SUMMARY AND ANALYSIS OF COMMENTS
ON THE
NOTICE OF PROPOSED RULEMAKING
FOR THE
CONTROL OF LIGHT-DUTY DIESEL PARTICULATE EMISSIONS
FROM 1981 AND LATER MODEL YEAR VEHICLES

ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF AIR, NOISE, AND RADIATION
OFFICE OF MOBILE SOURCE AIR POLLUTION CONTROL

OCTOBER 1979

Summary and Analysis of Comments
on the
Notice of Proposed Rulemaking for the Control of Light-Duty Diesel Particulate Emissions from 1981 and Later Model Year Vehicles

October 1979

Standards Development and Support Branch
Emission Control Technology Division
Office of Mobile Source Air Pollution Control
Office of Air, Noise and Radiation
U.S. Environmental Protection Agency

Summary

On February 1, 1979, EPA proposed an emission standard for particulate emissions from diesel-powered light-duty vehicles and diesel-powered light-duty trucks. The proposed particulate standard was 0.60 g/mi (0.37 g/km) beginning in 1981 to be reduced to 0.20 g/mi (0.12 g/km) in 1983. A public hearing was held on March 19-20, 1979 for interested parties to comment on the proposed emission standards. Parties that made presentations at the hearing are listed in Table S-1. A period of thirty days after the public hearing was provided for written comments to be submitted to EPA. This period ended April 19, 1979. Twenty-eight written submittals were received, and these are also shown in Table S-1.

The comments addressed seven main areas: environmental impact, control technology, leadtime, level of the standards, economic impact, alternative regulatory approaches, and test procedures. EPA has examined and analyzed these comments and a summary of the comments and EPA's recommendations immediately follows. Detailed analyses of the comments can be found in sections I to VIII of this report.

Environmental Impact

The comments discussed in this section generally addressed EPA's assessment of the need for this regulation. Chrysler and Congressman Dingell challenged that the proposed regulation was not based on any proven adverse health effects. This is not the case as there is a wealth of evidence of health effects associated with suspended particulate, much of which is discussed in Chapters 7 and 9 of a National Academy of Sciences report entitled "Airborne Particles". The Department of Energy (DOE) suggested that EPA should emphasize the fine particulate fraction of particulate emission on health effects, while Ford and Dr. Farkus of the University of Waterloo asked EPA to include data to show that diesel particulate has unusual toxic properties with respect to typical suspended particulate. These requests are well taken and a section should be devoted to these topics in the Regulatory Analysis. Ford also claimed that EPA must base its emission standard on some property of diesel particulate, other than mass, which related more to the health effect of the particulate and that this could only be done after a more complete assessment of diesel health effects had been made. EPA rejected this argument as Congress did not allow time for such an assessment before requiring emission standards and the precedent of using mass as a general indicator of hazard has long existed with the ambient air quality standard for particulate matter.

The Council of Wage and Price Stability (CWPS) and Congressman Kildee claimed EPA did not demonstrate that Kansas City was representative of the rest of the nation nor did EPA compare the

Table S-1

Commenters and Speakers for Proposed Emission Regulations for Light-Duty Diesel Particulate

NPRM Commenters for Proposed Light-Duty Diesel Particulate Regulations

1. U.S. Metric Board
2. Dr. Farkus of the University of Waterloo
3. BMW
4. Imperial Chemical Industries, Limited
5. American Motors Corporation
6. Fiat
7. Daimler-Benz
8. Ford Motor Company
9. International Harvester Corp.
10. General Motors Corporation
11. Volvo
12. F. Black, ORD, EPA
13. Chrysler Corporation
14. Council on Wage and Price Stability
15. Department of Commerce
16. Ricardo
17. Toyota
18. Peugeot-U.S. Technical Research
19. East Michigan Environmental Action Council
20. Hogan and Hartson
21. P.S.A. Peugeot-Citroen
22. Natural Resources Defense Council
23. Volkswagen of America
24. Congressman Dingell
25. Environmental Protection Agency Lab Branch
26. Department of Energy
27. Diesel Auto Association

Speakers at Public Hearing on March 19-20, 1979

1. Congressman Dale E. Kildee
2. Congressman Robert Carr
3. Dr. Ancker-Johnson of General Motors Corporation
4. Congressman Andrew Maguire
5. Mr. Misch of Ford Motor Company
6. Mr. Engel of Chrysler Corp.
7. Dr. Negro of Fiat Motor Co.
8. Mr. Cornetti of Fiat Motor Company
9. Mr. Buttgereit of Volkswagen of America
10. Mr. Van Winsen of Daimler-Benz
11. Jean Perez of Automobile Peugeot
12. Mr. Balgord of Environmental and Natural Resources Technology

relative diesel impact in Kansas City to that across the nation. This comment is also well taken and estimates of the diesel's impact in New York, Chicago, Los Angeles, and other cities should be made to insure that the impact determined is indeed a nationwide impact. CWPS and DOE also stated that the traffic growth rate was overestimated for a central city area. This is confirmed by traffic growth rates used in past CO modelling done by EPA so a 1% per year increase in VMT should be used in the studies of Kansas City and other cities, as opposed to the 1.5% growth rate originally used.

General Motors, DOE, and Congressman Kildee challenged EPA's sales projections believing them to be unrealistic. Based on additional information provided by the automobile companies and revised EPA estimates, the original sales scenario does seem to overestimate diesel sales prior to 1988. A revised scenario,based on the information submitted to EPA, has been assembled which results in a 17% decrease from the original estimate of light-duty diesel travel in 1990 and which is a much better estimate for diesel sales in the early 1980's.

Ford, DOE, and CWPS thought that EPA's estimate of the roadside impact of diesels was unrepresentative and overestimated. A closer examination of the origin of the correlation used to estimate this impact confirmed that an overestimation was made. This aspect of the Regulatory Analysis should be revised and the localized impacts will be placed in a more appropriate perspective with respect to time of exposure, extent of population exposed, etc. DOE made the objection that the population exposure was based on many questionable assumptions and extrapolations, and that it should be improved or deleted. Questionable assumptions and extrapolations contained in the population exposure analysis were found and some would require considerable effort to improve or defend. As this analysis is not crucial to the environmental analysis, it seems best to delete the population exposure analysis at this time and leave it to be improved and defended at a later date when its need is more pressing.

Control Technology

The comments discussed in this section address the ability of technology to reduce particulate emissions from diesels. Fiat, Peugeot, GM, Ricardo, DOE and Daimler-Benz (D-B) all commented on the ability of engine modifications to reduce particulate emissions with all except Peugeot believing that further reductions were possible. An analysis of these comments and the available data confirmed EPA's original position that potential reductions were and are still available from engine modifications. Ricardo, D-B, GM, Ford, and DOE all challenged EPA's position that turbocharging could reduce particulate emissions by one-third, while Peugeot and Fiat stated that turbocharging could reduce particulate emissions but would do so to a lesser extent or would require more time for implementation. From the available data, it appears that turbocharging is not a quick and easy technique for reducing particulate emissions. However, it appears that a concerted effort to turbocharge a diesel can reduce particulate emissions 20-30%.

There are considerable problems involved with utilizing catalyst technology to reduce particulate emissions. This is evident from comments by Ricardo, Fiat, BMW, GM, and Ford. Unless a technological breakthrough occurs, conventional catalytic converters are not likely to be used on diesels for particulate control. Ricardo, D-B, and GM all commented on the use of simple traps for reducing particulate emission. Although traps are efficient control devices over short distances (less than 1000 miles), they must be replaced or regenerated externally. Besides the technical problems with external regeneration, there are serious questions concerning the public's willingness and ability to service traps every 1000 miles. Because of this, traps do not appear promising at this time. Trap-oxidizers, which are traps which regenerate automatically on board, appear very promising, even though GM, D-B, Ford, and Imperial Chemical Industries Limited expressed concerns about the ability of trap-oxidizers to reduce particulate emissions without possible backpressure effects. Research is still needed to develop the optimum trapping material and improve the oxidation control, but given enough time these problems do not appear insurmountable and approximately a two-thirds reduction should be achievable by these devices.

D-B and GM suggested that fuel modifications appear to have some potential to reduce particulate emissions, but there are significant problems yet to be overcome. Fuel additives can cause a decrease in particulate emissions, but usually increase the emission of other pollutants, such as the additive itself (e.g., barium). Research on the effect of fuel composition on particulate and other emissions is still in an early stage and EPA will continue to stay abreast in this area. Finally, Ford did present data for their PROCO engine, showing its fuel economy to be as high as that of a diesel while producing lower particulate and NOx emissions. However, there are other problems with this engine which must be solved before it can be considered viable for production purposes.

Leadtime

The comments in this area primarily dealt with the time needed for various control techniques to be implemented on production vehicles. The three types of control technology addressed were engine modifications, turbochargers, and trap-oxidizers. Both D-B and DOE stated that the time remaining before the 1981 model year would not allow enough time for the introduction of any new engine modifications. This does appear to be the case. However, some engine modifications have already been developed and planned for introduction in 1980-81 which reduce particulate emissions and can be expected to be in place by 1981. GM and Volkswagen (VW) both commented that they could not turbocharge their engines before 1983 and 1982, respectively. It appears that widespread use of turbocharging cannot be expected until the 1983 model year, though some manufacturers who have been working in this area longer may have turbocharged engines available sooner. Both GM and VW stated that trap-oxidizers would not be available for the 1983 model year, but might be available for the 1985 model year. An analysis of the available information indicates that trap-oxidizers indeed will not be available in time for the 1983 model year, but should be available for the 1984 model year.

Level of Standards

This section includes comments regarding the proposed level of standards for light-duty diesel particulate emissions. The proposed standards were 0.6 g/mi (0.37 g/km) for 1981 to be reduced to 0.2 g/mi (0.12 g/km) for 1983, and were based on the lowest particulate levels achievable by the worst light-duty diesel with respect to particulate emissions. Chrysler challenged EPA's basis for proposing this standard, believing the standard should be 1.02 g/mi (0.63 g/km) or greater, arguing that the 1981 standard should be set at the highest particulate level EPA found in its baseline testing of 1979 certification diesel vehicles. However, Chrysler's argument is in conflict with the letter and spirit of the Clean Air Act, and does not weaken EPA's basis for the proposed standard. CWPS claimed that the proposed standard would be overly "technology forcing," while the Natural Resources Defense Council and Congressman Andrew Maguire stated that the standards should be set with an emphasis on the impact on public health. The Council's claim that technology is being forced too hard or too quickly cannot be accepted, as the technology is expected to be available in the time frame required (see Control Technology section). With respect to the latter commenters, this proposed standard should be protective of the environment and public health, but available technology is a limiting factor, as outlined in the Clean Air Act. Comments from Fiat, Ford, GM, and Congressman Kildee pointed out that current NOx control techniques cause particulate emission to increase. These comments are well taken and the particulate standard that is promulgated is based on a NOx waiver level of 1.5 g/mi (0.93 g/km) as opposed to the statutory NOx standard of 1.0 g/mi (0.62 g/km) for 1981.

Peugeot and GM each stated that a deterioration factor, ranging from 1.1 to 1.7, was necessary to account for durability considerations. An analysis of all the available data shows that the deterioration factor for particulate emissions should be very close to unity (1.0-1.1) and not 1.1-1.7. Peugeot, GM, and Volkswagen expressed concern that EPA had not accounted for car-to-car emission variability in determining the proposed standards. However, the statistical sampling program of the Selective Enforcement Auditing (SEA) program already accommodates vehicle-to-vehicle emission variability, so this factor was indeed accounted for.

Concerning the reasonableness of the proposed standards, Peugeot, CWPS, D-B,and Fiat all stated that the 0.6 g/mi (0.37 g/km) particulate standard for 1981 could be achievable by relaxing the NOx standard to 1.5 g/mi (0.93 g/km). Volkswagen believed that the 0.6 g/mi (0.37 g/km) particulate standard should be delayed to 1982, with a NOx waiver at 1.5 g/mi (0.93 g/km). GM, Ford and Chrysler claimed that the standard should be set at 1.0 g/mi (0.62 g/km) for 1981. As discussed thoroughly in the Control Technology section, the 0.6 g/mi (0.37 g/km) standard can be met with some engine modifications, with a NOx standard of 1.5 g/mi (0.93 g/km) or less. DOE, Volkswagen, Peugeot, Toyota, Department of Commerce, CWPS, Volvo, GM, and D-B were skeptical of meeting a particulate emission standard of 0.2 g/mi (0.12 g/km) beginning with the 1983 model year. EPA acknowledges that 1983 would be too early for all vehicles to meet that standard, and the 0.2 g/mi (0.12 g/km) standard should be deferred until 1984 (see also Leadtime section). The Natural Resources Defense Council was the only commenter to claim that a tighter standard could be met for 1983. We find no technical support for this position.

GM, International Harvester, D-B, Chrysler, and CWPS all commented that a higher standard should be proposed for light-duty trucks (LDTs). An analysis of the available data shows that particulate emissions increase 16-18% for a vehicle inertia weight increase of 1000 pounds. However,a 2.3 g/mi (1.43 g/km) NOx standard for LDT's is much less stringent than even the LDV NOx waiver level of 1.5 g/mi and should allow LDT manufacturers to meet a 0.6 g/mi (0.37 g/km) particulate standard in 1981. By 1985, the NOx standard for LDT's will be as stringent as the LDV standard and the inertia weight effect should be taken into account. Thus, a 30% increase in the emission standard has been allowed LDT's, to 0.26 g/mi (0.16g/km), beginning in 1984.

Some environmental groups suggested a more stringent standard for 1990. This is a possibility. A more stringent particulate standard in the future will have to be justified by health effects research showing diesel particulate to be a greater health threat than just as a contributor to total suspended particulate, and by a finding that the more stringent standard is technologically feasible.

Economic Impact

This section includes comments concerning the costs, economic methods, and cost-effectiveness of particulate control for light-duty diesels. A major item of concern was the cost of the trap-oxidizer system. BMW, Chrysler, and GM all stated that the cost of the trap-oxidizer system was underestimated. EPA performed a detailed analysis of the costs of all the components in a trap-oxidizer system and increased its original estimate of $114-$157 per vehicle (in 1979 dollars) to a fleetwide average of $189-224 per vehicle in 1984, which should reduce to $128-$152 per vehicle in 1988. This revised estimate was primarily based on component costs taken from a study by Leroy H. Lindgren (Rath and Strong), "Cost Estimation for Emission Control Related Components/Systems and Cost Methodolgy Description." Chrysler also claimed that the trap-oxidizer would require maintenance during the vehicle's life, while CWPS claimed that the trap-oxidizer would have to be replaced once during the life of the vehicle. EPA found Chrysler's claim to be reasonable and estimated this maintenence to cost about $30, occuring once after about five years of vehicle operation. The Council's claim was not accepted, however, since the trap-oxidizer is expected to be made of durable material, such as stainless steel, and last the life of a vehicle, as do current catalysts. However, EPA also found that use of the trap-oxidizer should reduce normal maintenance costs by $80, leaving a net savings of $50 due to use of trap-oxidizers.

Chrysler, D-B, Fiat, GM, Volkswagen, Ford, DOE, and the Department of Commerce criticized EPA for underestimating the cost of turbocharging and overestimating the fuel economy improvement of turbocharging. The original costs of turbocharging, between $145-$185, were reassessed and should be revised to $207-$238 due to the need for additional engine modifications which are necessary for the engine to be optimized with the turbocharger. A second analysis of the available data still shows that turbocharging should increase fuel economy by 8% and this estimate should not be revised. The Department of Commerce and CWPS suggested that EPA's projection that fuel costs would increase 10% per year faster than the general price index was too high. CWPS suggested that a 5% rate was more reasonable and that discounting fuel costs by a 5% rate (instead of 10%) would accomplish this. An analysis of price increases over the last six years did show 5% to be the more reasonable rate for long term considerations and should be used in the future.

International Harvester (IHC) and GM each challenged the original estimate of costs for test equipment and testing procedure. IHC believed EPA's regulation would add $270.10 per vehicle in 1981-82, and $562.67 in 1983-85. IHC also requested that they be allowed to assign deterioration factors rather than have to run a durability vehicle. This is already allowed under existing rules and this proposed regulation did not attempt to change these rules. Omission of the cost of the durability vehicle substantially decreases the overall cost to IHC, putting their costs in line with other manufacturers. GM claimed that facility modifications would be five times higher than predicted by EPA. Although

GM may actually intend to spend more than EPA has estimated for each test site and test facility, much of the additional expense seems to be for higher levels of automation which is discretionary, and must pay for itself in the long run or else GM should not move in that direction. EPA did reanalyze the potential costs of test cell and facility modifications and has increased the cost of each to $55,000 and $30,000, respectively.

CWPS stated that the marginal cost effectiveness of the 1983 standard appears to be too high when compared to other control techniques. This comment can not be accepted without further analysis, as cost effective figures expressed in simple dollars per ton units may not allow an accurate comparison of different control strategies to be made. A more appropriate measure of cost effectiveness will be developed in the final Regulatory Analysis and the CWPS data will be included. CWPS also suggested implementing street cleaning as an alternative economic control strategy to diesel particulate regulations. EPA found this control strategy to have minimal effect on regional air quality and even questionable effect in highly localized areas (curbsides). Thus, EPA found it to be an unacceptable alternative to light-duty diesel particulate regulations.

Alternative Regulatory Approaches

Comments in this section concern alternative approaches to controlling particulate emissions from light-duty diesels via a smoke standard, a Corporate Average Particulate Standard (CAPS), and a Diesel Average Particulate Standard (DAPS). American Motors suggested a smoke standard to satisfy the Clean Air Act requirement for the 1981 model year. The application of a smoke standard was rejected because smoke opacity does not correlate well with particulate emissions. Opacity is primarily a function of the optical properties of particulate, and as such is appropriate only for standards based on aesthetic considerations.

GM proposed the concept of a Corporate Average Particulate Standard (CAPS), resulting in a sequence of particulate standards based on the average level of particulate emissions of a manufacturer's entire gasoline and diesel fleet. In addition to GM, comments on this proposal were received from CWPS, Volvo, Ford, DOE, Volkswagen, Peugeot, Associate Professor Edward J. Farkas, Citizens for Clean Air, and the Natural Resource Defense Council. Proponents considered the main advantage of CAPS to be the increased flexibility a manufacturer would have in tolerating different levels of particulate emissions while meeting the CAPS standards and without affecting overall air quality. CAPS also puts an implicit ceiling on total light-duty diesel particulate emissions to the atmosphere. Opponents said it would favor large gasoline-powered vehicle manufacturers and would limit the fraction of diesel vehicles that could be sold by manufacturers who sell primarily diesels. It would likely necessitate major changes in existing enforcement procedures. Also, it would increase the likelihood of a concentrated amount of high particulate vehicles within a given region. GM's CAPS porposal will be evaluated by weighing the aforementioned advantages and disadvantages.

The Diesel Average Particulate Standard (DAPS) is a proposal by VW that is very similar to CAPS, with the exception that it averages diesel vehicles only rather than gasoline and diesel powered vehicles. In addition to Volkswagen, comments on the DAPS proposal were received from CWPS, Peugeot, and Volvo. Volkswagen pointed out that the main advantage of DAPS is that it does not favor large gasoline-powered vehicle manufacturers. On the other hand, DAPS does not limit the total light-duty diesel particulate emissions loading to the atmosphere as CAPS does. Otherwise DAPS shares many of the same advantages and disadvantages of CAPS.

EPA should continue to evaluate CAPS and DAPS as serious alternatives to the individual vehicle standards. Should the Agency decide to pursue an average standard, we agree with DOE that a new rulemaking would be required to give interested parties the opportunity to comment on the specific proposal.

Test Procedure

Comments in this section deal with the proposed test procedure for measuring light-duty diesel particulate emissions. GM and International Harvester commented that filter temperature specifications were unrealistic, causing some hydrocarbons to be counted as both particulate and gaseous hydrocarbons. While some hydrocarbons are indeed counted twice, it has not been proven that hydrocarbons do not leave the particle while suspended in the atmosphere. The stringency of the particulate standard is not affected by this double-counting since the particulate baseline was developed under the same conditions. GM, Ford, D-B, and Chrysler have commented that the 125°F particulate sample zone temperature is without technical foundation. Data now available support using this temperature which was chosen to prevent a loss of hydrocarbons by thermal desorption. Ford claimed that fluorocarbon-coated glass fiber filters have difficulty achieving the originally required 98% filter efficiency. This fact is acknowledged. A new filter acceptance criteria, requiring the use of a back-up filter and the inclusion of the particlate mass on this filter when the collection efficiency of the first filter is less then 95%, is being recommended.

GM recommended that the required particulate sample flow rate provision be dropped. This comment was accepted; specified filter flow rates will no longer be required. GM stated that regulations should be changed to require a 1-hour filter stabilization period after a vehicle test. This change is acceptable and the minimum post-test stabilization period will be changed to one hour even though a 0.5% increase in particulate may occur. GM also requested that the specific requirement for a heat exchanger (with the CFV sampler) should be replaced by a general requirement for flow proportionality. This change in test procedure can not be approved, as confirmatory data was not received showing the equivalency of the alternative system. GM commented that the tailpipe connecter specification is too rigid. This comment has brought to attention the need to conduct more testing in the area of tailpipe heat loss effects, which should be completed by the time the Final Rule is promulgated. GM suggested the use of flow measurement devices to replace gas meters, and that tolerance of ±2 percent on sample flow rate should replace the ±5 percent tolerance. It is agreed that gas meters are a burden and that flow measurement devices should also be allowed. However, the ±2 percent tolerance cannot be granted unless first proposed for comment. GM commented that commercially-available heated lines cannot meet the proposed temperature specifications. However, GM's own data verifies that the proposed temperature specifications can be met. It appeared that GM failed to realize the distinction between probe-wall temperature specifications and dilute exhaust gas specification. GM, American Motors, and Volkswagen all recommended clarifications of and minor modifications to the SEA procedure. It is agreed that an effort should be made to clarify the proposed SEA procedure by listing deviations to the referenced certification test procedure. This will be done before promulgation of the final rule.

