equity considerations which are the bases for individual vehicle standards.

Another serious drawback of CAPS involves manufacturer equity. Since the CAPS concept averages diesel and gasoline-powered vehicle particulate levels, and since the latter are typically very low, a manufacturer's corporate average particulate level would be dependent not only on its diesel vehicle particulate levels but also on its relative proportion of diesel to gasoline-powered vehicles. A manufacturer which produced a small percentage of diesels could tolerate much higher particulate levels on its diesels, and still comply with a specific CAPS, than could a manufacturer which marketed a much higher percentage of diesels. In effect, manufacturers which produce higher percentages of diesels would have to meet more stringent diesel particulate levels than manufacturers which market lower percentages of diesels. Thus, manufacturer A would be allowed to market "dirtier" diesels than manufacturer B, only because A produced more gasoline-powered vehicles (with both manufacturers having the same total diesel sales) or fewer diesels (with equivalent total vehicle sales). Of the present light-duty diesel manufacturers, GM would be the primary beneficiary of such an approach since diesels comprise such a small percentage of their overall sales. Daimler-Benz and Peugeot would be the manufacturers most negatively affected by CAPS. In fact, given their present diesel/gasoline vehicle mixes (approximately 65 percent diesel), CAPS would be much more stringent for both Daimler-Benz and Peugeot than the per vehicle standards of 0.6 g/mi (0.37 g/km) in 1982 and 0.2 g/mi (0.12 g/km) in 1985. Under GM's suggested numerical standards and assuming that gasoline-powered vehicle emissions are negligible, Daimler-Benz and Peugeot would have to average 0.31 g/mi (0.19 g/km) in 1982 and 0.11 g/mi (0.07 g/km) in 1985 on their diesel vehicles. Alternatively, GM has estimated that its 1982 diesels would average approximately 1.0 g/mi (0.62 g/km) and its 1985 diesels 0.50 g/mi (0.31 g/km) under CAPS.8/ This analysis indicates that under CAPS, GM would be allowed to market diesels which would be approximately 3 times "dirtier" in 1982 and 5 times "dirtier" in 1985 than diesels sold by Daimler-Benz and Peugeot, while marketing more diesels than either of these manufacturers, simply because it sells many more gasoline-powered vehicles. In effect, CAPS licenses a manufacturer to market greater quantities of and progressively "dirtier" diesels based on its gasoline-powered vehicle production and EPA considers such an approach to be unacceptable.

CAPS might also act to restrain competition in the industry as a firm which wanted to produce only light-duty diesel vehicles would likely find it impossible (or nearly so) to comply with CAPS without also producing similar quantities of gasoline-powered vehicles, which might make the necessary capital investment prohibitive. GM proposed two possible solutions to the manufacturer equity problems of CAPS.9/ One was that EPA could provide a temporary period of exemption from CAPS for certain manufacturers. The second was that a "regulatory administrative process could be developed that would allow a manufacturer to obtain an additional particulate emission tonnage from another manufacturer which was not using its particulate emission tonnage for a specific year," i.e., that particulate tonnage could be sold or traded between manufacturers. Temporary exemption is simplistic and unacceptable, but in any case does not solve the problem of manufacturer inequity in the long term. The selling and/or trading of particulate tonnage would be an administrative nightmare, and would simply magnify the equity discrepancies even more in favor of low-percentage diesel manufacturers. Neither of these "solutions" is acceptable to EPA.

EPA has determined that adoption of the CAPS concept would be inconsistent with the statutory authority for the diesel particulate regulations provided in Section 202 (a)(3)(A)(iii) of the Clean Air Act. As discussed in Chapter IV, EPA is convinced that "the greatest degree of emission reduction achievable" mandate of that section requires best available control technology which, in turn, necessitates standards based on that technology. This mandate is impossible to fulfill with the CAPS approach since the particulate emission levels that a manufacturer's diesel models would be required to meet are dependent upon that manufacturer's diesel/gasoline vehicle mix and the manufacturer would be able to adjust that mix to whatever extent desired. A manufacturer could clearly avoid using best available control technology, or, in many cases, any particulate control technologies at all, by simply producing only a very small percentage of diesels. CAPS would then serve predominantly as a sales-mix forcing concept rather than a technology-forcing concept. In fact, CAPS implicitly establishes an upper limit on light-duty diesel sales. It is very unlikely that any manufacturer could sell more than 50 percent diesels under GM's CAPS, and as pointed out previously two manufacturers already exceed that figure. Adoption of CAPS would restrict those manufacturers to fewer diesel sales than the market demand; these manufacturers so affected might very well market diesels which emit lower levels of particulate than the cars sold by other manufacturers not so restricted. EPA has consistently held that Section 202(a)(3)(A)(iii) of the Clean Air Act was not meant to restrict light-duty diesel production, but rather was designed to encourage "clean" diesel production. The CAPS approach does not necessarily motivate low particulate levels, because of the possibility of low diesel/gasoline-powered vehicle mixes, and actually restricts diesel sales at high diesel/gasoline-powered vehicle mixes. This latter problem could be alleviated somewhat by offering CAPS as an option to those manufacturers which might prefer it to the individual vehicle standards. There would still be an equity problem, however, as low-percentage diesel manufacturers would have a real choice between the two types of standards, while the high-percentage diesel manufacturers would be compelled to certify under the individual vehicle standards.