GM also submitted many minor miscellaneous comments. These comments will not be summarized here but are discussed in detail in Chapter VII of this report.

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I. Environmental Impact

All comments dealing with the environmental impact of diesels or of this proposed regulation will be discussed in this section. This includes comments on health effects, air quality modeling and the accompanying assumptions, impacts from other sources, sales scenarios, and population exposures. A number of commenters said that the proposed levels of control were too stringent given the air quality impact of light-duty diesels, but did not submit any additional data or rationalization to support their conclusions. EPA will take these comments into consideration, but they cannot really be analyzed. The Regulatory Analysis will examine all the available data, and present EPA's best judgment in this area.

A. Health Effects

Comment

Chrysler and Congressman Dingell -- alleged that this regulation is not based on any proven adverse health effects.

Analysis

EPA has tried to make it clear that this regulation was not based on any carcinogenic health effects of diesel particulate, but on the impact that diesel particulate has on ambient suspended particulate loadings. However, this does not mean that no health effects are involved. There are known health effects connected with suspended particulate matter, not unique to diesel particulate, upon which the primary national ambient air quality standard is based. These health effects are summarized in Chapters 7 and 9 of "Airborne Particles," National Academy of Sciences, November 1977, EPA-600/1-77-053.

Comment

The Department of Energy -- suggested that EPA should emphasize the fine particulate fraction of both diesel and overall particulate emissions as this is where the most significant health effects may occur.

Analysis

EPA agrees that the small size of diesel particulate should be emphasized with respect to health effects and to the emissions from other sources. The final Regulatory Analysis should contain an additional section outlining the health effects of fine particles. Also, the chapter concerned with cost effectiveness should examine control strategies on a fine particulate basis as well as on a total particulate basis.

Comment

Ford -- claimed that EPA has the burden of proving that its standards can be met with control technology which will pose no other unreasonable health hazard. In other words, EPA must demonstrate, or at least ascertain, that the control techniques with which it establishes technological feasibility will pose no unreasonable health hazards under Section 202 (a)(4) of the Clean Air Act, prior to promulgating an emission standard.

Analysis

While this comment can have general implications for EPA policy, this discussion will restrict itself to the issue at hand, that of diesel particulate standards. The comment is directed at the possibility of a control technique, such as a trap-oxidizer, being required to reduce the total mass of diesel particulate emissions while at the same time increasing the total toxicity of the particulate, or introducing a new health hazard into the environment. EPA recognizes that such an occurrence is a possibility, and we appreciate Ford's concern in this regard. Unfortunately, Ford suffers from the same inability to provide any conclusive data on the subject as does EPA. In fact, Ford did not submit any data supporting its claims. We, on the other hand, do have preliminary results from our in-house trap-oxidizer test program. They indicate that the particulate samples collected from the exhaust following the trap-oxidizer contain lower percentages of adsorbed organic matter than particulate samples obtained without the trap-oxidizer. While not conclusive by any means, these preliminary results support our expectation that it would be unlikely that there would be any increase in toxicity due to the addition of a trap-oxidizer. EPA intends to submit similar samples for bioassay testing.

At this time, EPA cannot absolutely demonstrate that diesels with trap-oxidizers will not be found to pose an "unreasonable risk" under Section 202(a)(4) of the Clean Air Act. If they are found to present such an unreasonable risk, it will likely be because of the inherent properties of the engine-out diesel exhaust and not because of any artificial effect of the trap-oxidizer on the engine-out exhaust. EPA has consistently affirmed that any final determinations about the public health acceptability of the diesel engine would have to await the results from the various health effects research projects now in progress. It would be impossible to make such a determination now on the risks of engine-out diesel exhaust, and would be equally impossible to make such a determination about diesels with trap-oxidizers (since the final design is not now known). Given this reality, EPA has concluded that the most appropriate action is to promulgate "standards which reflect the greatest degree of emission reduction achievable" (Section 202(a)(3)(A)(iii) of the Clean Air Act, emphasis added), as mandated by Congress, which clearly implies that mass reduction is the criteria to be considered, as long as more conclusive health effects evidence is unavailable. Should evidence be obtained in the future proving that the trap-oxidizer increases the public health risk of the diesel engine, EPA would clearly take action so as not to require its application.

Comment

Dr. Farkus of the University of Waterloo and Ford -- asked EPA to include any data in their analysis which shows diesel particulate to have unusual toxic properties with respect to general suspended particulate. In addition, Ford stated that EPA must perform a more complete assessment of the health effects of diesel particulate before a standard could be set and that it should not be based on mass but on a more appropriate measure of diesel particulate's effect on health.

Analysis

The Regulatory Analysis for the final regulation will include a section on the health effects of suspended particulate and will describe those properties of diesel particulate which would tend to increase or decrease its non-carcinogenic health effect relative to typical suspended particulate.

EPA agrees with Ford that a more comprehensive assessment of the health effects of diesel particulate emissions is needed; in fact, EPA and several other parties are currently involved in extensive diesel health effects research programs. The final determination of the acceptability of the diesel engine must await the conclusion of these studies. At the same time, Congress mandated particulate standards to "reflect the greatest degree of emission reduction achievable" by 1981, and EPA has responded with regulations that are based on the most recent data available. These standards are based on mass emission rates, which is justifiable on the grounds that the NAAQS for total suspended particulate is based on mass and that a significant number of air quality regions exceed the NAAQS for total suspended particulate. In addition, as noted above, the final Regulatory Analysis will include additional consideration of the properties of diesel particulate which make it especially hazardous to human health. The concern over the possible toxic or carcinogenic properties of diesel particulate is even more reason to promulgate standards promptly. Delaying action indefinitely in order to make one final determination of the acceptability of the diesel would allow diesels to emit at uncontrolled levels indefinitely, and would have air quality and public health implications. Should the results from the diesel health effects studies indicate that a refinement of the particulate standards was needed, EPA would certainly take action to do so. The prudent action at this time is to reduce diesel particulate emissions as much as is technologically feasible.

B. Air Quality Modeling - General

Comment

The Council of Wage and Price Stability -- questioned that estimated maximum 24-hour concentrations of diesel particulate could be compared to the 24-hour NAAQS, unless it can be shown that the maximum diesel impact occurs in the same time period as the maximum 24-hour TSP levels.

Analysis

The Council brought up a very good point that was not addressed in the Draft Regulatory Analysis. However, the first question which needs to be answered is whether it is the timing of emissions or the timing of meteorological conditions which has the greatest effect in causing exceptionally high ambient pollutant levels. The answer is quite obviously meteorological conditions. Air pollution episodes are not caused by a sudden upsurge of emissions. They are caused by adverse meteorological conditions which aggravate the effect of the same emissions which last week caused no harm. Short-term concentrations, such as 1-hour, 3-hour, and possibly 8-hour concentrations can be dependent on emission patterns since there are wide ranges of vehicle usage and industrial output throughout the day. Day-to-day variations are not nearly as great and could not produce the variations that are seen in ambient pollutant levels.

Returning to the original comment, the estimated maximum 24-hour concentrations of diesel particulate are those concentrations that would result from adverse meteorological conditions occuring on the average of once a year. The maximum 24-hour concentrations occuring from other sources will occur during the same adverse meteorological conditions (i.e., during the same time period). Thus, it is our conclusion that the 24-hour maximum concentrations determined in the Draft Regulatory Analysis can be compared to the 24-hour NAAQS.

Comment

The Council of Wage and Price Stability and Congressman Kildee -- both claimed that EPA did not demonstrate that Kansas City was representative of the rest of the nation.

Analysis

EPA recognizes that no special effort was made to show Kansas City to be representative of the rest of the nation, or at least representative of the metropolitan portion of the nation. In the final Regulatory Analysis, independent estimates of the diesel impact in more cities, including Chicago, New York, and Los Angeles, should be made, and this will place the Kansas City results into context with the rest of the nation.

Comment

Congressman Dale E. Kildee, the Department of Energy, and the Council of Wage and Price Stability -- all claimed that EPA overestimated the air quality impact of diesels, because the Air Quality Dispersion Model used in the impact study tends to overestimate mobile sources.

Analysis

EPA requested that PEDCo support the statement in their analysis that the AQDM overestimates mobile source pollutant concentrations.1/ PEDCo could not provide any substantial evidence to support their statement.

In reviewing the basic theory of AQDM, EPA found that the model is generally expected to underestimate mobile source contributions to some degree. This is due to the fact that AQDM assigns all emissions in a grid to a virtual point source at some point upwind of a receptor. Rather than treating the dispersion of diesel particulates as a microscale line source, the area source algorithms in AQDM treat it as a region-wide source. This may lead to some underestimation, certainly in microscale diesel particulate concentrations, and possibly in the area-wide estimates since only receptors near the virtual source may be properly exposed.

Due to the lack of validation exercises for completely reviewing the technical adequacies of AQDM, no quantitative estimate of any error can be made. Region-wide dispersion estimates of mobile source diesel particulates such as performed by PEDCo are probably well within the practical application limits of AQDM and should be acceptable.

Comment

The Council of Wage and Price Stability and the Department of Energy -- both said that the EPA overestimated the increase in traffic which would occur in downtown areas.

Analysis

The growth rate used in the Draft Regulatory Analysis was 36% in 20 years or 1.55% per year, compounded. This figure represented a prediction for the Kansas City metropolitan area as a whole. As such, it likely overestimated growth in the central city and underestimated growth in the suburbs. Because with this regulation

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1/ Nelligan, Robert E., Director, Monitoring and Analysis Division, EPA, "Information Concerning Particulate Emissions for Nonmobile Sources," Memorandum to Charles L. Gray, Jr., Director, Emission Control Technology Division, EPA, July 11, 1979.

the primary interest lies in the central city region, it would be more accurate to use a growth rate more suitable for this area. As it has been common to use a 1% growth rate in predicting CO emissions (see "An Analysis of Alternative Motor Vehicle Emission Standards," DOT, EPA, FEA, May 1977), which is an urban core problem, it would appear that a 1% growth rate would be suitable here also. It should be noted that EPA policy has been to use a 2% growth rate in predicting oxidant concentrations since this is more of a metropolitan regional problem.

Comment

Chrysler -- asserted that EPA cannot use measurements of gaseous pollutants to predict the levels of diesel particulate due to differences in dispersion characteristics.

Analysis

Chrysler was the only commenter to raise this issue. General Motors, on the other hand, obviously disagreed as they made predictions of ambient diesel particulate levels using measured ambient levels of carbon monoxide (an indicator of mobile source emissions). EPA also disagrees with Chrysler. We believe that there is adequate evidence available which shows that small submicron particles disperse essentially as a gas.2/

The same conclusion can be reached from a different route. In section D (on roadside impact), the appropriateness of the Record correlation to determine roadside diesel particulate impacts is challenged. EPA agrees. The problem with the correlation is that it is based on measurements of TSP near roadways. This particulate matter contains many large particles from reentrained dust and tire wear, which do not disperse at all like diesel particulate. Diesel particulate is submicron in size and disperses more like a gas than what is typically thought of as particulate, and thus gaseous surrogates are the best indicators available for diesel particulate modeling.

Comment

Chrysler, the Department of Energy, and the Council of Wage and
the Council of Wage and
Price Stability -- all claimed that EPA erroneously assumed that particulate emissions from stationary sources would remain constant.

2/ Cadle, Steven H., et. al., "General Motors Sulfate Dispersion Experiment: Experimental Procedures and Results," JAPCA, Vol. 27, No. 1, January 1977, pp. 33-38.

Analysis

EPA refers all commenters to a table taken from an EPA report dated May 1976.[3] The table has been reproduced here and follows. The report examines the potential for reducing particulate emissions from stationary sources through Federal standards. As can be seen, 1990 emissions could increase as much as 18.6% or decrease as much as 23.2% (Strategy #3) from 1975 levels. However, Strategy #3 is really not practical since EPA never contemplated setting all the standards in 1975, nor did it have the manpower to do it. The group designated FS (Strategy #5 and on) implies fuel switching is necessary to control emissions, either to oil or natural gas. From the current status of the nation concerning energy, it is pretty obvious that we are not going to restrict coal usage and force conversion to oil or natural gas. A strategy with the FS group postponed should then be chosen. The RD group contains those industries where research is needed to develop suitable control technologies. As of mid-1979, none of these standards have even been proposed. It is then reasonable to choose a strategy which postpones the RD group, also (Strategy #6). As can be seen, this already reduces the potential reduction in stationary source emissions to 6.7%. Even this strategy, however, requires 6 new standards to be set each year. Beginning in 1975, that would have required 24-30 new standards to have been set to date. So far, only 9 standards have been set, and these have had priority rankings (largest emission reduction receives a ranking of 1) of: 2, 4, 6, 8, 13, 32, 33, 37 and 39. From this it is evident that even the 6.7% reduction will not be attained. Strategy #8 shows the result of skipping only one large source, medium-sized boilers (priority 3). The result is a 5.7% increase in overall emissions in 1990. To date, a standard has not been proposed for medium-sized boilers. Strategy #8 would appear to be close to the plan that has been followed since 1975, except that it still overestimates the number of standards to be promulgated per year and it assumes that those standards will be set in order of greatest potential reduction, which is not occuring. The 0.7% reduction in overall emissions in 1990 is still optimistic. From all of this, it is quite reasonable to predict no reductions in stationary source emissions between 1975 and 1990.

C. Projections of Diesel Sales

Comment

General Motors, the Department of Energy and Congressman Dale E.

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[3] "Priorities and Procedures for Development of Standards of Performance for New Stationary Sources of Atmospheric Emissions," OAQPS, EPA, May 1976, EPA-450/3-76-020.

Particulates Priority Strategy Summary[a]

	Standard Setting Rate (no./yr)	Maximum Emission Rate		1985		1990		
Priority Strategy[b,c]		(10^6 tpy)	(yr)	Emissions (10^6 tpy)	% Change from 1975	Emissions (10^6 tpy)	% Change from 1975	Efficiency Ratio (%)[d]
1. State standards only		16.56	1990	14.08	+35.4	16.56	+59.3	-97.0
2. Only existing NSPS and state standards		12.34	1990	11.46	+10.2	12.34	18.6	0.0
3. All NSPS set in 1975		10.40	1975	8.72	-16.2	7.99	-23.2	100.0
4. NSPS set in Ts-Tn order	6	10.43	1975	9.12	-12.3	8.39	-19.3	90.7
5. Postpone RD group (UN/RD)	6	10.43	1975	9.31	-10.5	8.60	-17.3	85.9
6. Postpone FS and RD groups (UN/FS/RD)	6	10.45	1976	9.97	- 4.1	9.71	- 6.7	60.5
7. Postpone MCR, FS, RD groups (UN/MCR/FS/RD)	6	10.45	1976	9.99	- 3.9	9.73	- 6.4	59.9
8. Same as 7 with boilers ($10\text{-}250 \times 10^6$ Btu/hr) in FS group (UN/MCR/FS/RD)	6	10.52	1980	10.37	- 0.3	10.33	- 0.7	46.2
9. Postpone all constraint groups (UN/MCR/EQ/FS/RD)	6	10.45	1976	10.00	- 3.8	9.75	- 6.2	59.4
10. Same as 9 with UN sources less than 3000 tpy delayed with MCR group (UN[e]/MCR[f]/EQ/FS/RD)	6	10.45	1976	9.99	- 3.9	9.73	- 6.4	59.9
11. Same as 10	4	10.46	1977	10.08	- 3.1	9.84	- 5.4	57.5
12. Same as 10	10	10.44	1976	9.86	- 5.1	9.13	-12.2	73.6
13. Same as 12 with FS and RD excluded	10	10.44	1976	9.99	- 4.7	9.63	- 7.3	62.2
14. Postpone revised NSPS (UN[e]/MCR[f]/EQ/FS/RD/ES (revised))	6	10.45	1976	10.27	- 1.3	10.29	- 1.0	47.0

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[a] Stationary sources only.

[b] All strategies exclude standards for group with no demonstrated control technology (NC). The unconstrained (UN) group includes all sources in Ts-Tn order unless a specific constraint is involved.

[c] Except for Strategy 1, all strategies assume existing NSPS to be in effect in 1975. Except for Strategies 1-4, all revised NSPS are subject to at least a 5-year delay in addition to other constraints that may be involved in the revision.

[d] Computed from the formula $[(E_2-E_{strategy})/(E_2-E_3)]_{1990} \times 100\%$; i.e., Eqn 3-15 where E_2(Strategy 2) is E_{max} and E_3 (Strategy 3) is E_{min}.

[e] Only sources with Ts-Tn > 3000 tpy included.

[f] Unconstrained sources with Ts-Tn < 3000 tpy included.

Kildee -- all asserted that the sales projections for light-duty diesels used in the Regulatory Analysis are unrealistic.

Analysis

The above commenters have stated that the diesel sales projections used in the Draft Regulatory Analysis are too high. Unfortunately, the commenters were not much more specific than that. General Motors did project their diesel sales through 1985 and, via their CAPS proposal, through 1990. The Department of Energy suggested that EPA use the Department of Transportation's projections. The source of this projection was not given and only the 1985 projection was stated, 9%. We have examined the Department of Transportation's most recent Report to Congress on fuel economy, 4/ and the only projection of diesel sales found was 10% in 1985. Congressman Kildee did not recommend any alternative projections.

The range of diesel sales projections used by EPA in the Draft Regulatory Analysis are shown in Table I-1. While both scenarios reach 10% and 25% diesels rather early (1983), both scenarios remain constant at that level through 1990 and on. This latter aspect should be remembered when comparisons are being made against the projections of the early years. While 25% in 1983 may be quite high, 25% in 1990 is not unreasonable, particularly when it only represents an upper limit. As a best estimate, EPA chose a diesel penetration halfway between the two scenarios of Table I-1. Some commenters have centered their attention on the higher scenario (25%) as if this was the EPA's best estimate. Our best estimate for a final diesel penetration was only 17.5%, with a possible range of 10-25%.

It would be useful at this time to perform a rather detailed estimate to determine how reasonable the current scenarios really are. In Table I-2 a breakdown of 1978 sales of light-duty vehicles is shown by manufacturer. For the purposes of this analysis it will be assumed that these percentages will remain constant in future years. In Table I-3 the GM projections of their own diesel sales are shown. The projections between 1981 and 1985 have been taken directly from GM's formal comment to the rulemaking. The projections for 1986 and on have been calculated from a table contained in GM's CAPS proposal, which shows GM's average diesel particulate levels under a series of CAPS standards. The percentage of diesels was found by dividing the CAPS standard by the average diesel particulate level. Also shown in Table I-3 are estimates of industry-wide diesel penetration which GM used in the air quality analysis contained in their NOx waiver request.

4/ "Automotive Fuel Economy Program, Third Annual Report to Congress," NHTSA, DOT, January 1979, DOT-HS-803-777.

Table I-1

Percentage of New Vehicle Sales Powered by Diesel Engines

Model Year	Light-Duty Vehicles and Trucks Case A	Case B
1977	0.5	0.5
1978	0.5	0.5
1979	2.0	5.0
1980	4.0	10.0
1981	6.0	15.0
1982	8.0	20.0
1983	10.0	25.0
1984	10.0	25.0
1985	10.0	25.0
1986	10.0	25.0
1987	10.0	25.0
1988	10.0	25.0
1989	10.0	25.0
1990	10.0	25.0

Table I-2

Breakdown of New Passenger Car Sales in the U.S. by Manufacturer - 1978 1/

Manufacturer	New Car Sales	Percentage of New Car Sales
General Motors	5,385,282	47.6%
Ford	2,582,702	22.8%
Chrysler	1,146,258	10.1%
AMC	170,739	1.5%
VW 2/	239,306	2.1%
Mercedes-Benz	46,695	0.4%
Volvo	50,880	0.4%
Fiat	60,435	0.5%
BMW	31,457	0.3%
Audi	40,878	0.4%
Peugeot	9,061	0.1%
Other Imports	1,544,385	13.7%
TOTAL	11,308,078	100.0%

1/ Automotive News, 1979 market Data Book Issue, April 25, 1979, pp.18 and 52.

2/ Domestic and imported.

Table I-3

General Motors' Projections of the Percentage of Diesels in New Light-Duty Vehicle Sales

Model Year	GM Fleet 1/	Total Fleet 2/
1981	4.2%	4.7%
1982	8.9%	7.5%
1983	11.1%	8.9%
1984	12%	9.5%
1985	13.8%	
1986	17.5%	
1987	22%	
1988	23%	
1989	24%	
1990	25%	

1/ Source: 1981-1985 - GM's comment on the NPRM for light-duty diesel particulate regulations; 1986-1990 - derived from GM's CAPS proposal presented to the EPA on 3/16/79.

2/ Source: GM's air quality analysis contained in their request for a diesel NOx waiver.