Analysis has shown that there are difficulties associated with ensuring compliance under an average particulate standard approach. One approach that has received considerable attention adheres closely to the present philosophy of enforcement on an engine family basis. Each engine family would have a particulate enforcement level which would be the product of its certification level and the manufacturer's "safety factor," defined as the ratio of CAPS to the manufacturer's projected corporate average particulate level. Thus, if CAPS was 0.05 g/mi (0.031 g/km), and the manufacturer's projected corporate average particulate level was 0.04 g/mi (0.025 g/km), that manufacturer would have a safety factor of 1.25, and each of its engine families would have an enforcement level 25 percent greater than its certification value. Any engine family with an SEA particulate value in excess of its particulate enforcement level would then be subject to an order of corrective action.

The primary difficulties associated with this type of enforcement arise due to the fact that while the fleet-wide standard that must be met by the manufacturers would remain constant throughout the model year, the enforcement levels for the engine families would be subject to change. This is because the enforcement levels are dependent on the manufacturer's safety factor, and thus on the sales distribution (which could fluctuate throughout the model year) as well. During the certification process, the safety factor would be calculated based on the manufaturer's projected sales. Yet any final determination of the safety factor would not be possible until the end of the model year, when the final production figures would be known. This could lead to several possible problems.

For example, it can be shown that it is possible, due to a change in production distributions, for all of a manufacturer's engine families to be in compliance with their respective enforcement levels (as calculated during certification) while its corporate average particulate level could actually be exceeding CAPS. This is illustrated by the scenario shown in Table VIII-1 of a manufacturer with three diesel engine families. Based on its certification levels and sales projections, the manufacturer has a projected corporate average particulate level of 0.040 g/mi (0.025 g/km), and assuming a CAPS of 0.05 g/mi (0.031 g/km), a projected safety factor of 1.235. Its enforcement levels were as shown in Table VIII-1. The table shows that even though the actual SEA levels were less than the corresponding enforcement levels, the manufacturer was in noncompliance because its corporate average particulate level was 0.051 g/mi (0.032 g/km). In this case, the manufacturer did not produce any more diesels than it had projected, but simply produced more of engine family Z and less of engine family X. This resulted in a smaller safety margin and permitted fleet-wide noncompliance simultaneously with engine family compliance. The magnitude of this problem could be much worse if a manufacturer actually produced a higher percentage of diesels than projected, or if a much more marked sales shift from the "cleaner" diesel engine family to the "dirtier" diesel engine family occurred. Obviously this scenario could not be tolerated in an enforcement program. EPA could attempt to ameliorate this problem by constantly recalculating the safety factor throughout the model year. This precaution would not exclude the problem entirely, only make it less likely, as there is an inherent time interval between when a manufacturer changes production and EPA can recalculate its safety factor.

A second major drawback of this approach it that it would allow the scenario where an engine family would be declared to be in compliance immediately following an SEA test, but could actually be in noncompliance later in the model year. This could arise due to a changing production distribution resulting in a smaller safety factor and smaller enforcement levels. For example, in Table VIII-1, engine family X certified at 0.25 g/mi (0.16 g/km) and had a projected enforcement level of 0.31 g/mi (0.19 g/km). Assume that an SEA test was performed early in the model year and the mean particulate level was found to be 0.29 g/mi (0.18 g/km); the engine family would clearly be in compliance at that time. It could be quite possible that later in the model year, again due to a different production mix, that same engine family could have a revised enforcement level of 0.28 g/mi (0.17 g/km); at that point the engine family would be in noncompliance. This scenario raises the issue of how EPA would respond to such a discovery, especially at the end of a model year, when the only corrective action available is recall. The manufacturer would be forced to recall an entire engine family after it had been allowed to produce it for an entire model year. This also indicates the necessity of determining the mean particulate level for each SEA test, when enforcing on an engine family basis, since otherwise EPA would never know when the enforcement level might drop below the SEA mean particulate level for an engine family.

A third major difficulty with the engine family enforcement approach would arise when one engine family of a manufacturer exceeded its enforcement level, while an engine family which emitted more particulate did not exceed its enforcement level. For example, if SEA testing showed engine families X and Y (see Table VIII-1) to have mean particulate levels of 0.32 and 0.42 g/mi (0.20 and 0.26 g/km), respectively, the former would be in noncompliance while the latter would not. If this was discovered at the end of a model year, and recall action was instigated, that manufacturer would have to recall vehicles from the "cleaner" engine family while the "dirtier" engine family would be unaffected. This hardly seems logical or equitable, least of all to the consumer who may have purchased the former vehicle partly because of its lower particulate emission level.