We now have enough information available to determine GM's contribution to the diesel fleet, but we still need the fraction of diesels to be sold from the other manufacturers. None of these manufacturers gave EPA projections of their diesel sales, but reasonable projections can be made from the information available. Table I-4 lists the various manufacturers, other than GM, who are expected to sell diesels in the 1980's in the U.S. Others, such as Toyota and Datsun, may also sell diesels, but their plans to this date are too questionable for reasonable projections to be made. Their omission will contribute to the conservativeness of our estimates. Starting with the group of small foreign manufacturers who do not sell diesels in the U.S. to date, we project that overall Fiat, Volvo, and BMW will reach 10% diesels in 1985 and 20% in 1990. The desire for greater fuel economy should drive this increase particularly for Volvo and BMW. We have determined that this is reasonable by citing the situations of Mercedes-Benz and Peugeot, who both currently sell about 60% diesels.

We have projected that both Mercedes-Benz and Peugeot will increase their market penetration through 1990. Currently selling about 60% diesels, we have projected diesel sales of 75% (1985) and 90% (1990). Mercedes-Benz in particular appears to be turning more and more to the diesel for fuel economy improvements.

Volkswagen currently (1979) sells about 100,000 diesels per year and they have testified to the EPA that they expect this to remain the same in the near future. This amounts to 42% of their 1978 sales, domestic and foreign. Following their statements, this figure has not been changed through 1985. For 1990 though, we thought it unreasonable that Volkswagen would not increase production of diesels especially given the popularity of their current models. Taking this into account, we have projected a 50% increase in the diesel's share of Volkswagen's sales for 1990, up to 63%.

The last three manufacturers are Ford, Chrysler and American Motors. Chrysler has been developing a 6-cylinder diesel for some time, and AMC appears to be in a position to buy diesels from other manufacturers. With General Motors moving ahead strongly with diesels, and the fuel economy advantage of the diesel being relatively cheap compared to other fuel-saving techniques again it would be unreasonable to project Chrysler and AMC staying out of the diesel market. We have projected 10% (1985) and 20% (1990) diesels for both manufacturers. These represent figures somewhat below those of General Motors. While these projections might appear high to some, an examination of the total sales involved shows the reasonableness of the figures. For American Motors, 10% of their 1978 sales would be only 17,000 vehicles, and 20% would be 34,000 vehicles. Volkswagen sold 30,000 diesels in the second year they were offered (1978). For Chrysler, 10% of their 1978 sales would be 115,000 vehicles and 20% would be 230,000 vehicles.

Table I-4

Projected Percentage of Diesel-Powered Light-Duty Vehicles Sold by Manufacturer

Manufacturer	1985	1990
Ford	10%	15%
Chrysler	10%	20%
AMC	10%	20%
VW 1/	42%	63%
Mercedes-Benz	70%	90%
Peugeot	70%	90%
Volvo, Fiat, BMW	10%	20%

1/ Includes Audi.

General Motors has primarily been marketing their diesels through their Oldsmobile division which is about the same size as Chrysler. Since General Motors was able to produce and sell 180,000 diesels in their second year of production, it is certainly reasonable that Chrysler could reach that level in 11 years. Given General Motors commitment to diesels, it would be difficult for AMC or Chrysler to remain competitive without a comparable capacity of their own.

Finally, we are left with Ford. Their question is PROCO vs. diesel. It is a certainty that they will produce one of the two engines. While Ford clearly identifies PROCO as their primary project, there is ample evidence that Ford is going to have a diesel program ready as a backup if something goes wrong with the PROCO. Ford recently contracted the services of Cummins Engine Co. to perform the engineering designs for their diesel program. Given the length of time that Ford has been working on the PROCO without production being established, the emphasis being put on the back-up diesel program, and the on-going diesel program at competitor GM, the chances appear good that Ford will produce diesels. The desire for fuel efficiency exists today, and the PROCO is yet unproven, both in the manufacturing process and in the field. Taking all of this into consideration, we project Ford converting 10% of its sales to diesels by 1985, and 15% by 1990. The latter value (15% vs. 20% for Chrysler and 25% for General Motors) reflects the greater possibility of PROCOs being produced in significant numbers by 1990.

Combining the figures in Tables I-2, I-3, and I-4, the overall percentage of diesels being sold in 1985 and 1990 can be determined. In 1985, the diesel fraction is projected to be 11.4%, and in 1990, 19.7%. To project the diesel fraction of vehicle miles travelled, similar diesel fractions are needed for other years. For the sake of simplicity, the GM industry-wide projections will be used for 1981-1984 (see Table I-3). Simple interpolations between the 1985 and 1990 values will be used for all manufacturers except General Motors for 1986 through 1989. The projections shown in Table I-3 will be used for General Motors. After 1990, we will simply assume that the diesel penetration holds constant at 20%. All these values are shown in Table I-5.

To determine the diesel fraction of total vehicle-miles travelled, the breakdown of vehicle-miles travelled by model year, shown in Mobile Source Emissions Factors [5], will be used. The result is that 13.2% of the vehicle miles travelled by light-duty vehicles will be by diesel in 1990 and 18.3% in 1995.

The diesel penetration scenarios shown in Table I-1 yield very similar results. In 1990, 9.1-22.9% of light-duty vehicle miles

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[5] Mobile Source Emission Factors, EPA, March 1978, EPA 400/9-78-005, Table I-5.

Table I-5

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

Model Year	Diesel Fraction (%) 1/
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%

1/ Sources: 1981-1984 Table I-3;
1985, 1990 Tables I-2, I-3, I-4;
1986-1989 linear assumption between 1985 and 1990 levels;
1991-1995 assumption that diesel penetration levels off after 1990.

travelled are projected to be diesel, and in 1995, 10-25%. The best estimate scenario (halfway between the two scenarios of Table I-1) would yield projections of 16% in 1990 and 17.5% in 1995. While the two sets of scenarios yield similar results for 1990 and 1995, the more recent scenario shown in Table I-5 gives a much more accurate prediction through the 1980's. As accurate estimates of diesel penetration in the 1980's will be needed for economic analyses and the analysis of alternative standards, it appears that the more recent scenario (Table I-5) should be used in the Regulatory Analysis. However, a range of values would be appropriate to indicate the potential error in these predictions. Two scenarios based on Table I-5, one increased by 25 percent throughout and one decreased by 25 percent throughout, should satisfy this requirement.

D. Roadside Impact

Comments

Ford and the Department of Commerce -- objected to the use of a roadside impact determined three meters above and four meters from the road when EPA guidelines for monitor siting would not allow a monitor to be located that close to the road.

The Council of Wage and Price Stability -- asked that unless EPA can better justify using the roadside impact as a basis for control, only the regional impact should be used.

Analysis

The EPA guideline referred to was published in the Federal Register on August 7, 1978, pages 34892-34934. This guideline requires that ambient TSP monitors be located at least 5 meters away from, and 15 meters above a roadway, or at least 25 meters away from, and 5 meters above a road, or further away from a roadway than a line drawn between the above mentioned locations. There are two reasons for this restriction. First, monitors located closer to roadways do not generally represent 24-hour population exposures; people do not generally locate in such close proximity to streets for such periods of time. Second, monitors located closer to roadways would actually be in the concentrated plume of particulate emitted and generated by traffic. Except for special purpose monitoring studies, where the objective is to determine the impact of a single source, ambient monitors should not be located so as to measure the plume of a single source.

In the Draft Regulatory Analysis, the air quality dispersion model used to perform the primary air quality impact study in Kansas City only yielded ambient diesel particulate levels on a neighborhood scale (2 kilometer by 2 kilometer grids). Because many people would be exposed to higher concentrations at least part of the day, due to living, working or traveling on or near a street, the roadside impact was estimated. As such, the roadside impact, or any localized impact has an important role to play in any regulatory decision. While it is "generally" true that no one resides very close to highways for periods of 24 hours, it is important to determine the exposure of taxi and bus drivers, street vendors and apartment dwellers who live very close to busy streets and may be exposed for eight hours or more. Monitors to be used in nationwide comparisons must have somewhat uniform locations and be limited in number, which precludes the monitoring of any one source. At the same time, if people are breathing air from the plume of a source, it is the Agency's responsibility to ensure that those people are protected.

However, care must be taken to use any estimates of localized impacts in a responsible way. It would appear that the Draft Regulatory Analysis used the roadside impact without the necessary qualifiers (e.g., time of exposure, exposed population) and thereby placed too much emphasis on it. These areas should be corrected in the final version. In addition, EPA should attempt to better characterize the localized impacts used. Rather than simply using a roadside impact, impacts in street canyons, freeways, and actual urban monitoring stations should be determined. This should aid in using these localized impacts in a responsible manner.

Comment

General Motors -- raised the issue of why the Draft Regulatory Analysis quoted its roadside impact at 17,000 vehicles per day, while the PEDCo study it references quoted 25,000 vehicles per day. Also, General Motors claimed that EPA arbitrarily assumed that the roadside concentrations would exceed the regional concentration by a factor of 11.

Analysis

As to the first comment, PEDCo used the following correlation to determine the difference between roadside and regional concentrations:

$$C = (T/r)\ (0.265\sin^2 \theta + 0.07\cos^2 \theta)$$

Where: C = average contribution of paved road to measured TSP, $\mu g/m^{-3}$;

$\theta = \arctan (z/x)$;

T = average daily traffic, vehicles/day;

r = slant distance between monitor and roadway, ft.;

z = sampler height, ft.;

x = horizontal distance between roadway and monitor, ft.;

PEDCo determined that the existing TSP samplers averaged 7 meters in height and 31 meters from roadways carrying 17,000 vehicles per day. These locations were taken to represent regional ambient concentrations. The roadside location was chosen as 3 meters above ground, and 4 meters from a road carrying 25,000 vehicles per day. Using the above correlation, PEDCo determined that the difference between the regional and roadside impacts was a factor of 11. Upon repeating the calculations, we found that the factor of 11 was obtained simply from the difference in location (height and distance from road) without including the increase in traffic. With the increase in traffic, the factor rose to 16.5. Rather than increase the factor to account for the error, the roadside traffic condition was reduced to 17,000 vehicles per day to keep the factor at 11.

Comment

General Motors and Toyota -- both claimed that EPA's roadside impacts were too high, because the correlation was based on measurements which included tire wear and reentrained dust (i.e., larger particles) which have different dispersion characteristics than diesel exhaust particulate.

Analysis

The Record correlation was based on measurement of TSP near roadways, which would include larger particles as well as smaller ones. Since the larger particles would have different dispersion characteristics than the submicron diesel exhaust particulate, it does bring into question the ability to apply the correlation in this case. One would expect that the larger particles would not disperse as fast as the smaller particles and would settle out at a faster rate. Both tendencies would lead to a steeper concentration gradient for the larger particles. Since the correlation was used to determine roadside concentrations from regional concentrations, this would lead to an overestimate of the roadside concentrations of the smaller particles. Because of this, Record's correlation should not be used to estimate the roadside concentrations of diesel particulate.

Both General Motors and Toyota submitted data in support of their statements. These data should be included in the final Regulatory Analysis.

E. Population Exposure

Comment

The Council of Wage and Price Stability -- said that the nationwide population used in the population exposure calculations was overestimated. The Census Bureau now estimates the nationwide population to be 236-255 million people in 1990.

Analysis

Any population exposure used in the final Regulatory Analysis will be revised to use the latest Census Bureau figures.

Comment

The Department of Energy -- made the objection that the population exposure is based on many questionable assumptions and extrapolations, particularly the extrapolation of the Tri-State population exposure distribution to the Kansas City area and then the nation. The population exposure should be improved or deleted.

Analysis

There can be no argument against the comment that many assumptions and extrapolations were made to estimate the nationwide population exposure to diesel particulate. Most of these assumptions and extrapolations are sure to contain some error, in both directions. For the purposes of this regulation, rather than defending the exposure estimate, it would appear best to delete it from the analysis. This regulation is based on the diesel's impact on overall TSP levels and not on a population exposure to an absolute level of diesel particulate in the atmosphere, as a cancer risk assessment would require. For the purposes of this regulation, estimates of ambient levels of diesel particulate should be sufficient to demonstrate the diesel's impact on the nation's ability to meet the NAAQS for TSP.

While the population exposure will not be used for this regulation, EPA may use it in the future when its need is greater and time allows for a discussion of the various assumptions that were made. While its limitations must be recognized, it is likely the best estimate of its kind available.

F. Recommendations

As a result of the above analyses, the following changes should be made in the Regulatory Analysis:

1) In the area of health effects, a section should be added describing the adverse health effects of suspended particulate

matter, including the effect of fine particulate matter. The aspect of fine particulate should also be emphasized in the chapter dealing with cost effectiveness. The assertion that EPA could not promulgate this regulation until it had demonstrated that none of the control techniques used to comply with the regulation pose unreasonable risk under Section 202(a)(4) of the Clean Air Act has been rejected.

2) With respect to air quality modeling, the assertion that the maximum 24-hour estimates of ambient diesel particulate levels could not be directly compared to maximum 24-hour levels of TSP has been rejected. The Regulatory Analysis should include estimates of ambient diesel particulate levels from many cities besides Kansas City, putting the results from Kansas City in a proper perspective with respect to the rest of the nation. It has also been shown that the Air Quality Dispersion Model does not overpredict the air quality impacts of mobile sources, so no adjustments to the modeling results are necessary. It appears that the prediction that vehicle use in Kansas City will increase 1.5% per year would overestimate vehicle use in the central city area. To remedy this, a 1.0% per year growth factor should be used in all subsequent analyses. The assertion that measurements of gaseous pollutant concentrations could not legitimately be used to predict diesel particulate levels was shown to be unfounded, as was the claim that stationary source particulate emissions would substantially decrease between 1975 and 1990.

3) The light-duty diesel sales scenarios used in the Draft Regulatory Analysis should no longer be used in future analyses. They are accurate for long-term projections (1990 and 1995), but overestimate diesel sales in the early and mid-1980's. In its place should be used the scenario shown in Table I-5, which predicts that the diesel fraction of light-duty sales will reach 11.4 percent by 1985 and 19.7 percent by 1990. To indicate a range of possible penetrations, the values shown in Table I-5 should be increased and decreased by 25 percent.

4) The estimates of the roadside impact of diesel particulate emissions should be improved in the final Regulatory Analysis. The correlation originally used to estimate the roadside impact should be discarded because it was based on TSP measurements and likely overestimated the roadside levels of the smaller diesel particulate. To replace this correlation, more detailed scenarios and more sophisticated models should be used. Measurements of ambient levels of carbon monoxide, near roadways, will also be used to estimate roadside levels of diesel particulate. Also, future use of the roadside impact should be accompanied by the necessary qualifications concerning the likelihood of population exposure.

5) The quantitative estimate of the population exposed to diesel particulate should not be used in the final Regulatory

Analysis. It is not necessary to this Rulemaking and rather than burden the Analysis with justifications of all the assumptions involved, its use should be reserved for future regulatory actions which may require a quantitative exposure estimate.

II. Control Technology

A. Engine Modifications (excluding turbocharging)

EPA had predicted that minor engine modifications and redesign would make a significant contribution towards reducing particulate emissions from light-duty diesel vehicles. In the NPRM we suggested adjustments to timing, combustion chamber and fuel injector redesign, and insulation and derating of the engine as potential control technologies in this regard. For the discussion of turbocharging, see the following issue.

Comments

Fiat -- "A ten percent particulate reduction [by adjustment of timing] can cause a 30% NOx increase....The combustion [chamber design] system of a diesel engine is not very flexible from the point of view of an acceptable trade-off between emissions and fuel consumption....[Redesign of fuel injectors] could be effective especially with hole injectors....[With respect to insulation of the engine] at present no technology is available....[Derating] is not correct at least for light-duty diesels."

Peugeot -- "Delaying of the injection timing would be, of course, beneficial on the particulate standpoint but would not be acceptable as far as the HC are concerned. In actual practice, there is no possibility to improve the particulates by optimization of timing....[We] believe that the compression ratio modification is not a promising way to reduce the particulates....[We] think that the [combustion chamber] insulation is unfavorable to the particulates."

General Motors -- "Injection timing data...at constant speed and light load revealed that, as timing was retarded, particulates increased but NOx decreased. On the other hand, at the same speed but at a higher load, both particulates and NOx decreased as timing was retarded. At a given timing, particulates were reduced as injection supply pressure was increased; however, this reduction was accompanied by an increase in NOx....[With regard to combustion chamber design] very substantial improvements have been realized in the relatively new Oldsmobile system....Oldsmobile personnel in the course of their engine development program have evaluated nearly 3,000 combustion chamber/ fuel injection system combinations to date including most of the prechamber types presently in production in competitive engines in an effort to define the optimum configuration....In 1980 GM plans to introduce a modified system which incorporates a new poppet-type injector. This system will substantially reduce HC and particulate emissions compared to 1978-79 production configurations."

Ricardo -- "Ricardo feels that potential exists for optimizing the swirl chamber engine for low particulates at light load at the expense of some smoke-limited performance. The maximum reduction which could be expected from combustion changes is estimated to be about 15% over the drive cycle....Little data exists to show the benefit of insulating the combustion chamber....Significant gains may be possible by improving the power/weight ratio by fitting a more powerful engine or by lightening the vehicle. The effect would be to increase engine air/fuel ratios during the drive cycle which may be expected to lead to a reduction in particulates."

Department of Energy -- "DOE's technology analysis...summarized below indicates that...initial control of particulates through engine modification is possible given adequate development and leadtime. Injection system design, injection timing, combustion chamber design and driveline matching (or engine derating) will be the primary means of controlling particulates."

Daimler-Benz -- "It is common knowledge, and it is not disputed by Daimler-Benz, that past engine modification measures have been among the most effective means for improving today's diesel engine. Indeed, the quality and performance of today's diesel engine for application in the passenger car is directly related to engine modifications involving the injection system, injection rate and timing as well as the spray characteristics of the fuel nozzles utilized in light-duty vehicle diesel engines....The engine modifications which distinguish the 1979 300 D and 300 SD engines other than turbocharging include the following modifications contained in the 300 SD engine and not the 300 D engine:

(a) [A]n additional hole in the prechamber increasing the prechamber from five holes to six holes which results in a reduction of particulate....

(b) [A]n injection pump with modified injection characteristics....This modification resulted in less particulate matter emissions under part load conditions and lowered gaseous emission[s]...

(c) [A] modification was made to the...injection timer. This change resulted in retarded injection timing at part load causing a beneficial impact on particulate and gaseous emissions....

Daimler-Benz has incorporated in the model year 1980 300D engine design all the changes noted above which were used in the 1979 300 SD engine."

Analysis

Our position that engine modifications would be able to reduce particulate emissions had been primarily based on the fact that although many diesel engine designs had been optimized for smoke-limited performance, none had been optimized with respect to particulate emissions. Thus we expected some optimization to be possible, especially at light loads where the correlation between smoke and particulate is much less clear. Because particulate reductions due to minor engine modifications are strongly manufacturer-specific (dependent on the existing engine design, the extent to which that design had been optimized for smoke, the willingness and financial ability to perform the requisite research, etc.), we were not able to state the percentage improvement that could be expected from such changes, and therefore did not place a great deal of emphasis on minor engine modifications. Based on the above comments and manufacturers' data on 1980 certification and 1981 prototype designs, however, we seem to have underestimated the significant reductions in particulate emissions possible through minor engine modifications.

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, 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. Finally, no commenter expressed any confidence in engine insulation as a particulate control strategy.

EPA had tested a wide variety of 1979 light-duty diesel certification vehicles when establishing the diesel particulate baseline. Three manufacturers reported 1981 prototype particulate data on models which we had tested as part of the baseline. The comparison of these data is shown in Table II-1.

We believe these data prove that engine modifications have been a fertile source of particulate reductions in the past year. It is very important to note that the greatest particulate reductions achieved through engine modifications were by GM and Daimler-Benz, the manufacturers who had the highest 1979 certification particulate levels. Thus, our belief that particulate optimization was possible has been borne out, and even exceeded with respect to the largest diesel engines.

Table II-1

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

Manufacturer	Model	1979 Baseline Particulate Level (g/mi)	1979 Baseline Particulate Level (g/km)	Best 1981 Prototype Particulate Level* (g/mi)	Best 1981 Prototype Particulate Level* (g/km)
General Motors	"260"	0.73-1.02	0.45-0.63	0.29-0.50	0.18-0.35
	"350"	0.84	0.52	0.36-0.51	0.22-0.32
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

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*At NOx levels of 1.5 gpm or less.

The EPA technical staff is confident 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 who have not investigated these areas), timing adjustments and controls, and engine derating. 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. 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.

B. Turbochargers

EPA placed considerable emphasis upon turbocharging as a particulate control strategy in the light-duty diesel particulate Regulatory Analysis. Data available to us at that time indicated that turbocharging reduced particulate emissions by approximately one-third. This conclusion generated much discussion by the commenters.

Comments

Peugeot -- [O]nly [the] addition of a turbocharger is not sufficient to ensure lowering of the particulates emission. However, an appreciable reduction of about 20% has been realized with a turbocharged engine which included several complementary modifications (especially modification of the valve timing)."

Fiat -- "[Turbocharging] can be effective (up to 30% reduction of particulates with respect to N/A engine) but it needs a long time of development, not only to redesign the injection, intake, and exhaust systems and to match the turbocharger to the engine for emissions and fuel economy, but mainly to review engine design in order to insure acceptable reliability with the increased thermal loading and pressure."

Ricardo -- "Results from a number of sources indicate that by running with the higher air/fuel ratios afforded by turbocharging, particulates can be significantly reduced....Estimates of the reduction obtained by turbocharging vary considerably, but figures of 25% and above are typical."

Daimler-Benz -- "Turbocharging is simply a means of increasing the power output of a diesel engine with an established CID. The application of turbocharging results in the improvement of a vehicle's fuel economy resulting from the engine's increased thermal efficiency and ability to thereby lower a vehicle's rear axle ratio. Turbocharging does not reduce particulate matter emissions."