The Council on Wage and Price Stability (CWPS) suggested a similar but slightly different compliance mechanism (though proposed as part of a diesel-only average approach, it could also be part of a corporate average approach).10/ The manufacturer or EPA would set a limited number of categories, each with a separate, fixed particulate standard. Each engine family would have to certify under one of these distinct category standards; the category would presumably be chosen by the manufacturer based on the certification emission level of the emission-data vehicle for each engine family and any safety margin deemed necessary. At the beginning of a model year, the category standards and projected sales for each category would be used to determine whether a manufacturer would be issued a certificate of conformity. During and at the end of a model year, the actual production (or sales) figures and the category standards would be averaged to determine fleet-wide compliance. The category standards would also be used for SEA and recall testing. The advantage of this approach is that the SEA enforcement levels are fixed, and are not dependent on the manufacturer's sales distribution or safety margin. This compliance approach would avoid the aforementioned scenario where an engine family would be in compliance immediately following an SEA test, but would be in noncompliance later when the enforcement

Table VIII-1

Hypothetical Particulate Enforcement Scenario

| Engine Family | Certification Level (g/mi) | Projected Sales (%) | Enforcement Level (g/mi) | Actual SEA Level (g/mi) | Actual Sales (%) |
|---|---|---|---|---|---|
| X | 0.25 | 4.5 | 0.31 | 0.30 | 3.5 |
| Y | 0.35 | 4.5 | 0.43 | 0.42 | 4.5 |
| Z | 0.45 | 3.0 | 0.56 | 0.54 | 4.0 |

level changed. The other major problems could still occur--all of a manufacturer's engine families could be in compliance with their respective category standards though, due to a changing sales distribution, its fleet-wide average particulate level could be exceeding CAPS, and "cleaner" cars could be faced with corrective action even while "dirtier" cars sold by the same manufacturer remain unaffected. Thus, the CWPS suggestion eliminates one of the uncertainties involved in the engine family compliance approach (the changing enforcement level), but does not resolve the other problems inherent in such a compliance approach.

Finally, EPA could abandon the engine family compliance approach and enforce on a fleet-wide basis only. EPA would still test emission-data vehicles from each engine family for particulate emissions. The manufacturers would be required to submit their sales projections, on an engine family basis, for the model year. With the particulate emission levels and sales projections it would be possible for EPA to calculate the projected corporate average particulate level for each manufacturer. If this projected level is less than, or equal to, CAPS, and no engine family exceeded the maximum particulate level allowed (and assuming all other emissions requirements were fulfilled), EPA would grant the manufacturer a conditional certificate of conformity. The certificate would be conditioned on the manufacturer keeping its actual corporate average particulate level (at any time, based on production up to that time) under CAPS throughout the model year.

SEA would still be used by the Agency to ensure that production vehicles were in compliance with CAPS. Whenever the SEA particulate value exceeded that engine family's certification particulate value, the former would replace the latter in the calculation of the manufacturer's actual corporate average particulate level. The SEA test, however, would no longer indicate noncompliance on an engine family basis, but would be a contributing factor in indicating noncompliance on a fleet-wide basis. At regular intervals throughout the model year, and whenever an SEA resulted in the substitution of a higher particulate value for an engine family, each manufacturer would be required to report its actual and projected production figures and actual and projected corporate average particulate levels. As long as these levels remained at or below CAPS, the manufacturer would be in compliance. If, at any time during the model year, a manufacturer's actual or projected corporate average particulate level exceeded CAPS, due either to an SEA test or a shift in the sales distribution, the manufacturer would be required to notify EPA immediately and to take corrective action. The central enforcement tenet of this approach is that at no time is a manufacturer "allowed" to exceed CAPS.

Because this compliance approach is on a fleet-wide basis only, it avoids the problems of engine family enforcement discussed above. This approach would necessitate a whole new compliance apparatus, however. Whereas SEA is now designed to indicate whether a certain percentage of vehicles pass an emission standard, under this fleet-wide compliance approach SEA would have to be designed to determine the mean particulate level of the engine family tested. More SEA would likely be necessary in order to ensure that EPA does not underestimate a manufacturer's actual corporate average particulate level by relying heavily on certification emission levels. This approach would also commit EPA to much more monitoring and paperwork, as EPA would have to be continually monitoring actual and projected sales for each manufacturer, and recalculating actual and projected corporate average particulate levels.

In conclusion, while EPA considers engine family enforcement to entail many difficulties, we have determined that fleet-wide compliance could probably be made workable, although it would involve such structural changes in motor vehicle enforcement procedures as to make it uninviting unless other concerns compel its acceptance. As noted elsewhere in this section, we do not find such compelling factors.

Another question concerning CAPS is how to quantify the particulate emissions from gasoline-powered vehicles. There are three ways to incorporate gasoline-powered vehicles into CAPS: require them to certify and subject them to enforcement just like diesel vehicles, assume their particulate emissions to be zero, or exempt them completely from the average particulate standard. Requiring gasoline-powered vehicles to certify and subjecting them to enforcement would greatly increase the certification and enforcement workload both for EPA and for the industry. This does not seem justified in light of the low particulate levels exhibited by light-duty gasoline-powered vehicles. Assuming these emissions to be zero is not justifiable either, since for those manufacturers marketing 90 to 100 percent gasoline-powered vehicles gasoline exhaust particulate would be a major, and possibly a majority, contribution to the total corporate particulate tonnage. Finally, exempting gasoline-powered vehicles would violate the very basis of a corporate average particulate standard. We see no easy solution to this problem. It should be noted that there are no such problems with the per vehicle particulate standards, as EPA has determined that gasoline-powered vehicles emit far less particulate than even the 1985 standard. There is no need to certify gasoline-powered vehicles under per vehicle particulate standards.

Under GM's CAPS proposal, the maximum particulate level allowed would remain at the relatively high 1.0 g/mi (0.62 g/km) level even though the average values would be progressively tightened. This would allow the possibility of localized particulate impact problems in the future in certain cities, neighborhoods, or roadways which might have an unusually high concentration of diesels emitting at or near the 1.0 g/mi (0.62 g/km) particulate ceiling. One likely possibility would be the dieselization of the New York City taxi fleet. The magnitude of this problem could be alleviated by reducing the maximum particulate level allowed, but this would diminish the flexibility so desired by the manufacturers and which is a cornerstone of the averaging concept.

A final difficulty with GM's CAPS is simply the high particulate levels that it would allow manufacturers who market small percentages of diesel vehicles. GM provided to EPA "an indication of the average diesel emission performance required" of GM should CAPS be adopted as proposed. These data are given in Table VIII-2. The level of control that EPA has determined to be technologically feasible by 1982 (0.60 g/mi, 0.37 g/km) for all vehicles would not be reached by the average GM diesel until 1985. The level of control we expect by 1985 (0.20 g/mi, 0.12 g/km) would not be necessary for GM, under CAPS, until 1990. This despite the fact that GM is expected to be the largest light-duty diesel manufacturer (by far), producing nearly 1,000,000 light-duty diesels by 1985 and possibly twice as many by 1990 (see Tables III-3 and V-4).

GM would need to do absolutely no more additional particulate control work until the mid-1980's and would not need to do any major work until the late 1980's. This phenomenal leniency for the manufacturer which is expected to dominate the light-duty diesel market in the 1980's would be irresponsible public policy. It would be possible to make CAPS more stringent, of course, which would have the beneficial impact of forcing low-percentage diesel manufacturers (like GM) to recognize that particulate control must be a consideration of their diesel designs. But a more stringent CAPS would reduce the flexibility available to the manufacturers and, more critically, would only exascerbate the manufacturer inequity problems discussed earlier.

The multitude of serious problems discussed in this section have convinced EPA that the corporate average particulate standard proposed by GM is inferior to the per vehicle standards that are being finalized. Had the evaluation of CAPS been more promising, other questions would have to be considered, such as whether a completely new rulemaking would have to be initiated to allow for public comment. The possibility of giving manufacturers an option of choosing either per vehicle standards or an average standard was also rejected for the same environmental, equity, statutory, and enforcement reasons cited above. The increased flexibility available to the manufacturers clearly cannot justify the numerous difficulties inherent in the CAPS approach.

2. <u>Diesel Average Particulate Standard (DAPS)</u>

The second averaging approach proposed to EPA was conceptualized by VW:

Table VIII-2

GM Particulate Emissions Under CAPS 6/

| Model Year | CAPS | % Diesel Projected | Average Diesel Particulate Level (g/mi) |
|---|---|---|---|
| 1981 | 0.20 | 4 | 1.00 |
| 1982 | 0.20 | 9 | 1.00 |
| 1983 | 0.10 | 10 | 1.00 |
| 1984 | 0.10 | 12.5 | 0.80 |
| 1985 | 0.07 | 14 | 0.50 |
| 1986 | 0.07 | 17.5 | 0.40 |
| 1987 | 0.05 | 19 | 0.26 |
| 1988 | 0.05 | 21 | 0.24 |
| 1989 | 0.05 | 23 | 0.22 |
| 1990 | 0.05 | 25 | 0.20 |

> "DAPS limits the sales weighted mean of the particulate emissions of all diesel vehicles sold by a manufacturer during a model year [and] would allow manufacturers to mix the diesel models sold on the market in such manner so that their diesel fleets comply with DAPS. Compliance with DAPS is determined by calculating the Diesel Average Particulate Emissions (DAPE) for each manufacturer from the certification data and the Projected Sales Figures. Whenever the DAPE for a manufacturer is smaller than or equal to DAPS the Administrator shall issue a certificate of conformity with DAPS. Such certificate of conformity may provide that the sales mix may not be altered to such an extent that the manufacturer's DAPE exceeds DAPS at the end of the model year. In order to make the DAPS concept work with respect to the SEA, emission warranty, and recall provisions of the Act, it is necessary to establish individual control limits in addition to DAPS. Such control limits for individual vehicles and individual engine families could be called Diesel Individual Particulate Standards (DIPS). They would be used solely to determine compliance with the enforcement provisions of the Act....Reasoning for introduction of DAPS and DIPS: a) Contrary to the CAPS concept, the approach suggested here is consistent with the Clean Air Act as it can be implemented immediately upon introduction [without] having to amend the Clean Air Act; b) Contrary to CAPS concept, there is no negative impact on competition if the DIPS/DAPS concept is compared with a traditional standard concept; c) The DAPS/DIPS concept specifically regulates particulate emissions from all light-duty diesel vehicles. Therefore, such particulate standards are still technology-forcing, while standards under a CAPS concept are mainly sales-mix-forcing; d) The DAPS/DIPS concept would allow manufacturers to make use of diesel technology as a contribution to the effort of the U.S. to conserve energy. Because large diesel cars with relatively high particulate emissions could be offset by small diesel cars, the use of diesel technology is not restricted to small diesel cars....Under a diesel-bubble concept, DAPS of not lower than 0.6 g/mi for model years 1981 and 1982, 0.4 g/mi for model years 1983 and 1984, and 0.3 g/mi for model year 1985 and subsequent model years could be established."11/