General Motors -- "In the course of GM investigations of applying turbochargers to the diesel engine, we have not seen any substantial lowering of particulate levels by turbocharging in any of the installations where we have comparative data."

Ford -- "[C]urrently available data from turbocharged and naturally aspirated diesel engines show mixed results."

Department of Energy -- "Turbochargers are not an effective particulate emission control device as assumed by EPA, except to the extent they reduce fuel consumption. This is due in part to the fact that they are not operative during a large portion of the EPA test cycle."

Analysis

As the above quotations indicate, there is disagreement over whether turbocharging does indeed reduce particulate emissions. Peugeot and Fiat were the only manufacturers to emphatically support the application of turbocharging to reduce particulate emissions; Daimler-Benz and General Motors denied that turbocharging reduced particulate; and Volkswagen, Chrysler, Ford, Volvo, and BMW generally held that it was not clear whether turbocharging reduced particulate or not.

Both Peugeot and Fiat emphasized that it is not possible to achieve lower particulate levels by simply adding a turbocharger to an existing engine design; it is necessary to match the turbocharger to the engine's intake, exhaust, and injection systems. After doing so they reported particulate reductions of 20 and 30 percent, respectively. Surprisingly, it seems that none of the other manufacturers have chosen to seriously investigate turbocharging. Daimler-Benz spent much effort in showing why it was inappropriate for EPA to use their 1979 300 D (naturally aspirated) and 300 SD (turbocharged) vehicles as an example of how turbocharging reduces particulate, because of design differences between the two models in the 1979 model year (see previous issue). Yet there is no evidence that they thoroughly investigated the possibility of integrating turbocharging throughout their diesel model lines. General Motors did report the results of a test program designed to investigate the effect of turbocharging on particulate emissions. But from what we can ascertain from their comment, the program involved little more than turbocharger on/turbocharger off comparisons. Most of these comparisons showed turbocharging to cause higher particulate emissions. Clearly, however, GM did not perform the comprehensive test program one would expect if it truly wanted to utilize a turbocharger as a particulate control device. GM did admit that the use of a turbocharger permits the use of a lower numerical axle ratio, and reported tests indicating that lower axle ratios reduce particulate as well as HC, CO, and NOx emissions, but concluded that the particulate reduction would be "small" when using a "reasonable" decrease in axle ratio.

The comments have convinced the Agency that turbocharging can be an effective particulate control strategy, provided 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. Our initial estimate of a 33 percent reduction may have been somewhat optimistic, but it appears that reductions of 20 to 30 percent are achievable in many cases. Clearly, however, turbocharging is not the quick and simple control strategy that we had considered it in the Regulatory Analysis. This has definite ramifications with respect to lead time which will be discussed in the next section.

C. Catalytic Converters

EPA had estimated that the majority of light-duty diesel vehicles would have to utilize an aftertreatment device to meet the proposed 1983 particulate standard. This device could be either a catalytic converter, trap, or trap oxidizer. EPA had assumed that such an aftertreatment device would have a collection efficiency of 67 percent.

Comments

Ricardo -- "Platinum catalysts of monolithic construction are known to be extremely effective in reducing hydrocarbons in exhaust gases, but Ricardo has not found them to be effective in reducing particulate emissions. It has also been found that production of sulfates within the catalyst can be a problem if gas oils with a high sulfur content are used. The addition of a catalyst to a filtering medium may, however, have a beneficial effect since oxidation of soot depositing on the filter may be promoted."

Fiat -- "[Catalytic converter] is effective in reducing by 50% organics adsorbed on particulate, but with a strong increase in Sulfates in the form of SO_4 because of the presence in the fuel of large sulfur amounts....Furthermore plugging problems of catalytic converters during mileage accumulation have to be solved."

BMW -- "The main problem with an oxidation system is to provide the necessary temperature level and sufficient oxidation time. Adequate exhaust temperature of approximately 600°C for particulate oxidation may only be reached outside the CVS driving cycle."

General Motors -- "In general, we have found no catalyst to date which has aided in particulate reduction, although catalysts have shown at least temporary HC reduction."

Ford -- "[C]atalysts tend to have low efficiencies at the low exhaust temperatures of the diesel. Clogging of the catalyst with soot is a problem unless adequate temperature levels are achieved by installing the catalyst close to the exhaust port....However, with a close-coupled catalyst, sulfate emissions may increase."

Analysis

The primary difficulty of 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 appears that considerable progress has been made with converter technology in reducing the organic component of the particulate (see Ricardo and Fiat comments above), similar progress has not occurred with respect to the less easily oxidized carbon (soot) component. In addition, the possibility of greater sulfate emissions is of concern, although Volkswagen reported that this could be avoided by the selection of the proper catalyst.

Thus, unless a technical breakthrough occurs, it is unlikely that catalytic converters will play a major role in reducing diesel particulate emissions. It is quite possible that in the future converters will be used for HC and organics reductions, with some resulting reduction in total particulate emissions, and we expect research in this area to continue. Concerning total particulate emissions, the use of catalytic material in combination with trap oxidizers is most promising. This will be discussed below.

D. Traps

Comments

Ricardo -- "Traps filled with alumina-coated stainless steel wool have given particulate reductions of better than 50% over the FTP cycle, but after about 1,000 miles the traps became blocked, collection efficiency fell below 10%, and back pressures rose unacceptably. The recurring problem with these devices...is the very large volumes of soot which are collected."

Daimler-Benz -- "In principle exhaust gas temperature resistant as well as chemical resistant filters can eliminate particulate matter from the exhaust gas stream for a limited time period with 15 to 80 percent efficiency. The main problem with these filter systems is, however, the exhaust gas backpressure buildup process which takes place within hours. If this backpressure exceeds certain values, performance and fuel economy are reduced while particulate matter emissions of the engine increase. Thus, at the present time, Daimler-Benz has found no manufacturer with the capability of producing by 1983 trap filters which have acceptable durability and do not result in unacceptable backpressure buildup."

General Motors -- "Open structures of metal mesh and typical beads have yielded particulate collection efficiency of about 60% in properly proportioned volume and at low vehicle mileage. Trap capacity is limited when reasonable trap volumes are used, and some trap materials have been destroyed under certain driving conditions....The measured bulk density of particulates removed from the walls of an exhaust system or CVS tunnel is in the range of 0.07-0.10 g/cm^3. At this low density for typical emission levels, the particulate volume removed by an efficient trap may be well over a gallon per thousand miles. This particulate bulk is not distributed evenly through the trap material, but is concentrated more heavily near the trap inlet. For these reasons, traps of reasonable volume have capacity for only a few hundred miles of operation....A study is in progress to evaluate various cleaning methods for trap restoration by servicing with external (not onboard) equipment. It is recognized that such methods would require the availability of service stations of the necessary auxiliary cleaning equipment, and would entail a possibly difficult problem of particulate disposal at the service station. Also, considerable driver inconvenience and service costs would likely result....No trap and cleaning technique has yet been found which solves all the basic problems of backpressure buildup, decreasing efficiency, blow-off under acceleration, and disposal of the particulates once collected."

Analysis

The particulate collection efficiencies of many trap materials, when new, are quite acceptable. Daimler-Benz reported initial efficiencies as high as 80 percent, and General Motors reported initial efficiencies for paper elements as high as 90 percent, and for alumina coated metal mesh, metal wool, quadralobe catalyst beads, and alumina fiber material efficiencies of 60 to 65 percent. As mileage accumulation occurs and the particulate begins to build up on the trap, the collection efficiency decreases and the exhaust gas backpressure increases. A method is needed by which the trap can be periodically "cleaned" or regenerated to restore the collection efficiency and backpressure to desirable levels. The regeneration technique must also be compatible with the trap lasting 100,000 miles, as durability is a primary consideration. To date, the best reported trap with respect to durability 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 trap attrition and there was evidence of some particulate blow-off and self incineration. It is in the areas of regeneration and durability where research must be continued to optimize a particulate aftertreatment device.

It has been recognized that there are two basic classes of regeneration: external trap servicing and on-board automatic incineration. The latter distinguishes the trap oxidizer, which will be discussed in the next 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 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 a vehicle owner to abdicate his responsibility to service his 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.

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, we believe that traps with external restoration could be a feasible particulate control technology, if extensive research continues.

E. Trap Oxidizers

Comments

General Motors -- "Of the [aftertreatment] approaches investigated, a particulate trap with onboard incineration shows the most promise, but available hardware does not meet the requirements of a production configuration. We have not yet found a trapping material that exhibits good efficiency, adequate capacity, tolerable flow resistance, and durability. We also have not identified a control system for the incineration process. Many factors must be considered in the development of such a system, such as safety, effects on emissions of other pollutants, effects on fuel economy, etc....Currently, the most desirable solution to the trap regeneration problem appears to be on-board incineration of the particulates. Test data have shown that this can be effectively achieved under certain conditions by raising the temperature of the exhaust gases to approximately 480°C....Two approaches to diesel particulate incineration are being actively pursued. The first, intake throttling, reduces the dilution air through the engine and, thus, increases exhaust temperature. In the second approach, the additional energy required to initiate incineration is provided by a device such as an electric heating element....Repetitive incineration over a limited few cycles has been achieved with careful control using each of the two methods. However, it has not yet been established by experiment or theory that nondestructive incineration can be achieved at all possible operating conditions, nor have the particulate collection limits for nondestructive incineration been defined. Repetitive controlled incineration at arbitrary operating conditions, with or without auxiliary heat supply will likely require a complex algorithm and closed-loop control."

Daimler-Benz -- "As a general statement, Daimler-Benz believes that EPA's position fails to recognize the following difficulties resulting from the use of trap oxidizers....:

> a) The exhaust backpressure increase resulting from the use of trap oxidizers adversely affects diesel engine performance as well as fuel economy thereby reducing the major advantages which the diesel engine has over gasoline engines.
>
> b) The variable nature of the exhaust gas backpressure resulting from the use of trap oxidizers has a direct impact on EGR systems which can result in an EGR system becoming ineffective....

If the exhaust gas temperatures of an engine are checked over load and speed, it becomes clear that sufficiently high temperature levels [for combustion] are only available in the upper load and rpm range of an engine's performance map. These operating ranges are, however, rarely reached during CVS testing....Thus, Daimler-Benz sees no possibility for the use of traps or trap oxidizers as a means of particulate matter emission control, especially in conjunction with turbochargers."

Ford -- "Current technology traps and filters may have over 50% particulate collection efficiency when new, however, deterioration of collection efficiency is very rapid with mileage accumulation.

Adequate exhaust temperature for oxidation of the collected particulate material may be only reached outside the CVS driving cycle so that repetitive CVS testing may not result in regeneration of the filter. Furthermore, we are concerned that filters laden with particulate material can be subject to accidental ignition. Although our research for an effective regenerating oxidizer trap is continuing, our current assessment indicates significant shortcoming in these systems at their current state of development."

Imperial Chemical Industries Limited -- "Tests on [trap oxidizers] have been reported which utilized through-flow agglomerating filters, but these were subject to high pressure drop under flow. ICI have been investigating the use of particulate filters for diesel exhaust for some years and this resulted in the invention of a novel form of filter which greatly reduces the pressure drop. The filter provides for a diffusion mechanism to remove the particulate in a radial flow structure of 'Saffil' alumino fiber and nickel wire. Regeneration of the filter is effected by oxidizing the particulate principally to CO_2 when the exhaust gas temperature reaches around 450°C in the presence of a silver catalyst....It is stressed that this submission is based only on limited data and further evaluation and development are essential to achieve a production device."

Analysis

A trap oxidizer is simply a trap with a mechanism by which the collected particulate can be periodically oxidized in order to restore the collection efficiency and exhaust gas backpressure to desirable levels. Many of the comments revolved around the issue of regeneration. Most of the commenters stated that the minimum temperature required for combustion of the particulate to be 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's two suggested approaches, air intake throttling and use of an external heat supply, 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. Further research needs to be done to examine the impact of throttling on emissions and fuel economy. As mentioned earlier, it is also 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 also been shown to reduce collection efficiency only slightly. 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.

Volkswagen was the only other manufacturer to report any trap oxidizer development results, but they included no durability data. They stated that it might be possible, with the proper catalytic material, to lower the temperature necessary for particulate oxidation as low as 350°C. If so, this would greatly reduce, and might even eliminate the need for throttling or an external heat supply. It would not eliminate the need for some kind of incineration control mechanism. VW is experimenting with trap oxidizers mounted in place of the exhaust manifold (thus obtaining slightly higher temperatures) while GM places its trap oxidizers further downstream in the exhaust system.

GM's preliminary development work on the trap oxidizer indicates that on-board incineration is technically feasible. Other concerns about on-board incineration were expressed by the commenters. Certainly the emissions characteristics of a diesel powered vehicle during the regeneration mode should be thoroughly investigated, both from the standpoint of the regulated pollutants and particulate, and any unregulated pollutants as well. The concern that the trap oxidizer could be a safety hazard should also be fully investigated, though at this time we do not foresee this to be a major problem.

Ford's concern over the possibility that the regeneration mode might not occur during CVS testing is well taken. The manufacturers would want regeneration to occur in order to restore collection efficiency and backpressure to original levels, and EPA would need regeneration to take place so as to characterize the emissions under that mode. It is recognized that the FTP may have to be modified in order to ensure that regeneration occurs.

Daimler-Benz's concern over the effect of increased exhaust backpressure on diesel performance and fuel economy is overstated. 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. We therefore are inclined to agree with GM that some form of control over the incineration process is 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.

In the Regulatory Analysis, we assumed a lifetime collection efficiency of 67 percent. Due to the uncertainty which still exists due to the developing nature of the technology, we cannot be sure whether this assumption will be verified. We have received data which show that such efficiencies have been achieved on low mileage tests, and expect that such efficiencies will be realistic for trap oxidizers over the lifetime of the vehicle in the near future.

The significant progress that has been made in trap oxidizer development indicates that it will play a successful role in particulate emissions control. Admittedly, application of the technology on production vehicles is not yet feasible. Research must be continued on regeneration control techniques and the optimization of a trap material which can last for the vehicle lifetime at a relatively high efficiency.

F. Fuel Modifications

EPA did not assume any particulate reduction due to fuel modifications in the Regulatory Analysis.

Comments

Daimler-Benz -- "EPA's proposal makes no effort to consider the beneficial impact on diesel particulate emisions which would result if the contents of diesel fuel were regulated."

General Motors -- "Changes in fuel characteristics could reduce diesel particulates up to 25 percent, but implementation depends on the capabilities of the petroleum industry....Any significant change in the diesel fuel supplied throughout the country would require time for its implementation."

Citizens for Clean Air -- "If [a correlation is found between aromatic content of diesel fuel and polycyclic aromatic hydrocarbon emissions], EPA should develop standards limiting the maximum aromatic content of diesel fuel marketed in urban areas if the expected conversion to high aromatic synthetic fuels produced from coal, oil shales, and tar sands should occur."

Analysis

Potential exists for reductions in particulate matter emissions due to diesel fuel modifications. The two areas which have received the most attention are fuel additives and different fuel blending.

Additives can reduce particulate emissons by reducing ignition delay, catalyzing carbon combustion, and improving fuel droplet dispersion. GM reported a 17 percent particulate reduction over the FTP with an unknown additive. One significant drawback of additives, of course, is that they usually contribute to other combustion by-products that often have public health implications.

Thus, any decision to mandate the addition of diesel fuel additives should be preceded by comprehensive characterization and assessment work. Although this work may be going on at this time, few results have been reported to EPA.

A different fuel blending might also be useful in reducing particulate emissions. Both high aromatic content and the high final boiling point portions of diesel fuel have been hypothesized to contribute to increased diesel particulate emissions. Thus, a fuel blend with a lower aromatic content and less of the high boiling point compounds would likely reduce particulate emissions. Unfortunately, such a blend would probably result in slightly worse fuel economy. In addition, a decision to permanently shift to a different diesel fuel blend would necessitate major changes by the petroleum refineries which would have definite lead time implications.

An important issue with respect to additives and fuel blending is whether EPA has the authority to issue regulations mandating any of the aforementioned changes. In the past, EPA deliberations regarding fuel content have concentrated on the desirability of removing fuel additives or contaminants that have been shown to be health hazards.

EPA should continue to monitor research performed in this area, and would welcome the opportunity to work with the automotive and petrochemical industries in reducing particulate emissions through fuel modifications.

G. Alternative Engine

Comment

Ford -- "[W]e are considering the use of a diesel engine in our light-duty vehicles as a back up alternative to our PROCO engine. We continue to believe that PROCO and/or diesel are an essential element of any plan to continue to offer a range of vehicles which satisfy basic demand for new motor vehicles and at the same time allow us to meet future, more stringent fuel economy standards.... We are interested in the diesel [as] there is real question yet on PROCO. We are working diligently and we are enthusiastic about it and reasonably confident. [But] many things could still happen before we get these things into mass production."

Analysis

Although we have received little information on it, Ford's stratified-charge PROCO (programed combustion) engine appears to be a promising alternative powerplant to the diesel. Preliminary data reported by Ford indicates that the PROCO yields approximately the same fuel economy improvements as the diesel with the diesel being slightly superior in heavier vehicles but the PROCO improving in lighter vehicles. Conversely, the PROCO does not seem to share most of the disadvantages of the diesel. A 5.8-liter PROCO in a 4,000-pound vehicle emitted just 0.03 to 0.06 g/mi (0.02 to 0.04 g/km) particulate with a catalyst and unleaded fuel; this is well below the "second-step" standard of 0.20 g/mi (0.12 g/km). It is also expected that the PROCO would exhibit less mutagenic activity than the diesel. In a series of 15 tests, three 6.6-liter PROCO engines in 5,000-pound vehicles emitted just 0.73 to 0.82 g/mi (0.45 to 0.51 g/km) NOx, a level that has been approached by only the very smallest diesel vehicles. Finally, its performance appears to be superior to the diesel and comparable to present gasoline-fueled vehicles. Thus, the PROCO is very promising as a technology which satisfies both environmental and energy requirements. The primary question about the PROCO concerns its feasibility in mass production. Ford did not offer any specific predictions about the cost of the PROCO, but did speculate that it might be more expensive than the diesel due to the need for electronic controls and an oxidation catalyst. It should be noted that the cost of the PROCO relative to the diesel will likely improve as trap oxidizers and electronically-controlled EGR become necessary for diesels to meet future emissions requirements.

H. Recommendation

From the foregoing analyses, it is clear that while we were overly optimistic about the effectiveness and availability of turbochargers to reduce particulate emissions in the near term, we were not able to foresee the significant reductions achieved through engine modifications, especially by manufacturers of the largest diesel vehicles. We continue to consider trap oxidizers to be the most promising aftertreatment technology. Research should continue in the area of fuel modifications.

III. Lead Time

A. Engine Modifications

EPA had projected that there would be sufficient lead time for manufacturers to make minor engine modifications by the 1981 model year.

Comments

Daimler-Benz -- "Daimler-Benz knows of no way that in the next three to six months any new technology can be developed or placed into production for the control of particulate matter. Thus, Daimler-Benz believes that the particulate matter standard established by EPA for model year 1981 must be capable of being achieved with presently available and adaptable technology."

Department of Energy -- "In view of the less than six months between the time this rule will likely be promulgated and the beginning of 1981 model year certification, 1982 is the first model year for which it is reasonable to expect improvements in particulate control...."

Analysis

As indicated in the earlier section on engine modifications, significant particulate reductions have already been achieved by minor engine redesign, especially by those manufacturers who had the highest particulate levels in our baseline testing. Very little lead time remains for the 1981 model year (many manufacturers will begin the 1981 certification process in late 1979). All that would be possible at this late date would be to fine-tune minor parameters with respect to particulate emissions. EPA's conclusions regarding the particulate level achievable in 1981 should be based only on that technology that is already available and which was discussed in the earlier section on engine modifications.

B. Turbochargers

EPA had stated in the NPRM that manufacturers would have sufficient lead time to incorporate turbochargers into their 1981 designs, should they so desire.

Comments

General Motors -- "Using current available manpower with a normal design program, it is estimated that GM could add turbocharging capability on their planned V-6 and V-8 diesel engines for the 1983 start of production. This presumes no major durability problems requiring new engine tooling."

Volkswagen -- "We have investigated turbochargers for several years . . . and think that they can be developed without unreasonable technical risk for the 1982 model year, although we do not regard them as particulate control devices."

Analysis

Very few comments were made on our turbocharger lead time projections. With respect to 1981 production, given the reality that most manufacturers will begin their 1981 certification process in the fall of 1979, it is certainly true that for those manufacturers who have not aggressively pursued turbocharger development, there is not sufficient time to integrate turbochargers into production designs. This situation has been brought about partly because turbocharging is not as "quick and simple" a way to reduce particulate as we had previously believed, and partly because many manufacturers have simply not moved rapidly with turbocharger development because of their belief that turbochargers do not reduce particulate. Nevertheless, it should be noted that Daimler-Benz will continue to market their turbocharged 300 SD model, and that Peugeot appears ready to introduce a turbocharged model in the 1981 model year. Neither of these manufacturers expressed any concern over turbocharger availability problems, though certainly their efforts are eased by the low volumes needed.

Turbochargers apparently will not be utilized by all manufacturers for the 1981 model year. For some manufacturers turbochargers will not be available on a mass scale until 1983. The effects of this situation on the 1981 standard should be considered under the level of standards issue.

C. Trap Oxidizers

EPA had projected that trap oxidizers could be a viable particulate control technology by the 1983 model year.