The primary difference between GM's CAPS proposal and VW's DAPS proposal is that the latter averages particulate emission levels from diesel vehicles only. Like CAPS, DAPS gives the manufacturer increased flexibility and the opportunity to optimize its diesel particulate control technologies with respect to economics. DAPS also avoids some of the serious problems inherent in the CAPS concept. DAPS is more equitable to those manufacturers who produce significant percentages of diesels. Regardless of how many gasoline-powered or diesel vehicles a manufacturer produces, each manufacturer would have to comply with the same average diesel particulate level. DAPS also satisfactorily resolves the dilemma concerning gasoline-powered vehicles since, by definition, it excludes them completely. Finally, EPA has concluded that DAPS could be designed to be consistent with Section 202(a)(3)(A)(iii) of the Clean Air Act. By lowering the DAPS values below those proposed by VW, we are convinced that DAPS could satisfy the "greatest degree of emission reduction achievable" mandate of that section. Under a stringent DAPS, it would be impossible for a manufacturer to market high particulate-emitting diesels since they could only be "balanced out" by very low particulate-emitting diesels (and not by gasoline-powered vehicles) and there is a limit to the extent to which this balancing can work. In any case, the low average diesel particulate level would have to be maintained. Thus, DAPS could be designed to require best available control technology and to accommodate the technology-forcing concept. Also DAPS does not implicitly limit diesel sales.

DAPS does share many of the drawbacks of the CAPS concept which were delineated above. It violates both of the primary bases for individual vehicle standards--the structure of Title II of the Clean Air Act and vehicle/vehicle equity. DAPS involves the same enforcement dilemma as CAPS--basing compliance and enforcement on an engine family basis involves too many difficulties, basing compliance and enforcement on a fleet-wide basis only would necessitate major administrative changes. EPA has the same localized impact concern with DAPS; VW did not propose any maximum allowable level, but one would be necessary. An averaging approach is not inviting to the manufacturers unless EPA allows maximum levels greater than the 0.60 and 0.20 g/mi (0.37 and 0.12 g/km) standards that would otherwise apply. Yet any incremental increase in the maximum levels allowed increases our concern for those urban areas which might be subjected to an atypically high concentration of high particulate diesel vehicles.

EPA considers the VW proposal of 0.60 g/mi (0.37 g/km) in 1981, 0.40 g/mi (0.25 g/km) in 1983, and 0.30 g/mi (0.19 g/km) in 1985 to be too lenient. Levels which would be more consistent with feasible technology would likely be opposed by the industry. Obviously, it becomes progressively more difficult to "balance out" a high particulate-emitting engine family as the average standard decreases. Under a DAPS, it is impossible to "balance out" high emitters by simply producing gasoline-powered vehicles. Thus, lower DAPS levels would remove much of the flexibility that is the primary motivation behind the averaging proposals.

One other distinction must be made between the CAPS and DAPS proposals. CAPS implicitly establishes a ceiling on total light-duty diesel particulate emissions--once a manufacturer reaches approximate equilibrium with the CAPS levels, any increase in the number of diesels produced would have to be accompanied by a reduction in the average diesel particulate level. DAPS does not perform this function as it constrains only the average diesel particulate level, and not the total corporate particulate tonnage.

In conclusion, DAPS is inconsistent with legal and regulatory policy, shares many of the environmental and enforcement difficulties of CAPS, and results in less flexibility to the manufacturers. Thus, we reject its use as a regulatory approach for particulate control, both as a replacement for the individual vehicle standards and as an option for those manufacturers who might choose it.

D. Alternative Individual Vehicle Standards

Now that it has been shown that an individual vehicle standard for light-duty diesels is necessary (i.e., no other alternatives are preferable), the timing and stringency of this standard is all that remains to be discussed. The following discussion will first examine the initial level of control and then examine the second and final level of control. Within each discussion, the standard for diesel-powered light-duty vehicles (LDV-D's) will be examined first and then that for diesel-powered light-duty trucks (LDT-D's).

1. Initial Level of Control

The first level of control for LDV-D's is 0.6 g/mi (0.37 g/km) beginning in 1982. This standard could be more or less stringent and could be implemented earlier or later. From the analysis of the lead-time available before the 1981 model year contained in Chapter IV, there is enough time available for the manufacturers to implement the necessary technology. However, unless they had started their 1981 certification process before the final promulgation of this regulation, there would not be enough time for manufacturers to complete a certification program for all of their vehicles. Thus, the earliest year of mandatory certification is 1982.* The discussion of available technology in Chapter IV also makes it quite clear that a standard more stringent than 0.6 g/mi (0.37 g/km) would result in the elimination of the diesel engine from some model lines. This would clearly be in violation of EPA's stated approach of setting the standard based on the worst-case vehicle. 12/ Thus, it is not possible to promulgate a standard more stringent than 0.6 g/mi (0.37 g/km).

It would be possible to delay the implementation of the first standard by one year. The benefit of such a decision would be to give the manufacturers one more year to meet the standard. The control technology would not be expected to be any different so the cost of meeting the standard should be the same as in 1982.

* In an effort to reduce costs, manufacturers are being allowed the option of certifying to the particulate standard in 1981 and obtaining carryover for 1982. As the NOx standard is being reduced in 1981, most vehicles will have to be certified in 1981 regardless. With the option, it is hoped that most manufacturers will be able to avoid recertification in 1982.

Overall light-duty diesel emissions in 1990 would increase by 0.5% or by 173-288 metric tons per year.

Ambient levels of light-duty diesel particulate would also increase by 0.5%, but this would be less than 0.05 micrograms per cubic meter in any of the 15 cities shown in Table V-14. This increase would be difficult to measure. Thus, the benefit of a delay would be to allow the manufacturers another year to implement control and the detriment would be a very slight increase in ambient particulate levels. This is often the case for a one-year delay in any emission standard and often leads to the argument that the standard should be delayed. However, extending this argument one year at a time could lead to the conclusion that a longer delay would also have only a slight detrimental affect on the environment, while the effect would indeed be significant.

As outlined in Chapter IV, the manufacturers should actually be able to meet a 0.6 g/mi (0.37 g/km) standard in 1981. Because there would not be enough time available to assure that all vehicles could be certified before the normal start of the model year, the standard was postponed a year to 1982. To delay the standard another year would simply allow manufacturers to move ahead even more slowly than was possible. As this extra time is not necessary and no significant cost reductions are foreseen, there appears to be no compelling reason to delay the 1982 standard.

The last issue is whether or not the 1982 standard should be any less stringent than 0.6 g/mi (0.37 g/km). Reasonable alternatives would be 0.8 g/mi (0.5 g/km), as suggested by the Department of Energy 1/, or 1.0 g/mi (0.62 g/km), as suggested by a number of manufacturers.1/ Again, the primary benefit would be accrued by the manufacturers. Less work would be required of them in meeting the standard. The 1.0 g/mi (0.62 g/km) level should be high enough to preclude any real control, while the 0.8 g/mi (0.5 g/km) level would require some control from one manufacturer. It is difficult to calculate any cost savings from these higher levels since much of the costs involved with meeting the 0.6 g/mi standard are amortized research and development costs which have already been incurred. With the 0.8 g/mi standard, light-duty diesel particulate levels in 1990 would increase 9%, or 0.04-0.3 micrograms per cubic meter in the 15 cities of Table V-14. With the 1.0 g/mi standard, light-duty diesel particulate levels in 1990 would increase by 19% or 0.08-0.6 micrograms per cubic meter. These calculations assume a 1985 standard of 0.2 g/mi (0.12 g/km).

The real question again is whether or not the 0.6 g/mi (0.37 g/km) level can be met in 1982. The cost savings involved with less stringent standards are small, less than $10 per vehicle (Chapter VI). The air quality impacts of the higher standards are small, but now measurable, if a 1985 standard of 0.2 g/mi (0.12

g/km) is assumed. As shown in Chapter VII, the cost effectiveness of the 0.6 g/mi standard is excellent. Its cost effectiveness ratio is about one-tenth that for the 0.2 g/mi standard, which itself is in the same range as those from stationary sources. The only reason the 0.6 g/mi standard should not be promulgated is if it couldn't be met. As outlined in Chapter IV, this is not the case. Thus, the 1982 standard for LDV-D's should be 0.6 g/mi.

The arguments outlined above for implementing the initial standard in 1982 are essentially the same for diesel-powered light-duty trucks (LDT-D's). However, the choice of level of this LDT-D standard deserves some attention. It was shown in Chapter IV that the difference in weight and size of LDT-D's vs LDV-D's could cause particulate emissions to increase 20%. On the other hand, the NOx standard for LDT-D's through 1984 will be 2.3 g/mi (1.43 g/km). This standard was set to be equally stringent to a 2.0 g/mi (1.24 g/km) NOx standard for LDV-D's. The beneficial effect on particulate emissions of raising the NOx standard to 2.0 g/mi from 1.5 g/mi (LDV-D waiver level) appears much greater than 20% (Chapter IV). The net result of the two differences between LDV-D's and LDT-D's is that it should actually be easier for LDT-D's to meet a 0.6 g/mi (0.36 g/km) standard than for LDV-D's to meet the standard. To raise the standard for LDT-D's above 0.6 g/mi would aggravate this difference. This would encourage the dieselization of light-duty trucks over that of light-duty vehicles since less control would be required. This would result in inefficient use of control technology since more advanced technology would have to be used on LDV-D's than LDT-D's at a conceivably poorer cost effectiveness. It would also result in worse air quality than would occur if the same technology was used on both classes of vehicles. Thus, for these two reasons, a standard higher than 0.6 g/mi for 1982 is unacceptable for LDT-D's.