Comments

Volkswagen -- "Taking into account the necessary [trap oxidizer] development time, assuming the best possible results at each phase, we cannot complete development prior to mid-1982. Thereafter, 18 to 24 months are needed to purchase and set up production equipment. This means the earliest possible introduction date for trap oxidizers is the 1985 model year."

General Motors (written comment) -- "A number of ideas and suggestions have been considered in this [trap oxidizer] program, however only one system concept was used to estimate lead time requirements....Lead time is estimated to be approximately 50 months from system design selection. Based on the current program status, this would indicate a possibility of 1985 model year introduction."

General Motors (public hearing) -- "Judging by our development results to date, [a trap oxidizer] could not be available by the 1983 model year as postulated by EPA. Durable material and system developments are needed plus an estimated 2 1/2 to 3 years production leadtime after an acceptable method is defined."

Analysis

When the NPRM was being prepared, our best estimate was that trap oxidizers would be available for the 1983 model year. That assessment has been reevaluated in view of the input received from the commenters with regards to the state-of-the-art of trap oxidizer technology.

As was concluded in the control technology section on trap oxidizers, 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, we have concluded 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 lead time. 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 years, while Daimler-Benz estimated 3 years (for major engine modifications in general). 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 lead time would be required "after an acceptable method is defined", while in its written comment GM claimed it needed 50 months from "system design selection." In response to questions about lead time 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 lead time 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 lead time that we expect to be necessary, we conclude that trap oxidizers will be feasible on production vehicles within 4 years. Starting from mid-1979 then, trap oxidizers can be integrated into production by mid-1983, or in time for the 1984 model year.

Thus, we agree with the majority of the commenters that it is not likely that trap oxidizers will be integrated into production vehicles by the 1983 model year. However, we forecast that with an aggressive, good faith effort on the part of the manufacturers, trap oxidizers can be utilized on production vehicles by the 1984 model year.

D. Recommendation

The 1981 standards should be based on readily available technology. Turbochargers will not be universally available until the 1983 model year. Trap oxidizers probably will not be universally available prior to the 1984 model year. Any standard based on successful utilization of trap oxidizer technology should be delayed to the 1984 model year.

IV. Standards

A. Basis and Nature of Standards

EPA based the levels of the proposed standards on the lowest particulate levels achievable by the worst light-duty diesel with respect to particulate emissions. This approach assumes that at least some manufacturers would be required to utilize the best available control technology.

Comments

Chrysler -- "The EPA did not follow its own declared procedure based on reasonableness for setting the particulate standards.... The subsequent analysis not only disregards production variation and degradation factors but presumes a modified Oldsmobile 'with EGR and redesigned chamber and nozzles'....If they had followed their stated procedure, the 1981 MY particulate standard would be at least 1.02 grams per mile (from the Olds 260 CID)."

Council on Wage and Price Stability -- "The proposed diesel particulate standards represent an effort at 'technology forcing' by EPA. We recognize EPA's legitimate concern in this area. Since particulate emissions represent a genuine negative externality, it is unlikely the vehicle buyers would voluntarily buy control devices, and therefore it is unlikely that manufacturers would voluntarily provide them. Further, in the absence of some kind of government action, the manufacturers would have little incentive to develop new and improved technology in this area. But, just as there are drawbacks to too little technology forcing, there are also dangers in trying to force technology too hard. The rush to meet stringent standards under short deadlines may produce high cost, inefficient technological solutions, whereas a less rushed development might lead to lower cost technologies....Alternatively, if the standards are considered to be unachievable, development and spread of the technology may be delayed; given the long lead times and large financial sums involved in the automobile industry, producers are unlikely to commit substantial resources to a technology that may not meet a future set of standards. Yet another alternative is that there will be last minute delays in the imposition of the standards, with heightened costly uncertainties for all parties concerned."

Natural Resources Defense Council -- "In rejecting the option to base the standard on the lowest particulate level achievable by the best light-duty diesel with respect to particulate emissions, EPA gave the explanation that 'it would have prevented all diesels from meeting the standard except subcompacts and small pick-ups equipped with small engines.' EPA does not support this statement nor elaborate upon it. Therefore, we do not see why, given the lead-time, manufacturers will not be able to meet a tighter standard for model year 1983. In any case, the question of whether a standard should be set so that all manufacturers can meet it should be not determinative. In International Harvester Company v. Ruckelshaus, 478 F.2d 615,640 (1973), the Court agreed that an emission standard should be technology-forcing and further stated: 'We are inclined to agree with the Administrator that as long as feasible technology permits the demand for new passenger automobiles to be generally met, the basic requirements of the Act would be satisfied, even though this might occasion fewer models and a more limited choice of engine types.'"

Congressman Andrew Maguire -- "The [1977 Clean Air Act] passed by Congress embodied two very important precepts as its cornerstones. First that the primary purpose of the act was to protect the public health and second that in so doing, it was deemed appropriate in some cases to require the use of the best available technology to control pollution. EPA has used that requirement to set the standards.... [The manufacturers] have always had to be pushed, they have always been behind other manufacturers in the rest of the world on emission control, on safety, on fuel efficiency. It's just an unfortunate fact that the historical record shows they have to be brought kicking and screaming along with the responsibilities that they ought to discharge to the larger public interest."

Analysis

The statutory authority for the diesel particulate regulations is found in Section 202(a)(3)(A)(iii) of the Clean Air Act, which provides 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."

We agree with Congressman Maguire and the Council on Wage and Price Stability (CWPS) that this section mandates best available control technology and, accordingly, technology forcing standards. Otherwise it is very unlikely that the "greatest degree of emission reduction achievable" mandate would be met. The CWPS claim that we may be forcing technology "too hard" is certainly a valid concern. And because of the limited leadtime available for the 1981 model year the 1981 standard should be based on technology that is already readily available. We have already analyzed the leadtime requirements for trap oxidizers and have concluded that another entire year is necessary for successful application of this technology. We are confident that we are not forcing any control technology too hard or too quickly.

In its comment Chrysler claims that the 1981 standard should be "at least 1.02" g/mi (0.63 g/km). This appears to be based on the argument that the 1981 standard should be set at the highest particulate level that EPA found in its baseline testing of 1979 certification vehicles. This line of reasoning is clearly in conflict with the letter and spirit of the Clean Air Act quoted above, and ignores the reality that significant particulate emission reductions have been achieved since the 1979 certification vehicles were designed (presumably late 1977). In effect, Chrysler's reasoning would "freeze" the particulate standard forever at 1.02 g/mi (0.63 g/km). It should also be noted that the 1.02 g/mi (0.63 g/km) figure was the highest particulate level EPA recorded for the Oldsmobile 260 engine but was not the only value; EPA recorded levels as low as 0.73 g/mi (0.45 g/km) as well.

The Natural Resources Defense Council (NRDC) argues that EPA has the statutory authority to set standards based on the lowest particulate level achievable by the best light-duty diesel vehicle. Thus, we could set standards that would force some diesel models out of production. Reading Section 202(a)(3)(A)(iii) above in full, with its emphasis on the leadtime necessary for compliance, and on energy and safety factors, leads us to dismiss this argument.

B. Particulate/NOx Relationship

The proposed standards were set under the assumption that the 1981 statutory NOx standard of 1.0 g/mi (0.62 g/km) would not be waived for any diesel manufacturer. EPA recognized that current NOx control techniques, such as exhaust gas recirculation, tend to increase particulate emissions.

Comments

Fiat -- "[T]he most effective ways [to reduce NOx emissions], i.e., exhaust gas recirculation or retarding injection timing in connection with the oxidation catalyst, decrease NOx while they increase particulates....[A]ny future solution for decreasing NOx will compromise 0.6 gpm particulate emission standards proposed by EPA. In other words at present a correct approach to particulate limitation must take into account an acceptable level of NOx."

Ford -- "We believe it is also unreasonable to rely on particulate emission data obtained from vehicles designed to meet a 2.0 gpm NOx standard as being indicative of the particulate control which can be achieved with vehicles which must also meet a 1.0 gpm NOx standard."

General Motors -- "The use of EGR has always resulted in a particulate emission increase, and this penalty becomes more severe as additional EGR is required to lower NOx levels....Full-size cars appear to have a double disadvantage in this particulate-NOx trade off. Full-sized vehicle NOx emissions require the largest percent reduction, and, in addition, the full-sized cars show the highest particulate penalties for a given NOx reduction."

Congressman Dale E. Kildee -- "While I recognize that no application for a waiver of the NOx standard has been made yet, I am also disturbed by what appears to be a prejudgment on the question of a waiver of the NOx standard. This question of whether a waiver of the NOx standard will be sought or granted is essential to the whole issue involved in this rulemaking....In examining the proposed regulations and rulemaking support paper, I am left with the impression that the Environmental Protection Agency has prejudged the issue. If so, this would seem to indicate disregard for congressional intent and the existing law."

Analysis

EPA has recognized throughout this rulemaking that many of the technologies currently available to reduce NOx emissions tend to increase particulate emissions. Although we based our proposed standards on the assumption that no NOx waiver would be granted, we did so not, as Congressman Kildee suggests, because we had prejudged the issue; rather, we did so because we felt it was necessary to base our analysis on a worst-case scenario for particulate emissions. To have done otherwise, i.e., to have assumed a NOx waiver when it might not actually be granted, might have led us to propose more stringent particulate standards than we did. Thus our position was based on fairness to the manufacturers.

Data received from the industry in both this rulemaking and the NOx waiver public hearings 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 a more difficult technical problem than particulate control. Thus, the optimum position is to promulgate the most stringent particulate levels feasible within NOx constraints of 1.5 g/mi (0.93 g/km) in 1981 and 1.0 g/mi (0.62 g/km) in 1984, and then resolve the NOx waiver issue based on the constraint provided by the particulate standards.

C. Deterioration Factor

Comments

Peugeot -- "To establish the levels of the particulate standards, the EPA has considered that no major deterioration of the levels of the particulates will occur during the useful life of the vehicle.... For this assumption, the EPA's judgment was in particular based upon the fact that 'particulates and hydrocarbon emissions follow each other directionally when changes are made in a given engine'. We believe that an inverse phenomenon may happen under certain conditions. As far as the deterioration factor is concerned, we are lacking mileage accumulation results, however, we have measured on a diesel 504 a level of particulates of 0.62 gram per mile at about 100,000 miles. Taking into account the estimated production variation it may be supposed that the deterioration factor, for this particulate case, is between 1.15 and 1.72. This result allows to assume that the deterioration factor cannot be considered as negligible even for a 50,000 miles durability."

General Motors -- "Emission development targets must be established with consideration of deterioration factors....[T]he available particulate data on emission tests are inadequate for accurate determination of particulate deterioration factors. The limited data indicate generally positive factors ranging from 1.2 to 1.4."

Analysis

Unfortunately, we received very little data on the effect of mileage accumulation on particulate emission levels. Our original assumption of a negligible deterioration factor was based on the low HC deterioration factors of 1978 certification diesel vehicles and on the well known stable nature of the compression ignition engine. The stability of the diesel engine with respect to HC emissions is reaffirmed by the 1979 certification data; the average HC deterioration factor was 1.06 (assuming all deterioration factors less than 1.0 to be 1.0).

We cannot refute Peugeot's comment that HC and particulate emissions sometimes have an inverse relationship, but we must point out that this is an atypical claim. It must also be noted that the data upon which Peugeot relies for this statement shows particulate to drop only slightly while HC emissions rise sharply with retarded timing. While HC deterioration factors are not perfect indicators of particulate deterioration factors, they are one gauge we have to predict particulate deterioration factors. Based on the very low diesel HC deterioration factors that have been observed, we expect particulate deterioration factors to be very close to unity.

We did receive a small amount of particulate data on vehicles which had accumulated mileage. Peugeot reported that one of their 504D vehicles emitted 0.62 g/mi (0.39 g/km) particulate at approximately 100,000 miles. Their own measurements have shown the 504D to emit between 0.36 and 0.59 g/mi (0.22 and 0.37 g/km) at low mileage, thus this vehicle is estimated to have had a deterioration factor of between 1.05 and 1.72 (rather than the range of 1.15 to

1.72 that Peugeot quoted) over 100,000 miles or between 1.03 and 1.36 over 50,000 miles. It must be emphasized that while certification deterioration factors are based on a least-squares regression of data taken at low mileage, at 50,000 miles, and at regular intervals in between, the only particulate measurement made on this vehicle was at 100,000 miles. Thus no data are available for this vehicle which would actually be used in the calculation of the deterioration factor, and we have little confidence in the estimated range.

General Motors reported limited particulate durability emissions data. They calculated particulate deterioration factors for four cars, shown in Table IV-1.

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 except 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 limited mileage accumulation in GM's NOx Waiver Request submitted to EPA in May, 1979. 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.

The foregoing analysis of GM's own durability data indicates that there is no basis for assuming that deterioration factors for particulate emissions will be in the range of 1.2 to 1.4. Rather, GM's data, along with the low diesel HC deterioration factors and the stable nature of the compression ignition engine, indicate that particulate deterioration factors will be very low, most likely in the 1.0 to 1.1 range.

D. Design Targets

Comments

Peugeot -- "If taking into account the today 504 Diesel the results made at Peugeot facilities on some vehicles with low mileage, set

Table IV-1

GM Particulate Deterioration Factors

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

the dispersion range at 0.36/0.59 gram per mile. Results recorded by the EPA on such a model varies according to our knowledge, from 0.29 gram per mile to 0.50 gram per mile. If we take into consideration all these results on a limited number of vehicles the mass production variation is probably higher than 50% (±25%) of the average measured value."

General Motors -- "Emission development targets must be established with consideration of...engine-to-engine variability and repeatability of emission measurements on individual vehicles." GM estimated their car-to-car variability to be ±30% with respect to particulate emissions.

Volkswagen -- "It is our impression that EPA has not considered the absolutely necessary safety margin between any standard and the certification level....Traditionally, the safety margin has been 40 to 50 percent in order to account for prototype-to-production slippage, statistical spreads and systematic measurement deviations."

Analysis

We understand the necessity of designing research prototype vehicles to an emission level below that of the standard which production vehicles must ultimately comply with. But, the safety margins claimed to be necessary by the manufacturers are overstated.

There will be a certain "slippage" between the particulate levels achieved by research prototype vehicles and the levels a manufacturer could confidently expect to meet with certification vehicles. Based on our experience with the certification process, and absent any data with regard to particulate emissions, this slippage should be small, likely on the order of 10 percent.

The manufacturers' concerns over production car-to-car variability are misplaced, however. Although there no doubt will be production variability with respect to particulate emissions, the statistical sampling program used in Selective Enforcement Auditing (SEA) accommodates such variability.

Test-to-test variability, which can be considered a part of car-to-car variability, also does not seem to be a major problem. EPA has found diesel particulate test-to-test variability to be less than 5 percent and GM has reported similar results. We expect this variability to improve even more in the future as the industry accumulates more experience with the test procedure.

E. Proposed 1981 Standard

EPA proposed a standard of 0.60 g/mi (0.37 g/km) beginning with the 1981 model year for all light-duty diesel vehicles.

Comments

Peugeot -- "It is Peugeot's point of view that to meet 0.6 gpm particulates level, the NOx standard should be relaxed to 1.5 gpm."

Council on Wage and Price Stability -- "We recommend that the 1981 standard be promulgated only if EPA is prepared to grant the appropriate waivers for nitrogen oxide emissions in 1981-1984."

Daimler-Benz -- "At a 1.5 NOx standard, Daimler-Benz believes that there is a reasonable chance that a particulate matter standard of 0.6 for model year 1981 can be achieved and maintained for 50,000 miles."

Fiat -- "If EPA were to waive the 1981 Federal NOx standard of 1.0 gpm, raising it to at least 1.5 gpm, the manufacturers could concentrate their effort to try, with a probability of success, to obtain reductions of particulates equivalent to the 0.6 gpm standard."

Ford -- "EPA should promptly promulgate a 1981 and subsequent model year particulate standard which represents the greatest control achievable without use of control devices or technologies whose effect on unregulated pollutants is yet to be investigated. In the case of passenger cars, we believe this level to be approximately 1 gpm."

General Motors -- ""[T]he technically achievable standard for 1981 would be 1.0 gpm particulates based upon receiving a waiver to 1.5 gpm NOx."

Volvo -- "Volvo believes that the granting of a waiver...to 1.5 gpm NOx will be essential [along with a] particulate standard of 1.0 gpm in 1981."

Chrysler -- "Chrysler suggests that the standard be set at 1.0 gpm for 1981."

Volkswagen -- "[A]ssuming that EPA grants our NOx waiver request, a reasonable schedule for meeting a 0.6 gpm particulate standard would be model year 1982."

Department of Energy -- "A particulate standard higher than 0.8 gpm will be required for the 1981 model year....With a 1.5 gpm NOx waiver, a 0.6 gpm particulate emission level is technically achievable by 1982."

Analysis

As discussed earlier, we no longer consider turbochargers to be universally available for the 1981 model year. Despite the fact that it has been shown that turbochargers can substantially reduce particulate emission levels, we cannot rely on them as a basis for the 1981 standard. Nevertheless, the industry should be able to comply with a final standard of 0.6 g/mi (0.37 g/km) particulate in 1981. Our position is based on three points. First, as has already been discussed, the manufacturers have made much more progress in reducing particulate emissions through engine modifications than EPA had projected. Second, we now consider it appropriate to determine the most stringent particulate level achievable within the 1.0 to 1.5 g/mi (0.62 to 0.93 g/km) NOx framework, rather than being constrained by the 1.0 g/mi (0.62 g/km) no-waiver scenario. Finally, and most importantly, the manufacturer's own data show that they can comply with a 0.6 g/mi (0.37 g/km) particulate standard at a NOx level of 1.5 g/mi (0.93 g/km) or less. Table IV-2 summarizes the most promising data received from each of the manufacturers who reported particulate/NOx data from their own research programs.

As the comments indicated, Mercedes, Peugeot, and Fiat all believe that it is quite probable that they can meet 0.6 g/mi (0.37 g/km) particulate at a NOx level of 1.5 g/mi (0.93 g/km). Their data in Table IV-2 supports their positions. Thus, these manufacturers' positions need no further analysis.

Volkswagen has admitted that their two most popular models, the Rabbit and the Dasher, would have no problem meeting the 0.6 g/mi (0.37 g/km) standard. They claim that their Audi 5000D cannot meet 0.6 g/mi (0.37 g/km) until the 1982 model year. As Table IV-2 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 0.6 g/mi (0.37 g/km) particulate and 1.5 g/mi (0.93 g/km) NOx 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 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-3 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 ve-

Table IV-2

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							
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							
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							
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	2.4	3,000	0.53	0.33	1.19	0.74	Prototype w/EGR, TC
General Motors							
"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-3

EPA/Volkswagen Particulate Measurement Comparisons

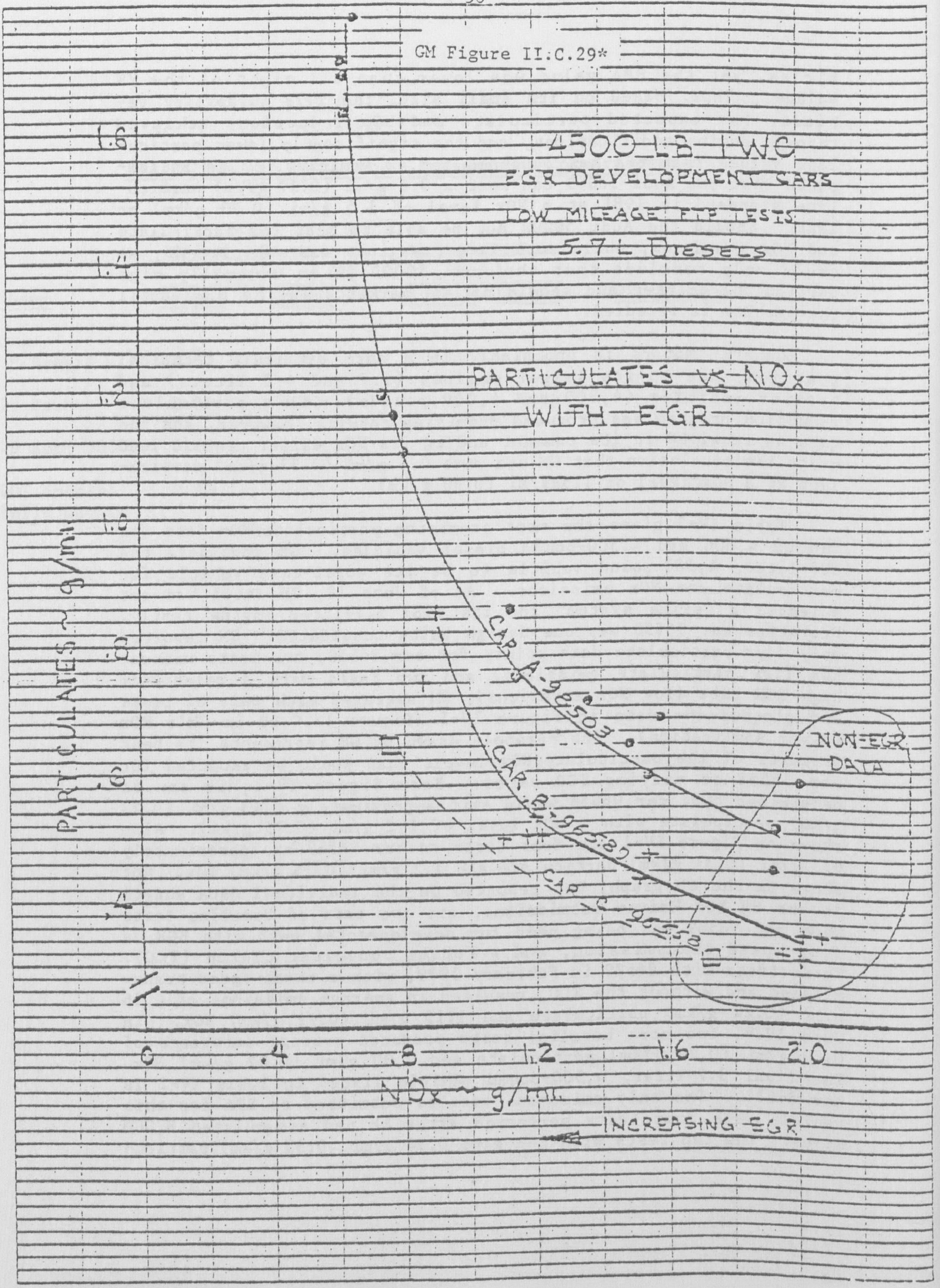
Model	EPA Particulate Result		VW Particulate Result		Difference
	(g/mi)	(g/km)	(g/mi)	(g/km)	
79 Rabbit	0.23	0.14	0.33	0.21	+ 43%
79 Dasher	0.32	0.20	0.42	0.26	+ 31%
79 Audi 5000D	0.46	0.29	0.65	0.40	+ 41%
DOT Special Build Rabbit	0.20	0.12	0.25	0.16	+ 25%

hicles, 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 can meet a 0.6 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. Should the Audi 5000D not be able to meet the particulate and NOx standards, while much larger engines and vehicles do, we could only conclude that the Audi 5000D is an unusually high particulate emitter and should not be marketed in the U.S. until the problem is remedied.