If the effect of a higher NOx standard does more than overcome the weight and size penalty of light-duty trucks, then an equally stringent standard for LDT-D's could be less than 0.6 g/mi (0.37 g/km). However, this lower standard would not be much below 0.6 g/mi and could only stay in effect through 1984, since the NOx standard for LDT-D's will decrease in 1985. For example, if the standard would be lowered to 0.5 g/mi (0.31 g/km), light-duty diesel particulate emissions would only decrease by 0.4% and the ambient levels in the cities in Table V-14 would improve at most 0.02 micrograms per cubic meter. It is also likely that many people would be confused and believe that EPA was controlling light-duty trucks more stringently then passenger cars. Given the minimal air quality benefit, the small magnitude and temporary nature of any inequality, and the potential confusion of the public, it appears to be in the best interest of all to not promulgate a standard any lower than 0.6 g/mi for LDT-D's.

## 2. Second Level of Control

The second level of control is expected to consist primarily of the introduction of trap-oxidizer technology. As such, alternatives to the 0.2 g/mi (0.12 g/km) standard in 1985 involve 1) the levels which can be achieved with and without this new level of control technology and 2) the date that trap-oxidizer technology can be available. As EPA knows of no viable control technology at this time which would allow the expected LDV-D fleet to meet a standard more stringent than 0.2 g/mi (Chapter IV), no standard below 0.2 g/mi will be discussed here.

The first alternative to examine is trap-oxidizer technology vs. no trap-oxidizer technology in 1985. As outlined in Chapter IV, with trap-oxidizers LDV-D's are expected to be able to meet a 0.2 g/mi (0.12 g/km) standard. Without trap-oxidizers LDV-D's would be expected to be able to meet a 0.5 g/mi (0.31 g/km) standard. Both of these determinations include the need to meet a 1.0 g/mi (0.62 g/km) NOx standard, which will be in place no later than 1985. Using the methodology of Chapter V, the 0.5 g/mi standard would cause 1990 light-duty diesel particulate emissions to increase 97% over emissions occurring under a 0.2 g/mi standard. (For the purpose of this discussion a similar increase in the LDT-D standard will be assumed.) This would cause ambient levels of particulate from light-duty diesels to increase similarly by 97%. The absolute effect on ambient levels is shown in Table VIII-3 for [illegible] cities. As can be seen, the effect of the higher standard is [illegible] easurable. In Chicago, ambient regional levels of light-[illegible] esel particulate would increase by 0.8-2.7 micrograms per cubic meter over what they would be under a 0.2 g/mi (0.12 g/km) standard. Regional levels in Dallas would increase by 1.6-2.7 micrograms per cubic meter. Localized impacts would similarly increase by 97%.

While the higher standard would increase ambient particulate levels, it would also reduce costs. From Chapter VI, the removal of the trap-oxidizer would reduce the overall cost of the standard by $107-133. Using the methodology of Chapter VI, Section C, this would reduce the 5-year aggregate cost of the 1985 standard (1985-89) by $897-1857 million (present value taken in 1985, 1979 dollars). Using the methodology of Chapter VII, the incremental cost-effectiveness ratio (C/E ratio) of adding the trap-oxidizer would be $3,567-4,433 per metric ton ($107 to $133 divided by 0.03 metric tons lifetime reduction). On an inhalable particulate basis, the C/E ratio would remain $3,567-4,433 per metric ton. On a fine particulate basis the C/E ratio would increase to $3,716-4,618 per metric ton.

It is evident that both significant air quality and economic effects result from the addition of trap-oxidizers to light-duty diesels. An indication of whether the increased effectiveness is

Table VIII-3

Large-Scale Air Quality Impact of Light-Duty Diesels Under Two Different Emissions Standards in 1985

| Population Category | City | Light-Duty Diesel Ambient Particulate Level (micrograms per cubic meter) 0.5 g/mi 1/ | 0.2 g/mi 2/ |
|---|---|---|---|
| Over 1 million | New York | 1.0 - 2.4 | 0.5 - 1.2 |
| | Los Angeles | 2.8 - 5.7 | 1.4 - 2.9 |
| | Chicago | 1.6 - 5.5 | 0.8 - 2.8 |
| | Philadelphia | 1.4 - 2.2 | 0.7 - 1.1 |
| | Houston | 2.2 - 3.7 | 1.1 - 1.9 |
| | Detroit | 1.0 - 1.8 | 0.5 - 0.9 |
| 500,000 to | Dallas | 3.3 - 5.5 | 1.7 - 2.8 |
| 1,000,000 | New Orleans | 1.2 - 2.0 | 0.6 - 1.0 |
| | Boston | 1.0 - 1.8 | 0.5 - 0.9 |
| | Denver | 1.0 - 1.8 | 0.5 - 0.9 |
| | Pittsburgh | 1.0 - 1.6 | 0.5 - 0.8 |
| | San Diego | 1.2 - 2.0 | 0.6 - 1.0 |
| | Phoenix | 2.2 - 3.7 | 1.1 - 1.9 |
| | St. Louis | 1.2 - 2.2 | 0.6 - 1.1 |
| | Kansas City, MO | 0.8 - 1.2 | 0.4 - 0.6 |

1/ Emission standard for LDV-D's (0.31 g/km). Assumes LDT-D standard of 0.6 g/mi (0.37 g/km).