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 can meet 0.6 g/mi (0.37 g/km) particulate at a NOx level of 1.5 g/mi (0.93 g/km).

Table IV-2 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. 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 data sheets in the GM NOx Waiver submissions, are two sets of baseline tests when car 96589 was being used for developmental work with EGR, a four-speed transmission, and a torque converter clutch (TCC). Three tests with 96589 in February 1979, with a three-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-2 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) particu-

FIGURE IV-1



GM Figure II.C.29*

*From General Motors Application for Waiver of the 1981-1984 NOx Emission Standards for Light-Duty Diesel Engines, May 1979 late 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 can meet the 0.6 g/mi (0.37 g/km) particulate standard in 1981, taking into account the necessary safety margin for prototype-to-production slippage, variability, and deterioration factor. 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.

Data from four 4.3-liter, 4,000-pound GM diesel prototypes are also shown in Table IV-2. Three of the four prototypes were of the very same design, with car 93514 "a slightly different technology." 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 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 can meet the 0.6 g/mi (0.37 g/km) particulate standard in 1981.

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."

It is not clear what GM meant by this statement, but it does lend credence to our conclusion that GM can meet 0.6 g/mi (0.37 g/km) particulate in 1981.

Neither International, Ford, Chrysler, Volvo, BMW, AMC, nor Toyota reported any original data on their own diesel engines. International is the only one of these manufacturers currently marketing a light-duty diesel in the U.S.; its a light-duty truck and will be considered later in this section.

In summary, we conclude that every light-duty diesel manufacturer can meet a 1981 particulate standard of 0.6 g/mi (0.37 g/km) at NOx levels of 1.5 g/mi (0.93 g/km) or less, utilizing readily available control technology.

F. Proposed 1983 Standard

EPA proposed a standard of 0.20 g/mi (0.12 g/km) beginning with the 1983 model year for all light-duty diesel vehicles.

Comments

Department of Energy -- "EPA should not set a more stringent standard requiring aftertreatment control devices until basic questions concerning the effectiveness, safety, and durability of aftertreatment devices are answered....Emission levels of 0.5 gpm particulate and 1.3 gpm NOx represent realistic goals for 1983.... Research goals of 0.3 gpm particulate and 1.0 gpm NOx for 1985 should be established."

Volkswagen -- "[W]e recommend that a decision to set a standard requiring a trap oxidizer be postponed until 1980 or 1981.... [A]n ultimate standard of 0.4 gpm could be met not sooner than model year 1985."

Natural Resources Defense Council -- "[W]e do not see why, given the leadtime, manufacturers will not be able to meet a tighter standard for model year 1983."

Peugeot -- "[W]e propose the postponement of this stringent 1983 particulate standard until it is demonstrated that the exhaust post treatment in view to reduce the particulates, is feasible in production."

Toyota -- "Set a standard for 1983 and subsequent model years of 0.8 gpm particulates. Delay the decision of whether or not to set a more stringent standard to the time when the need for such becomes evident and the technology to meet a lower particulate emissions level simultaneously with the 1.0 gpm NOx requirement is available."

Department of Commerce --"We question the plan for more stringent standards in 1983....[N]ew engineering developments will enable a stricter standard to be met by the middle or late 1980s."

Council on Wage and Price Stability -- "[T]he 1983 standard may be overly stringent....Since the National Ambient Air Quality Standard for particulates is currently under review, since the carcinogenic properties of diesel particulates are still uncertain, and since the proper role of adjustments in the composition of diesel fuel to control particulates is still unclear, this does not appear to be the proper time to be promulgating a very stringent standard for 1983."

Volvo -- "Particulate standard of...0.4 gpm in 1985 [is] proposed as the lowest feasible level."

General Motors -- "Our goal would be to reduce particulate levels by over 50% by 1985 [to 0.5 gpm], while at the same time reducing NOx to a 1.0 gpm standard....Any lower standard will most probably eliminate diesels from heavier vehicles."

Daimler-Benz -- "At a 1.5 NOx standard Daimler-Benz believes that it is not possible to achieve the proposed 0.2 gpm particulate matter standard for 1983."

Analysis

EPA has consistently maintained that a 0.2 g/mi (0.12 g/km) particulate standard could be universally met only by the utilization of trap oxidizers with approximately 67 percent efficiency over the lifetime of the vehicle. Since we have concluded elsewhere in this analysis that successful trap oxidizer application is not expected prior to the 1984 model year, the 0.2 g/mi (0.12 g/km) standard should be delayed for one year until 1984.

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 0.2 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. It is true that at this time the primary NOx control technique, EGR, significantly increases particulate emissions. But EPA is convinced that as the EGR/particulate 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 developed which will not necessarily increase particulate emissions; it is certainly plausible that a NOx control technique might reduce particulate emissions.

EPA's technical staff also expects additional particulate reductions in the 1981 to 1985 time frame other than that due to the trap oxidizer. As concluded earlier, it is extremely unlikely that the many engine parameters that can affect particulate emissions have all been discovered and optimized in the two years since particulate control development work began. Should additional manufacturers decide to turbocharge their engines, it would enable them to utilize smaller engines with reduced particulate levels, while retaining comparable performance. Finally, with the Corporate Average Fuel Economy standards increasing annually until 1985, and with other emission standards decreasing, EPA expects that many manufacturers will continue to downsize their vehicles in order to comply with the impending regulations. All these factors should contribute to lower particulate levels by 1985, and EPA has determined that all diesel models will be able to comply with 0.2 g/mi (0.12 g/km) particulate and 1.0 g/mi (0.62 g/km) NOx standards by 1985.

We cannot accept the recommendations of those commenters who held that any more stringent standard (than the 1981 standard) should await further research, or of those who recommended a much lower or much-delayed "second step" standard. As was thoroughly discussed in section A, the Clean Air Act mandated "the greatest degree of emission reduction achievable" which implies use of the best available control technology. Past experience has shown that only through the application of technology forcing standards will that mandated particulate reduction occur. In the previous two sections, we analyzed trap oxidizer development and concluded that trap oxidizers could be available for the 1984 model year. Should the industry aggressively pursue trap oxidizer development, but fail, it would be possible for the industry to petition EPA for a possible relaxation of the standards.

G. Light-Duty Trucks

EPA's position in the NPRM was that diesel-powered light-duty trucks (LDTs) should be required to meet the same particulate emission level as diesel-powered light-duty vehicles (LDVs). EPA believed that if one category of vehicles was regulated more stringently than another, with both categories using the same diesel engine, this would create a bias in favor of the less stringently regulated vehicles.

Comments

General Motors -- "Only a limited amount of emission data currently exists relating to vehicles heavier than 4,500-pounds inertia weight. The following are FTP data obtained from two cars, both tested at three different inertia weights and all at 14 hp. The first car shown was a 1980 preproduction vehicle with modified injection timing.

Particulates

Inertia Weight	3,500	4,500	5,500
Vehicle Number			
89589	.30	.35	.46
78504	.65	.71	.81

Emission data for the Oldsmobile 350 installed in heavier trucks is also fragmentary at this time; however, the following data was obtained for one vehicle of 8,500 pounds GVW and tested at 20 hp.

Inertia Weight	Particulates
5,000 pounds	.58
5,500 pounds	.76

These data again demonstrate the relationship of particulates to inertia weight."

International Harvester -- "I.H. vehemently objects to the Administrator's classification of trucks over 6,000 pounds as light-duty vehicles for the purpose of establishing one common standard for particulate control. This classification is erroneous and contrary to the intent of Congress. It is also obvious from a review of the Clean Air Act Amendments that Congress desired to treat light-duty vehicles and heavy-duty vehicles differently. EPA's own regulations, as well as NHTSA's, account for this difference by establishing different roadload horsepower (RLHP) and inertia weight (IW) requirements as well as the application of separate exhaust emissions and fuel economy standards....In promulgating regulations concerning trucks between 6,000-8,500 pounds, the Administrator has no alternative other than to follow the parameters set forth by Congress for heavy-duty vehicles, including the promulgation of a non-conformance penalty."

Daimler-Benz -- "Daimler-Benz undertook a series of additional tests which indicate that EPA should give more consideration than it has up to now to the impact the inertia weight of a vehicle has on particulate matter and NOx emissions....A 300D vehicle with a naturally aspirated engine which represented an NOx concept of 1.5 gpm was tested under various inertia weight settings....[C]oncerning NOx emissions, a clear and distinct increase was found each time inertia weight and roadload settings were increased...concerning particulate matter emissions, increases in inertia weight settings resulted in substantial increases in particulate emissions."

Chrysler -- "EPA states that increased inertia weight in diesel tests does not increase particulate emissions. Chrysler data refutes this point. Chrysler has found that increasing inertia weight from 2,500 to 4,500 pounds causes diesel particulate emissions to increase by approximately 33%. Assuming this trend continues to 8,500 pounds, it will be considerably more difficult for trucks than it is for cars to meet the proposed particulate emissions standards."

Council on Wage and Price Stability -- "[I]t is clear that larger vehicles require larger engines (especially if the vehicles are expected to carry heavy loads) and that the larger engines generally emit more particulates and have more difficulty in achieving any given standard. For example, for the 11 diesel vehicles whose emissions are reported in the Preamble to the NPRM, the simple correlation coefficient between particulate emissions and cubic inches of displacement is + 0.72. Since light-duty trucks have load-carrying roles to play and since they require bigger engines, they should have a separate standard. The only offsetting factor is that, for 1981 and 1982, light-duty trucks will have less stringent NOx standards of 2.3 g/mi, which should make particulate control less difficult. The NOx standard may be tightened in 1983."

Analysis

The LDT particulate standards proposed in the NPRM were the same as those proposed for LDVs. Absolute technical justification for a separate LDT standard was not available when the NPRM was published. Data which EPA had were contradictory and inconclusive.

In the comments we received some data on the effects of inertia weight and road load considerations on LDT diesel particulate emissions. All 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 slight effect of road load on particulate emissions. At most, the higher road load settings of LDTs 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 an 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 (IW) to represent the heaviest "typical" LDV test IW to 6,500 pounds IW which represented the heaviest "typical" LDT test IW. 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:

FIGURE IV-2

PARTICULATE EMISSIONS AS A FUNCTION OF ROADLOAD

FTP DRIVING CYCLE

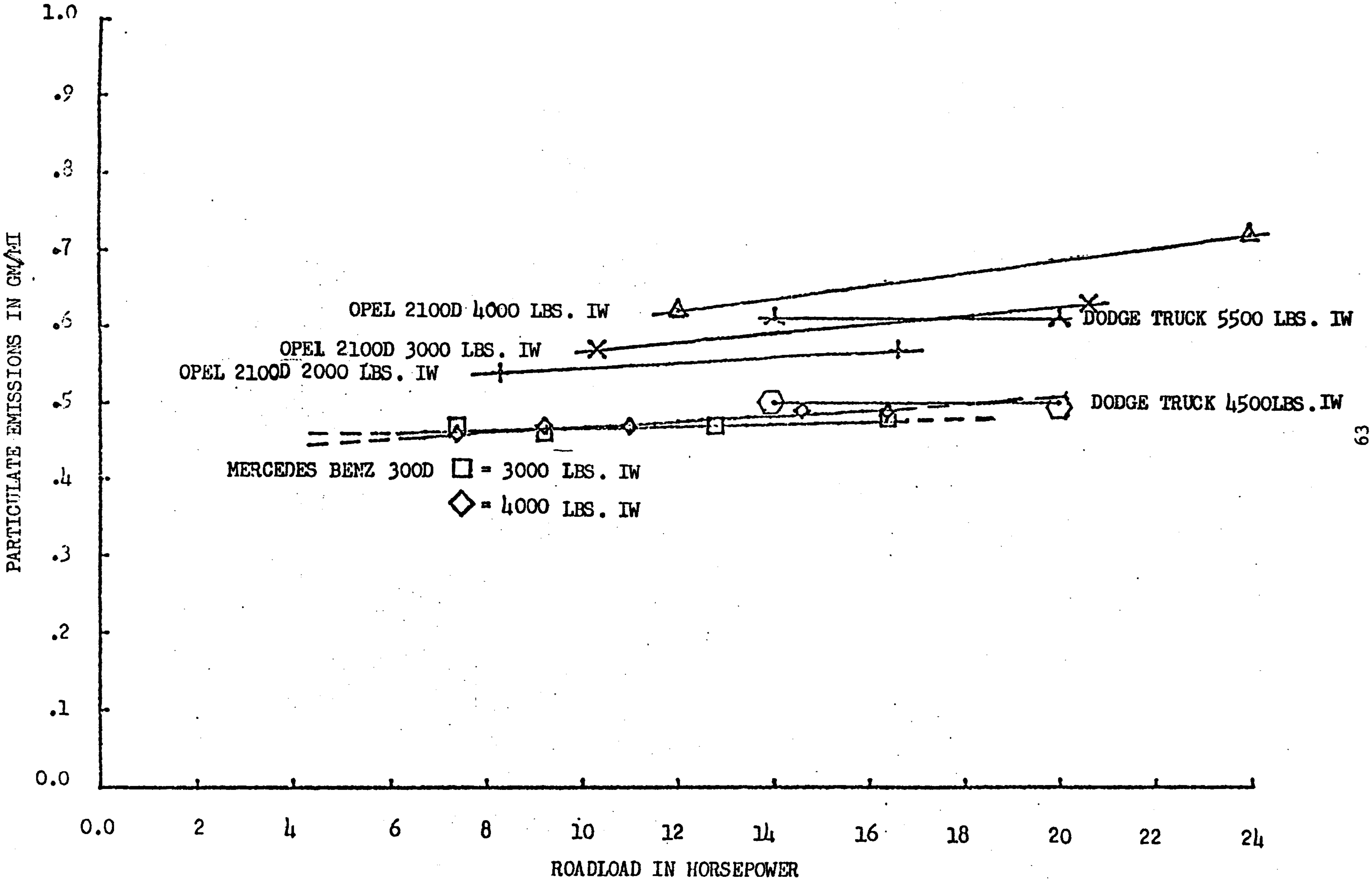
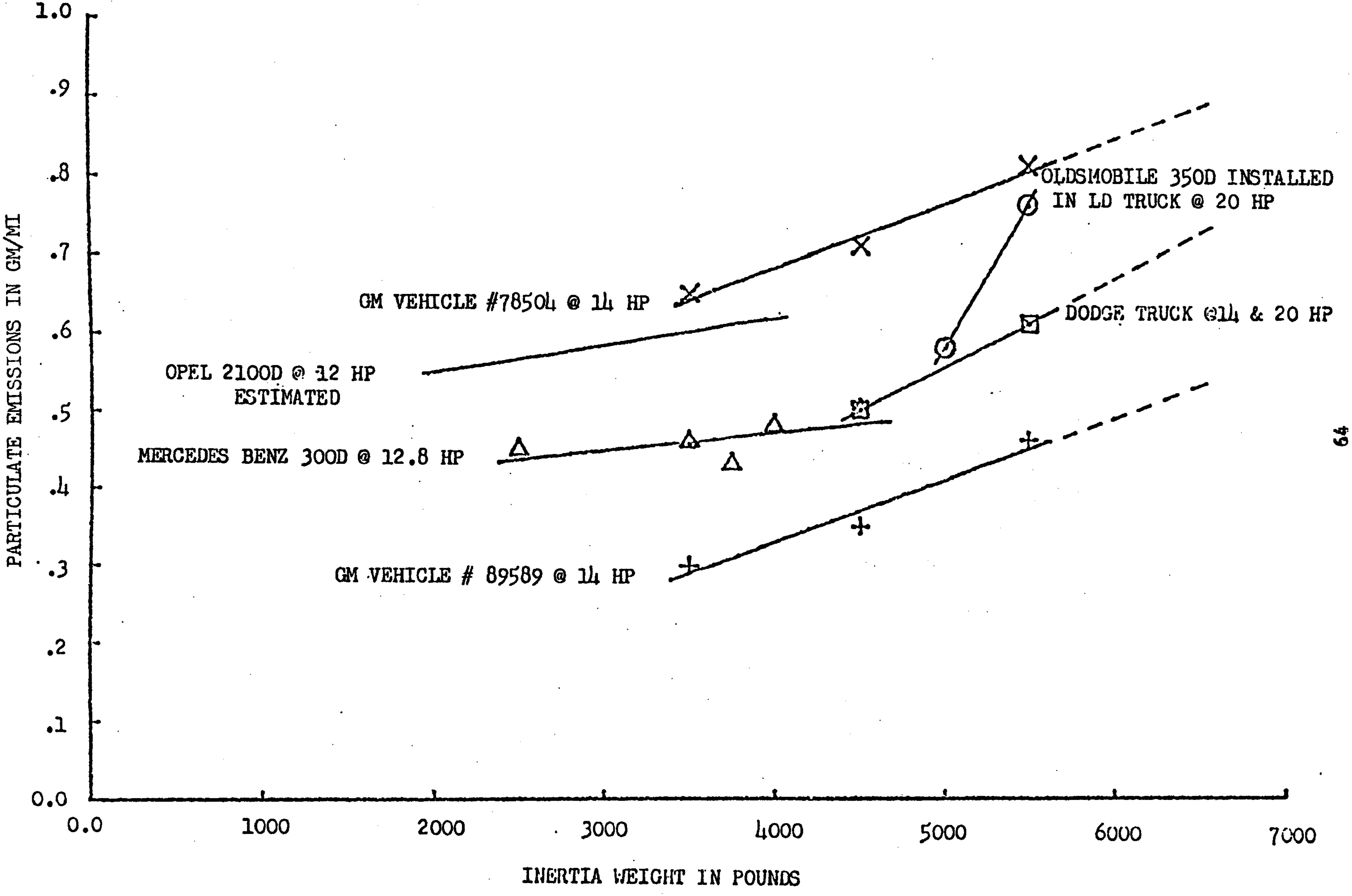


FIGURE IV-3

PARTICULATE EMISSIONS AS A FUNCTION OF INERTIA WEIGHT

FTP DRIVING CYCLE



Vehicle	Increase in Particulate From 5,500 pounds IW to 6,500 pounds IW
GM #89589	19%
GM #78504	10%
Dodge Truck	18%
Average	16%

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

Vehicle	Increase in Particulate From 4,500 pounds IW to 5,500 pounds 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 the Chrysler comment in which Chrysler claimed there was an approximate 17% increase in particulate emissions for a 1,000 pounds IW increase (or 33% for a 2,000 pound IW 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. Further, GM labeled this data as "fragmentary." 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, we would recommend diesel particulate standards for LDTs which would be 20 percent greater than the LDV diesel particulate standards.

As the CWPS pointed out, however, 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 decision, 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 1981 to 1984. Not only does this much larger NOx level account for the greater NOx emissions (likely approximately 20 to 30 percent) that would be expected from LDTs, but because of the relationship between NOx and particulate emissions, it also can allow for the 20 percent higher particulate emissions that would otherwise be expected due to the greater inertia weights of LDTs. For example, it is unlikely that any diesel LDT would need much 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 heavy 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) particulate standard in model years 1981 to 1983.

Two factors change this situation in 1985. First, as a result of the statutory requirement for a 75 percent NOx reduction from HDVs, 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. Secondly, 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 percent particulate cushion for LDTs. Thus, we recommend that the 1984 LDT particulate standard be 30 percent greater than the 1984 LDV particulate standard and set at 0.26 g/mi (0.16 g/km). Because the NOx LDV/LDT discrepancy will still be in effect in 1984, it would be possible to set the 1984 LDT particulate standard at 0.20 g/mi (0.12 g/km) and raise it to 0.26 g/mi (0.16 g/km) in 1985. But for simplicity, we recommend the 0.26 g/mi (0.16 g/km) standard be promulgated for 1984 and later model years.

Thus, we recommend that LDT diesel particulate standards be set at 0.60 g/mi (0.37 g/km) in 1981 and 0.26 g/mi (0.16 g/km) in 1984.

H. Additional Standard

Comments

Citizens for Clean Air -- "We question whether an ultimate standard of 0.2 gpm will adequately protect public health in subsequent years when diesel powered light-duty vehicles could become a significant fraction of the national fleet....The Agency [should] establish a target particulate emission standard of 0.1 gpm to take effect by 1990."

Natural Resources Defense Council -- "NRDC recommends that an additional target particulate emission standard be adopted for model year 1990. [S]uch a standard is necessary in order to protect public health and the environment from emissions arising from a growing diesel-powered vehicle fleet."

Analysis

Both of the commenters support a "third-step" diesel particulate standard in 1990. EPA does not rule out such a possibility. But there is no justification for setting a standard eleven years in advance when it is likely that in the interim research will justify either a more or a less stringent standard than the one that could be suggested at this time. It is well known that EPA is presently carrying out a comprehensive diesel health effects research program. Having maximized the protection of the environment and public health within the Clean Air Act mandate, any more stringent particulate standard will have to be justified either by results of research showing that diesel particulate is a more significant health threat than just as a contributor to total suspended particulate emissions or by a finding that the more stringent standard is technologically feasible. Neither of these justifications is possible at this time.

I. Recommendation

Based on the preceding analyses, EPA should promulgate a final diesel particulate standard of 0.60 g/mi (0.37 g/km) in 1981 for light-duty vehicles and light-duty trucks. For 1984, EPA should promulgate final standards of 0.20 g/mi (0.12 g/km) for light-duty vehicles and 0.26 g/mi (0.16 g/km) for light-duty trucks.

V. Economic Impact

All comments dealing with costs, economic methods, or cost-effectiveness will be considered in this section.

A. Trap-Oxidizer

Comments

BMW -- estimated ("very approximately due to their lack of experience in the area") that a trap-oxidizer would cost $350.

Chrysler -- claimed that EPA had underestimated the cost of a trap-oxidizer.

General Motors -- estimated that a trap-oxidizer would cost $470-610 depending on the size of the engine. They also stated that: (1) EPA had failed to account for the cost of thermocouples, sensors, a throttle body and actuator, and mounting provisions, (2) the muffler would still be needed, (3) the electronic control unit would cost twice EPA's estimate, and (4) two traps would be needed for their largest engines.

Analysis

EPA estimated the average cost of a trap-oxidizer to be $114-$157 (1978 dollars). This cost included $70-86 for the trap itself, $24-51 for port liners and an insulated exhaust pipe and $58 for electronic oxidation control. A $15 credit was taken because the need for either the muffler or resonator could be eliminated. Also, it was believed that the exhaust gas recirculation systems used to meet the 1981 NOx standard would also require the electronic control unit ($45) which was included in the electronic oxidation control above. Thus, the cost of the unit was split between particulate and NOx control. Last, the assumed production was 820,000 (V-8), 300,000 (V-6), and 500,000 (I-4).

Before addressing the manufacturers' specific comments, the original EPA cost estimates will be revised using: 1) updated production estimates, 2) a more detailed cost methodology, and 3) revised projections of the necessary hardware items comprising a trap-oxidizer system. If manufacturers' comments address any of the specific items contained in these revisions they will be considered at that time. Otherwise, these comments will be considered after EPA's cost estimates have been revised.

Because the costs of trap-oxidizers will depend on the production volume expected, it will be necessary to make adjustments to the above assumed production figures before calculating the cost of each item in the system. The first step in this analysis will be to estimate light-duty diesel production volumes between 1984 and

1988. This five-year period was chosen because it will correspond with the period used to calculate the aggregate cost of the 1984 standard, which will be performed in the Regulatory Analysis.

Both the overall light-duty diesel production and the breakdown by manufacturer is needed. These can be found in Section I, Environmental Impact, in the discussion of diesel sales. Tables V-1 and V-2 show the breakdown of new light-duty vehicle and truck sales by manufacturer for 1978. These two tables are combined in Table V-3 to yield a breakdown of combined light-duty vehicle and light-duty truck sales by manufacturer. Two assumptions were made to combine the two tables; first, the light-duty truck data in Table V-2 includes the sale of trucks having a gross vehicle weight (GVW) between 8,500 and 10,000 pounds which are actually heavy-duty vehicles by EPA's definition. These heavy-duty vehicles represent about 5% of total sales up to 10,000 pounds GVW, but the 5% does not necessarily hold for each manufacturer. For this analysis, however, the 5% figure should be accurate enough, and the sales shown in Table V-2 were multiplied by 0.95 before being added to the sales in Table V-1. Second, a further breakdown of the "Other" category in Table V-2 was not available. The assumption was made that these sales would apportion themselves among the manufacturers in Table V-1 not represented in Table V-2.

The breakdown of light-duty sales for 1978 shown in Table V-3 will be assumed to stay constant in the future. The total number of vehicles sold will be assumed to increase 2% per year compounded. Table I-5 in Section I shows the fraction of light-duty sales which are expected to be diesel. From this and the total light-duty sales for each year, the total sales of light-duty diesels for 1984 and 1988 can be calculated. However, each manufacturer could design and produce its own trap oxidizers and have its own production volume. If this was the case, then the production of each manufacturer must be determined. To do this the data in Table V-3 can be used but the diesel fraction of total sales must be known for each manufacturer. Estimates of these fractions can be found in Table I-4 for 1985 and 1990. Using linear interpolation, these figures have been estimated and are shown in Table V-4. The fractions for General Motors have been taken from Table I-3. From all of the above information, the number of light-duty diesels sold by each manufacturer between 1984 and 1988 can be determined. These figures are shown in Table V-5. Now that the necessary corporate production data are available, it will be helpful to step aside for a moment and examine the theory of the effect of production volume on the cost of production.

In manufacturing, it is a common occurrence that the cost of production decreases with experience. This experience is usually measured in terms of accumulated production. The relationship between cost and accumulated production is called a learning curve and is usually described by the logarithmic function:

Table V-1

Breakdown of New Passenger Car Sales in the U.S. by Manufacturer - 1978 1/

Manufacturer	New Car Sales	Percentage of New Car Sales
General Motors	5,285,282	47.6%
Ford	2,582,702	22.8%
Chrysler	1,146,258	10.1%
AMC	170,739	1.5%
VW 2/	239,306	2.1%
Mercedes-Benz	46,695	0.4%
Volvo	50,880	0.4%
Fiat	60,435	0.5%
BMW	31,457	0.3%
Audi	40,878	0.4%
Peugeot	9,061	0.1%
Other Imports	1,544,385	13.7%
TOTAL	11,308,078	100.0%

1/ Automotive News, 1979 Market Data Book Issue, April 25, 1979, pp. 18 and 52.

2/ Domestic and imported.

Table V-2

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

Manufacturer	Number of U.S. LDT Sales	Percent 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 lbs. GVW.

2/ Includes imports.

Table V-3

Breakdown of Combined Light-Duty Vehicle and Light-Duty Truck Sales in U.S. in 1978 [1/]

Manufacturer	New Car Sales	Percentage of New Car Sales
General Motors	6,826,880	46.5%
Ford	3,741,410	25.5%
Chrysler	1,530,546	10.4%
AMC	326,110	2.2%
VW	262,716	1.8%
IHC	34,262	0.2%
Mercedes-Benz	51,154	0.4%
Volvo	55,339	0.4%
Fiat	66,009	0.4%
BMW	34,801	0.2%
Audi	45,337	0.3%
Peugeot	10,176	0.1%
Other Imports	1,697,105	11.6%
TOTAL	14,681,845	100.0%

1/ Light-duty trucks defined as 0-8500 pounds GVW.

Table V-4

Projected Percentage of Diesel-Powered Light-Duty Vehicles Sold by Manufacturer

Manufacturer	1984	1985	1986	1987	1988
General Motors	12%	13.8%	17.5%	22%	23%
Ford	8%	10%	11%	12%	13%
Chrysler	8%	10%	12%	14%	16%
AMC	8%	10%	12%	14%	16%
VW 1/	42%	42%	46%	50%	55%
Mercedes-Benz	66%	70%	74%	78%	82%
Peugeot	66%	70%	74%	78%	82%
Volvo, Fiat, IHC, BMW	8%	10%	12%	14%	16%

1/ Includes Audi.

Table V-5

Light-Duty Diesel Sales by Manufacturer (Excepting Rabbits) Between 1984 and 1988 in Thousands of Vehicles (Percents of Total)

Manufacturer	1984	1985	1986	1987	1988
General Motors	893 (60.1%)	1082 (58.7%)	1400 (62.1%)	1795 (69.6%)	1914 (65.2%)
Ford	326 (21.9%)	430 (23.3%)	483 (21.4%)	537 (20.8%)	593 (20.2%)
Chrysler	134 (9.0%)	175 (9.5%)	215 (9.5%)	255 (9.9%)	298 (10.2%)
AMC	28 (1.9%)	37 (2.0%)	45 (2.0%)	54 (2.1%)	63 (2.1%)
VW 1/	36 (2.4%)	38 (2.1%)	43 (1.9%)	47 (1.8%)	53 (1.8%)
Daimler-Benz	43 (2.9%)	47 (2.6%)	51 (2.3%)	55 (2.1%)	59 (2.0%)
Peugeot	10 (0.7%)	12 (0.7%)	13 (0.6%)	14 (0.5%)	15 (0.5%)
Fiat	5 (0.3%)	7 (0.4%)	8 (0.4%)	10 (0.4%)	11 (0.4%)
BMW	3 (0.2%)	3 (0.2%)	4 (0.2%)	5 (0.2%)	6 (0.2%)
IHC	3 (0.2%)	3 (0.2%)	4 (0.2%)	5 (0.2%)	6 (0.2%)
Volvo	5 (0.3%)	7 (0.4%)	8 (0.4%)	10 (0.4%)	11 (0.4%)
TOTAL	486 (100%)	1842 (100%)	2274 (100%)	2787 (100%)	3029 (100%)

1/ Includes Audi, excludes Rabbits.

$$\frac{C_2}{C1} = \left(\frac{P_2}{P1}\right)^{\left(\frac{\ln(1.0-z)}{\ln 2}\right)} \qquad (1)$$

where,

P_1 and P_2 = two different levels of accumulated production.
z = the fraction or percent that costs are reduced each time the accumulated production is doubled.
C_1 and C_2 = costs of the item with total accumulated production of P_1 and P_2.

For the purposes of this analysis, z will be assumed to be 0.12, or that the cost of a trap-oxidizer system will decrease 12% each time the accumulated production is doubled (based on discussions with experts in the emission control technology costing field). Given the cost at a specified accumulated production, a new cost at a different production can then be found using equation (1).

A number of different costs of trap-oxidizers are important to this analysis. First, the fleet-wide average cost for each of the first five years of trap-oxidizer usage is important because it can be coupled with vehicle production estimates to determine the five-year aggregate cost of the 1984 standard. This aggregate cost is an important indicator of the effect of a regulation on the economy. Second, the system cost to small manufacaturers is important. If it is assumed that each manufacturer will produce his own traps, then a small manufacturer will have a small production volume, resulting in a higher cost. Third, it is similarly important to determine the cost to a large manufacturer, as it could be considerably lower than the cost to smaller manufacturers if these small manufacturers do not purchase their systems from a larger supplier. It is important to know this differential cost. The fleetwide average cost of trap-oxidizer systems will be determined first, followed by the costs to both the smallest and the largest manufacturers. These costs will be determined for each of the first five years of trap-oxidizer production.

The fleetwide average cost of trap-oxidizers is simply a sales-weighted average of the costs to each manufacturer and is described by the equation:

$$C_{ave,j} = \frac{\sum_{i=1}^{M} C_{ij} \times P_{ij}}{\sum_{i=1}^{M} P_{ij}} \qquad (2)$$

where,

C_{ave} = Sales-weighted average cost in years.

C_{ij} = Cost of item to manufacturer i in year j.

P_{ij} = Production of manufacturer i in year j.

M = Number of manufacturers.

The cost of each component (or the system) to a manufacturer (C_{ij}) will depend on his total production, and the number of different components (or systems) needed. For items such as traps, throttle assemblies, exhaust pipes, etc., a different component will be needed for each basic engine size (4-cylinder, 6-cylinder, 8-cylinder). For other items such as thermocouples and electronic control units, one type can be used on all the manufacturers models. In general, if it is assumed that a manufacturer will produce equal amounts of each component (or system) type, then, using equation (1), the average cost to each manufacturer (C_{ij}) is as follows:

$$C_{ij} = C_{ref} \times \left(\frac{\sum_{k=1}^{j} P_{ik}}{NxP_{ref}}\right)^{\left(\frac{\ln(1.0 - z)}{\ln 2}\right)} \tag{3}$$

where,

N = Number of types of each component.

P_{ref} = Reference production volume.

C_{ref} = Cost of component at a production volume of P_{ref}.

If 0.12 is substituted for z, then equation (3) becomes:

$$C_{ij} = C_{ref} \times \left(\frac{\sum_{k=1}^{j} P_{ik}}{NxP_{ref}}\right)^{-0.1844} \tag{4}$$

This relationship for C_{ij} can now be substituted into equation (2) which yields:

$$C_{ave,j} = \frac{\sum_{i=1}^{M} P_{ij} \times C_{ref} \times \left(\frac{\sum_{k=1}^{j} P_{ik}}{N x P_{ref}}\right)^{-0.1844}}{\sum_{i=1}^{M} P_{ij}} \qquad (5)$$

or

$$C_{ave,j} = C_{ref} \times \left(\frac{\sum_{i=1}^{M} P_{ij} \cdot \left(\frac{\sum_{k=1}^{j} P_{ik}}{N x P_{ref}}\right)^{-0.1844}}{\sum_{i=1}^{M} P_{ij}}\right) \qquad (6)$$

Once the reference production (P_{ref}) is chosen and the C_{ref} determined, equation (6) will allow the average cost for all manufacturers to be determined in any given year.

As will be seen below, there are a number of components in a trap-oxidizer system and the cost of each has to be determined separately. Rather than use equation (6) in its present state for each of these components, an intermediate step can be made which will reduce the total number of necessary calculations. Except for C_{ref} and N, the right-hand side of equation (6) is independent of the component being examined. P_{ref} can be chosen to be the same for all components. As explained above, there will only be two sets of values for N; one set for those components which will need to vary with engine size, and one set for those that will not. Thus, the value for ($C_{ave,j}/C_{ref}$) can be calculated once for each set of values for N. For components such as thermocouples and electronic countrol units, only one type should be needed for a manufacturer's entire line, and N should be 1.0 for all manufacturers. For components which depend upon basic engine class, N should be the number of basic engine classes a manufacturer will produce. A basic engine class will be assumed to be characterized by the number of cylinders in the engine. General Motors, Ford and Chrysler will be assumed to build three basic engine classes. AMC, VW and Daimler-Benz will be assumed to build two classes. Fiat, Peugeot, BMW, International Harvester, and Volvo will be assumed to build a single engine class.

The production data shown in Table V-5 can now be used directly to calculate (C_{avej}/C_{ref}) for the years 1984-1988 (j=1-5). P_{ref} will be assumed to be 300,000 units. The results are shown in Table V-6. As can be seen, the cost of components which vary with basic engine class (N = 1,2, and 3) starts out 15% greater than the

Table V-6

Values for the Ratio of the Actual Cost of a Component to Its Cost at an Accumulated Production of 300,000 Units

	1984	1985	1986	1987	1988
j =	1	2	3	4	5
Fleetwide Average					
N = 1	0.955	0.823	0.742	0.683	0.648
N = 1, 2, & 3	1.15	0.993	0.896	0.825	0.783
Largest Manufacturer (GM)					
N = 1	0.818	0.706	0.640	0.592	0.558
N = 1, 2, & 3	1.001	0.865	0.784	0.724	0.684
Smallest Manufacturer (IHC)					
N = 1	2.34	2.06	1.87	1.74	1.63

basic engine class (N = 1,2, and 3) starts out 15% greater than the cost at an accumulated production of 300,000 units (1984) and four years later is 22% less than the cost at 300,000 units. A similar result occurs for those uniform components (N = 1). In 1984, the cost is 4.5% less than the cost at the reference production and by 1988 the cost is 35% less than C_{ref}.

Equation (6) can also be used to calculate similar values for just the largest manufacturer and just the smallest manufacturer. This will be useful in determining the range of costs that will occur between manufacturers, which has already been mentioned as an important piece of information for subsequent analyses. These results are also shown in Table V-6. As can be seen, the costs for General Motors could be about 13% less than the fleet average, based on differences in production volumes, while the costs for International Harvester could be slightly over twice the fleet average. The results for International Harvester (IHC) are conservative since it was assumed that IHC would produce its own trap-oxidizer system at very low production volumes. This may not be the case as IHC may choose to purchase these systems from a supplier and take advantage of higher production volumes. This statement is true for all of the smaller manufacturers shown in Table V-5. If a number of these smaller manufacturers were able to purchase trap-oxidizer systems from a large supplier, the fleetwide average cost would be lower than that indicated in Table V-6.

EPA's original cost estimates of the individual components of a trap-oxidizer system were taken from a study of the costs of emission control systems.1/ The formula used to determine the retail price equivalent of each item is shown below.

$$\begin{aligned}\begin{matrix}\text{Retail}\\ \text{Price}\\ \text{Equivalent}\end{matrix} &= [[(\begin{matrix}\text{Direct}\\ \text{Material}\end{matrix}) + (\begin{matrix}\text{Direct}\\ \text{Labor}\end{matrix}) + \begin{matrix}\text{Fixed}\\ (\text{Variable})]\\ \text{Overhead}\end{matrix} \\ &\quad \times [1 + (0.2\ \begin{matrix}\text{Corporate}\\ \text{Allocation}\end{matrix}) + (0.2\ \begin{matrix}\text{Supplier}\\ \text{Profit}\end{matrix})] + (\begin{matrix}\text{Tooling}\\ \text{Expense}\end{matrix}) \\ &\quad + (\begin{matrix}\text{Land \&}\\ \text{Building}\\ \text{Expense}\end{matrix})] \times [1 + (0.2\ \begin{matrix}\text{Corporate}\\ \text{Allocation}\end{matrix}) + (0.2\ \begin{matrix}\text{Corporate}\\ \text{Profit}\end{matrix}) + (0.4\ \begin{matrix}\text{Dealer}\\ \text{Overhead}\\ \text{\& Profit}\end{matrix})] \\ &\quad + (\begin{matrix}\text{Research \&}\\ \text{Development}\end{matrix}) + (\begin{matrix}\text{Tooling}\\ \text{Expense}\end{matrix}) \qquad (7)\end{aligned}$$

or, in abbreviated form:

1/ Lindgren, Leroy H., "Cost Estimations for Emission Control Related Components/ Systems and Cost Methodology Description," Rath and Strong for EPA, March 1978, EPA-460/3-78-002.

$$RPE = [(DM + DL + OH)(1.4) + TE + LBE](1.8) + RD + TE \quad (8)$$

Direct materials entail those materials of which a given component is comprised. Direct labor includes the cost of laborers directly involved in the fabrication of a given component. Overhead includes both the fixed and variable components of overhead. The fixed portion includes supervisory salaries, building maintenance, heat, power, lighting, and other costs which are substantially unaffected by production volume while the variable portion includes small expendable tools, devices, and materials used in production, repairs and maintenance made to machines directly involved, and other overhead costs which tend to vary with production volume. A straight 40% of the direct labor amount was used to determine all overhead costs.

A figure of 20% applied to the sum of material, labor, and overhead costs was used to determine corporate allocation. In other words, this is the amount needed to cover the supplier's support from its front office. Also, to the sum of material, labor, and overhead costs, a figure of 20% was applied to determine the supplier's profit. Approximately half of this 20% is used to pay corporate taxes with the remaining portion being divided between dividend disbursements to stockholders and retained earnings, which are used to finance working capital requirements (increases in current assets and/or decreases in current liabilities) and/or new capital expenditures (long-term assets).

Tooling expense consists of four components: one year recurring tooling expenses (tool bits, disposable jigs and fixtures, etc.); three year non-recurring tooling expenses (dies, etc.); twelve year machinery and equipment expenses; and twelve year launching costs (machinery foundations and other incidental set-up costs) which was assumed to be 10% of the cost of machinery and equipment.

The sum of the above costs, material, labor, plant overhead, tooling expense, corporate allocation, and profit, makes up the price (or, in the case to a division, transfer price) which the supplier charges the vehicle manufacturer for a given component. At the vehicle assembly level, 20% of this price is charged or allocated for the vehicle manufacturer's corporate level support and 20% for corporate profit. Also, a figure of 40% is applied to the supplier price to account for the dealer's margin which includes sales commissions, overhead, and profit.

Because of the need, in many instances, to make modifications to the engine or body to incorporate a component and to assemble it into a vehicle, these have also been accounted for at the division level and transferred to the corporate level at vehicle assembly.

Lindgren's study primarily focused on determining the manufacturing costs of emission control equipment. Much effort was expended to accurately determine the cost of materials, labor, tooling, etc. EPA has available a number of confidential cost estimates from emission-control equipment suppliers and these costs confirm Lindgren's estimates at the vendor level.

Less resources were available to Lindgren to determine overhead costs and profit margins and, in general, rules of thumb were used in equation (8). These estimates of overhead costs and profit margins at the corporate and dealer levels could be improved with a more detailed analysis. Overhead and profit at the vendor level will not be reexamined because the independent vendor estimates mentioned above confirmed Lindgren's estimates at that level.