2/ Emission standard for LDV-D's (0.12 g/km). Assumes LDT-D standard of 0.26 g/mi (0.16 g/km).

worth the increased costs can be found from comparing the incremental cost effectiveness to those from other control strategies (See Chapter VII). Unfortunately, the data necessary to truly perform such a comparison is not available and any comparisons must be made using very rough measures of effectiveness. This was done in Chapter VII and the incremental cost effectiveness of a number of nationwide stationary source strategies were estimated and shown in Table VII-2. Placing greatest emphasis on the fine and inhalable particulate bases, the C/E ratios calculated in the previous paragraph for the addition of trap-oxidizers are not inconsistent with those from stationary source strategies. Given that further control of particulate emissions is needed (See Chapter V), the addition of trap-oxidizers appears to be a reasonable strategy.

Some caution should be placed on the use of any comparison such as the one performed in the previous paragraph. While the estimates of the cost effectiveness of the various strategies represent the best available, the cost-effectiveness measures used do not represent the true effectiveness of any of the strategies. Factors such as source location, population exposures, particle composition, etc., have not been taken into account due to a lack of data. Any one of these factors could have a major effect on the outcome of any cost-effectiveness comparison.

For example, motor vehicle emissions occur at ground level and tend to be concentrated in urban areas. This would increase the relative ambient impact and population exposure to diesel particulate emissions compared to a source with a tall stack located in a rural area. In Chapter VII, it was very roughly estimated that emissions from light-duty diesels have between 0.8 and 134 times the ambient impact as an equivalent amount of emissions from electric utility steam generators. The range and the absolute size of the above estimate indicate the potential effect that factors such as this one can have on any cost effectiveness comparison. Thus, while this regulation appears reasonable with respect to cost effectiveness, it should be remembered that any such comparison performed at this time is lacking in completeness and only a minimum amount of weight can be given to the comparison.

The final set of alternatives now revolves around the implementation year of the second standard, which is directly tied to the availability of trap-oxidizer technology. Since our technical analysis (see Chapter IV) indicated a strong likelihood of successful trap-oxidizer application by 1984, one alternative would be to promulgate the 0.2 g/mi (0.12 g/km) standard for 1984. The Agency has seriously considered doing exactly that. It was a difficult decision, but because of the uncertainty that exists with regard to trap-oxidizer durability and vehicle application EPA has decided to minimize the economic risk of this rulemaking by delaying the implementation of the 0.2 g/mi (0.12 g/km) standard until 1985. This delay will increase light-duty diesel particulate emissions in 1990 by 9 percent, but will ensure that the manufacturers will have the ability to optimize trap-oxidizer application.

Since it is always possible to delay the implementation of a standard, a second alternative would be to promulgate the 0.2 g/mi (0.12 g/km) standard for 1986. This delay from 1985 to 1986 would increase light-duty diesel particulate emissions in 1990 by 12 percent. It would also give the manufacturers additional leadtime for trap-oxidizer optimization. But since we have determined that trap-oxidizers might very well be feasible by 1984, and are delaying implementation of the 0.2 g/mi (0.12 g/km) standard to 1985 in order to ensure optimum trap-oxidizer development, there is no reason to delay implementation until 1986. Thus we are rejecting this latter alternative as well.

Concerning LDT-D's, the rationale for implementing a 0.26 g/mi (0.16 g/km) standard in 1985 and rejecting all other alternatives is analogous to that described above for LDV-D's. The only area not dealt with above is that of setting the LDT-D standard at the same technological stringency as the LDV-D standard. As the data in Chapter IV shows that a 30% increase in particulate emissions could result from the greater size and weight of LDT-D's, a 30% cushion over the 0.2 g/mi (0.12 g/km) LDV-D standard should result in equally stringent standards. A lower or higher standard for LDT-D's would result in an artificial bias toward the dieselization of one of the two vehicle classes. This would have negative effects on air quality since the bias would be toward the worst polluting class. For this reason, any standard for LDT-D's other than 0.26 g/mi (0.16 g/km) should be rejected.

## References


1/ "Summary and Analysis of Comments to Proposed Particulate Regulations for Light-Duty Diesels," MSAPC, EPA, October, 1979.

2/ "Impact of New Source Performance Standards on 1985 National Emissions from Stationary Sources," EPA-450/3-76-017, April 1977.

3/ Chapter V.

4/ "1975 National Emissions Report," OAQPS, EPA, May 1978, EPA 450/2-78-020.

5/ "General Motors Response to EPA Notice of Proposed Rulemaking on Particulate Regulation for Light-Duty Diesel Vehicles," April 19, 1979, Attachment 2.

6/ "Selective Enforcement Auditing Procedures," Federal Register, Vol. 41, No. 146, Wednesday, July 28, 1976, p. 31474.

7/ Ibid., p. 31480.

8/ "General Motors Reponse...," Attachment 2, Figure 5.

9/ Ibid., Attachment 6.

10/ "Comments of the Council on Wage and Price Stability on the Particulate Regulation for Light-Duty Diesel Vehicles," p. 44.

11/ "Supplementary Information to the Record of the EPA Hearing on March 19, 1979, Concerning Proposed Particulate Emission Standards for Light-Duty Diesel Vehicles" submitted by Volkswagen in April 1979, Section 4.

12/ "Particulate Regulation for Light-Duty Diesel Vehicles," Federal Register, Vol. 44, No. 23, Thursday, February 1, 1979, pp. 6650-6671.