The first two factors to be examined are those indicating the corporate overhead and corporate profit. Typical levels of overhead and profit can be obtained from Moody's Industrial Manual.2/ An examination of the financial data of the three largest American manufacturers reveals some interesting facts. Corporate overhead as a percentage of cost of sales (in Lindgren's terminology, vendor cost plus research and development and tooling expenses) is approximately the same for the three manufacturers and very close to 10% for 1976-1978. This overall factor is reasonable to use for allocating overhead to emission control devices since these devices are an integral part of the vehicle and not an optional accessory. The net income before taxes as a percentage of cost of sales differs considerably between the three manufacturers. Between 1976 and 1978, General Motors' profit in these terms was the highest (14%) and Chrysler's the lowest (1.1%). It does not seem appropriate to include the Chrysler profit in any calculation of industry profit because it does not reflect the necessary long-term profit margin of a healthy corporation. It seems most.appropriate to simply use the profit level of General Motors as the appropriate level as it is the industry leader. Even if Ford and Chrysler are not attaining the profit level of General Motors, that is their goal and it does signify the profit level of a healthy corporation. Thus, 10% will be used to allocate corporate overhead and 14% for corporate profit.

The last factors to be determined are the levels of dealer overhead and profit. An important tenet to keep in mind here is that we are searching for the incremental cost at the dealer level of adding emission control devices. It may not be appropriate to allocate overhead to these devices at the average rate because the presence of these devices may not affect the cost of overhead. On the other hand, profits should increase because the presence of the emission control devices will raise the cost of the vehicle to the dealer, increasing his capital investment.

2/ Moody's Industrial Manual, 1979, Vol. 1, A-I.

The net profit on sales after taxes of the average motor vehicle dealer in 1977 was 1.46%.3/ The average profit on sales before taxes would then be about 3%. As emission controls are an integral part of the vehicle, the average profit on the entire vehicle would seem appropriate for emission control devices.

The area of dealer overhead, however, may be one cost which should not be allocated at the existing rate (i.e., some percentage of sales). As mentioned before, it is not the average cost that is being examined, but the incremental cost, the marginal cost. Is the addition of a pollution control device really going to increase the overhead? The costs of land and buildings should not increase. It doesn't take any more space to store a car with pollution controls than one without the controls. At most, some additional space may be needed to store extra parts, but even this should rightly be charged as overhead for maintenance costs, and should be charged to persons paying for the maintenance or buying the part. Few would argue that the cost of replacement parts does not include the cost of storage.

The number of secretaries or salesmen should not be affected either. No extra paperwork is involved on the dealer level because of emission controls. If the cost of the device is small enough, sales should not be impacted significantly, particularly since competitors will have to increase their prices by approximately the same amount.

Lastly, it could be said that mechanics will have to be retrained to be able to maintain the new devices. However, this cost, like the space needed for parts storage, should be placed on the maintainance fee, probably as the cost of labor. Thus, it too should not be added to the initial price of the vehicle.

Now that revised estimates of corporate and dealer overhead and profit have been developed, these revised estimates can be substituted into equation (7) to form a new costing equation. The new factors for corporate overhead and corporate profit and 0.10 and 0.14, respectively. However, since research and development costs and tooling expense were included in the cost of sales upon which these factors were based, these two costs (RD and TE) should also be increased by the overhead and profit factors in the new costing equation. The new factor for dealer overhead and profit is 0.03. However, this factor was based on the cost to the dealer, which includes corporate overhead and profit. Thus, the entire cost up to the dealer level should be increased by 3%. The resulting equation is shown below:

$$\begin{aligned} RPE = [((DM + DL + OH)(1.4) + TE + LBE) \\ + RD + TE](1.24)(1.03) \end{aligned} \tag{9}$$

3/ Dun's Review, September 1978, Vol. 112, No. 3, pp. 124, 125.

Now that the revised retail cost methodology is available, the next step will be to calculate the cost of the various components which together form a trap-oxidizer system. A standard production volume of 300,000 units will be used for the time being. After the cost of all the components has been determined, the ratios shown in Table V-6 will be used to calculate the fleetwide average costs and the cost to both the smallest and largest manufacturer.

The major portion of the cost of a trap oxidizer is the trap itself. In the Draft Regulatory Analysis, this was approximated by the cost of a pelleted oxidation catalyst. Though no comment was directly received concerning this approximation, the most promising trap designs fall closer to a monolithic catalyst than a pelleted catalyst. In some cases, actual monolithic substrates are being used with and without washcoat and noble metals for prototype trap testing.4/ In other cases, the trapping material is alumina-coated steel wool or saffil fiber.5/ The manufacturing of a trap out of these materials should follow more closely to that of a monolithic catalyst than to a pelleted catalyst. Rather than continue using a pelleted catalyst to approximate trap costs, then, the cost of a monolithic catalyst will be used instead.

The costs for three trap volumes will be calculated, accounting for the different sizes which will be required by different engine sizes. The basis for the sizes is the successful testing of a 5.3-liter trap fitted to an Opel 2100D.3/ Extrapolations of trap size were made to larger and smaller engines using the ratios of the fuel consumptions over the FTP of the various engines (vehicles). Fuel consumption is a good, available indicator of volumetric flow through the trap, which should be one of the main considerations in sizing the trap. Assuming that typical fuel economies of 4-, 6-, and 8-cylinder engines were 35, 28, and 21 miles per gallon, respectively, the trap volumes were calculated to be 4.6 (281), 5.8 (354), and 7.3 (445), liters (cubic inches), respectively.

Lindgren (p. 145) has determined the cost of a monolithic catalyst as a function of volume and noble metal content and put it in a formula equivalent to equation (8):

$$\text{RPE (Trap)} = (\text{NM} + \$2.52 + 0.1013 \times V) \times 2.52 + \$5.995 \qquad (10)$$

Where:

4/ Penninga, Thomas, TAEB, EPA, "Diesel Particulate Trap Study: Interim Report on Status of Study and Effects of Throttling," Memorandum to Ralph C. Stahman, Chief, TAEB, EPA, May 18, 1979.

5/ Rykowski, Richard A., SDSB, "Size Considerations Concerning the Use of Trap-Oxidizers in Light-Duty Diesels," Memorandum to Robert E. Maxwell, Chief, SDSB, EPA, October 15, 1979.

RPE (Trap) = Retail price equivalent of a trap (monolithic catalyst).

NM = Cost of noble metals at manufacturing level.

V = Volume of trap in cubic inches.

The multiplicative factor of 2.52 in equation (10) is the product of the factors for vendor overhead and profit (1.4) and corporate and dealer overhead and profit (1.8). In the revised methodology of equation (9), the first factor remains the same, but the second factor becomes 1.277 (1.24 x 1.03). Also, the factor of 1.277 is applied to the \$5.995 cost of research and development and tooling. Thus, in terms of the revised methodology of equation (9), equation (10) becomes:

$$\text{RPE(Trap)} = ((\text{NM} + \$2.52 + 0.1013 \times V) \times 1.4 + \$5.995) \times 1.277 \quad (11)$$

The trap volumes needed for equation (11) are already available, but the noble metal loadings are not. At this point in time, it is not known whether or not diesel particulate traps require noble metals. The purpose of the noble metals, if present, would be to lower the temperature necessary to ignite the trapped particulate and possibly to aid the oxidation process to reach carbon dioxide and water. To cover the range of possibilities, two loadings will be assumed, one with no noble metals and one with oxidation-promoting metals (Pt and Pd) at a level found in current oxidation catalysts for gasoline engines, which is around 0.012 gram per cubic inch with a 2:1 ratio of Pt to Pd. Noble metal costs are currently around \$8.67 per gram for Pt and \$2.72 per gram for Pd.[6] However, since the Lindgren costs represent 1977 prices and a general inflation rate of 8 percent per year will be used to adjust the total costs, these current (1979) noble metal costs will be divided by 1.1664 so that when they are adjusted for inflation later, they will represent 1979 prices. Using Lindgren's formula for the cost of the noble metals (p. 134):

$$\text{NM} = \$7.43 \times 0.008\ V + \$2.33 \times 0.004\ V + \$0.14 \times 0.0012\ V$$

or

$$\text{NM} = \$0.0690\ V \quad (12)$$

The last term accounts for manufacturing costs.

Equation (11) includes the cost of a washcoat. However, if no

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[6] American Metals Market, June, 1979, reduced by 23 percent to reflect prices available to large-volume buyers (auto manufacturers).

noble metals are to be present, the washcoat should not be necessary and its cost should be deleted. From a breakdown of catalyst costs at various volumes (Lindgren p. 360), it is found that the cost of the washcoat is proportional to the volume of the catalyst and represents 10.3 percent of the 0.1013 term in equation (11), or 0.0104 V. Subtracting this and the noble metal cost from equation (11) yields the cost for a trap without washcoat or noble metals:

$$\text{RPE (Trap)} = ((\$2.52 + 0.0909V) \times 1.4 + 5.995) \times 1.277 \qquad (11a)$$

Two final adjustments are needed before calculating the costs of the traps. One, inflation needs to be considered. The costs that Lindgren quotes are from 1977. An 8 percent per annum inflation rate will be used to convert these costs to 1979 costs, or a factor of 1.1664. Two, production volume needs to be taken into account. Lindgren assumed a production volume of 2,000,000 catalysts (p. 115). The production volume of interest here is 300,000 units. Using equation (1) with $Z = 0.12$, it is found that the cost should be a factor of 1.364 higher at the lower production volume. Combining the inflation and production factors, the costs determined by equations (11) and (11a), should be increased by a factor of 1.591.

The necessary equations ((11), (11a), and (12)) are now available with which the cost of the trap can be determined. Substituting equation (12) into equation (11) and multiplying equations (11) and (11a) by 1.591:

Trap cost - No noble metals

$$\text{RPE (Trap)} = ((\$2.52 + 0.0909\ V) \times 1.4 + 5.995) \times 1.277 \times 1.591$$

or

$$\text{RPE (Trap)} = \$19.35 + 0.2586\ V \qquad (13)$$

Trap cost - With noble metals

$$\text{RPE (Trap)} = ((\$2.52 + (0.1013 + 0.0690)V) \times 1.4 + 5.995) \times 1.277 \times 1.591$$

or

$$\text{RPE (Trap)} = \$19.35 + 0.4844V \qquad (13a)$$

Using equations (13) and (13a) the costs of the traps at various volumes can now be calculated. These are shown in Table V-7.

Port liners, insulated exhaust manifolds and an insulated exhaust pipe may also be necessary to ensure that the exhaust gas temperature remains high enough to permit oxidation in the trap. From Lindgren (p. 195), the manufacturer's cost (vendor cost plus research and development and tooling) of port liners for a 4-cylinder engine is \$5.40. Taking inflation (16.64 percent) and corporate and dealer overhead (27.7 percent) would increase this to \$8.04. The production volume assumed was 400,000 engines. Using equation (1), with $z = 0.12$, to convert to 300,000 units results in a cost increase of 4.8 percent to \$8.43, or \$8. It will be assumed that port liners will cost 50 percent more for a 6-cylinder engine (\$13) and 100 percent more for an 8-cylinder engine (\$17). These costs are shown in Table V-7.

The cost of an insulated exhaust manifold has also been indirectly determined by Lindgren (pp. 171-90). From Lindgren's treatment of a thermal reactor, the cost of simply insulating the manifold can be determined. For a 4-cylinder engine, the manufacturer's cost of ceramic liners and insulation is \$6.55 (p. 179). Research and development cost of \$1.00 per manifold (p. 180) will be taken to be entirely due to the thermal reactor function and will be taken to be zero for simply insulating a manifold. Vehicle assembly and engine modifications amount to \$0.69 for the entire thermal reactor (p. 180). Subtracting from this the cost of assembling a standard manifold (\$0.56 for a 6-cylinder engine, p. 188) results in a negligible net cost and will not be considered. It will be assumed that the cost of the manifold itself will not change. This should be multiplied by 1.277 (see equation (9)) to obtain the retail price equivalent, which is \$8.36. The production volume assumed was the same as in the case of port liners above, 400,000 units. Thus, the conversion factor for inflation and production volume is the same as above, 1.222 (1.1664 x 1.0489). Taking this factor into account, the cost of insulating a 4-cylinder manifold in 1979 is then \$10.22 or \$10. The cost of insulating a manifold for a 6-cylinder engine will be assumed to be 50 percent more (\$15) and 100 percent more for an 8-cylinder engine (\$20). These costs are shown in Table V-7.

Looking next at the exhaust pipe, there are two levels at which it can be improved. One, the standard steel material must be converted to stainless steel if the system will be expected to last 100,000 miles. There is no guarantee that people would replace a rusted-out exhaust pipe before it developed holes, which would allow exhaust to bypass the trap and also cool the exhaust, possibly to the point of preventing any oxidation from ocurring. Two, the exhaust pipe may have to be insulated to keep the exhaust temperature high enough for oxidation to occur.

The cost of changing the exhaust pipe to stainless steel can be taken from Lindgren. The manufacturing cost (DM + DL + OH in equation (8)) of a standard steel exhaust pipe is \$2.66 (6-cylinder engine) and \$4.60 (8-cylinder engine) (p. 254 and 258).

Table V-7

Estimated Cost of a Trap-Oxidizer System 1/

	Number of Cylinders in Engine					
	Four		Six		Eight	
	Original	Revised	Original	Revised	Original	Revised
Trap 2/						
Without catalyst	$70	92	75	111	86	134
With catalyst		155		191		235
Port Liners	10	8	16	13	18	17
Stainless Steel Exhaust Pipe 3/	0	13	0	13	0	22
Insulate Exhaust Pipe	14	34	23	34	33	53
Insulate Exhaust Manifold	0	10	0	15	0	20
Electronic Control Unit	22	34	22	34	22	34
Sensors	5	8	5	8	5	8
Throttle Body Actuator	8	15	8	15	8	15
Electro-Mechanical Control	-	5		5		5
Muffler (Credit)	-15	-9	-15	-11	-15	-13

1/ "Cost Estimations for Emission Control Related Components/ Systems and Cost Methodology Descriptions," Rath and Strong for EPA, March 1978, EPA-460/3-78-002. Assumed production volume of 300,000 units.

2/ Costs shown are for an oxidation catalyst, 8 liters for an 8-cylinder engine, 6 liters for a 6-cylinder engine, and 4.9 liters for a 4-cylinder engine.

3/ Includes credit for steel exhaust pipe which it replaces; $7-10 for 4- and 6-cylinder and $12-17 for 8-cylinder engines.

Tooling costs are only $0.10 per pipe. Using equation (9), the retail price equivalents of these two pipes are $4.88 and $8.44, respectively. The retail price equivalents of stainless steel exhaust pipes are $13.89 and $24.24 respectively (p. 251 and equation (9)). The cost of converting to stainless steel is then $9.01 for a 6-cylinder engine and $15.80 for a 8-cylinder engine. The assumed production in both cases was 1,000,000. Using equation (1), these costs need to be increased by 21.8 percent to convert to a production of 300,000 units. They also need to be increased by 16.64 percent because of inflation. In total, then, the cost of converting the exhaust pipe to stainless steel is $13 for a 6-cylinder engine and $22 for an 8-cylinder engine. It will be assumed that the cost for a 4-cylinder engine will be the same as that for a 6-cylinder engine. These costs are also shown in Table V-7.

The cost of adding a double wall to the exhaust pipe with insulation in between is next to be determined. Again from Lindgren (p. 272 and equation (9)), the retail price equivalent of a double-walled, stainless steel, insulated pipe is $37.98 for a 6-cylinder engine and $61.33 for an 8-cylinder engine. Subtracting the costs of the stainless steel pipe calculated above leaves $24.09 (6-cylinder) and $37.09 (8-cylinder). Using the same adjustments for production volume and inflation, and the same assumption concerning the 4-cylinder engine, the cost of converting a stainless steel exhaust pipe to a double-walled, insulated, stainless steel pipe is $34 for a 4- or 6-cylinder engine and $53 for a 8-cylinder engine (Table V-7).

If the exhaust pipe is to be made out of stainless steel, whether single or double-walled, it should last the entire life of the vehicle. This means that replacements which would have normally occurred with steel pipes will no longer occur with stainless steel pipes. This will result in a reduction in vehicle operating costs. It will be assumed that exhaust pipes normally need to be replaced once during a vehicle's life. For convenience, this will be taken to occur halfway through the vehicle's life, after five years. At this point, the consumer does not save only the retail price equivalent, but the aftermarket cost and labor costs. Lindgren estimates aftermarket costs (material) to be four times the vendor cost. Previously, the retail price equivalents for steel exhaust pipes were found to be $4.88 (4- and 6-cylinder) and $8.44 (8-cylinder). These costs had not been adjusted for production (they represent a production volume of one million units) or inflation (they are 1977 costs). Using equation (1) and multiplying by 1.1664 for inflation, the proper 1979 retail price equivalents are $6.93 (4- and 6-cylinder) and $11.99 (8-cylinder). The 1979 vendor costs (using equation (9)) are $5.43 (4- and 6-cylinder) and $9.39 (8-cylinder). Using Lindgren's factor of four, the aftermarket prices would be $22 (4- and 6-cylinder) and $38 (8-cylinder). A survey of muffler shop prices confirmed these figures and also revealed that the cost of clamps and brackets amounted to about 5 percent of the cost of the exhaust pipe and labor costs were about 25 percent of the total material cost. Thus, the complete cost (in this case savings) of replacing an exhaust pipe would be \$29 (4- and 6-cylinder) and \$50 (8-cylinder). To be comparable to the initial price increases discussed in this section, these savings need to be discounted back five years since the savings will not occur until then. Using a 10 percent discount rate, the savings (in the year the car was bought) would be \$18 (4- and 6-cylinder) and \$31 (8-cylinder).

The oxidation control unit was originally estimated to cost \$35. Included in this figure were \$22 for half of an electronic control unit and \$13 for sensors, thermocouples and a throttle for raising the temperature of the exhaust. The revised estimates are shown in Table V-7 and are based on the following. In his study, Lindgren solicited estimates of the cost of an electronic control unit (ECU) which monitored and controlled a large number of sensors and controllers (p. 320). This type of ECU should be of the same capacity as that needed to control the oxidation process of a trap-oxidizer system. The industry estimate was \$45. Taking this to be a vendor level cost, the retail price equivalent would be \$57. Inflating this to 1979 prices, the cost increases to \$67. However, half of this cost will be alotted to particulate control and half to NOx control. The presence of the electronic control unit will allow the use of programmed exhaust gas recirculation systems, which should provide reductions in NOx emissions from light-duty diesels. These reductions are definitely needed as evidenced by the recent need to waive the 1.0 g/mi (0.62 g/km) NOx standard to 1.5 g/mi (0.93 g/km) NOx for many diesel-powered light-duty vehicles. Thus, the cost of the unit due to diesel particulate regulations is \$34, which is shown in Table V-7.

The costs of the sensors, throttle body and actuator can also be taken from the same Lindgren table (p. 320). Allowing for two thermocouples near the trap, an engine speed sensor, and a rack position sensor, the vendor cost at a production volume of 300,000 is approximately \$5. With two year's inflation, this cost would increase to around \$6. If equation (9) is used to calculate the retail price equivalent, the cost becomes \$8. The throttle switch and body should cost about \$10 at the vendor level (p. 320) at a production volume of 300,000 units. With inflation and conversion to retail price equialents, the cost should be \$15. Both costs are shown in Table V-7.

It may also be possible that a much simpler control device would suffice in the situation. If all that was needed was a periodic boost in exhaust temperature during some general engine condition, then a controller on the order of an automatic choke or an odometer-controlled maintenance light (e.g., EGR light) should be satisfactory. For example, if the throttle actuator was keyed to the odometer and rack position, it could operate periodically, for set period of time at a certain rack position. This type of control system would only require two or three sensors and mechanical or electrical connections to the throttle actuator. From sensor costs shown by Lindgren (p. 320)and equation (9), this system should only cost about $5. This option has been included among the components shown in Table V-7.

It is very likely that addition of a trap to the exhaust would allow either the muffler or resonator to be deleted. This would result in a savings to the consumer, not only initially, but every time the standard steel exhaust system would need replacement. From Lindgren (p. 264) and equation (9), the retail price equivalent of a muffler is $6.95 (6-cylinder) and $8.36 (8-cylinder) at a production volume of 2,000,000. Using equation (1) to adjust to a production volume of 300,000 units, the costs would be $9.47 and $11.40, respectively. Finally, two year's inflation would increase these costs to $11.05 (6-cylinder) and $13.30 (8-cylinder). Extrapolating linearly to a 4-cylinder engine results in a cost of $8.80. These are shown in Table V-7.

The additional savings accrued during the life of the vehicle come from not needing to replace the muffler (or resonator) when it otherwise would have needed to be replaced. In this situation, the prices being paid are not retail price equivalents, but aftermarket prices and labor costs. Due to the large number of firms in the aftermarket muffler business, it will be assumed that this market is fairly competitive and that excess profits are not obtained. The cost paid by the purchaser, then, is the actual cost to the economy, excepting taxes which will be included for simplicity.

From Lindgren (p. 265), the aftermarket material costs are about four times the vendor level cost. The reasons for this would be smaller volume purchases, storage, and transporation costs. This relationship has been confirmed above in the case of exhaust pipes. Using equation (9) to adjust the retail price equivalents of Table V-7, the vendor level costs turn out to be $6.90 (4-cylinder) $8.65 (6-cylinder) and $10.41 (8-cylinder). If aftermarket prices are four times vendor-level costs, then the aftermarket prices would be $28 (4-cylinder), $35 (6-cylinder), and $42 (8-cylinder).

While it may seem that mufflers need replacement more often, it appears that on the average, mufflers are replaced once every five years.7/ There are, of course, regional and model-to-model variations below and above this average. Given that light-duty

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7/ "Car Maintenance in the U.S.A.," Motor and Equipment Manufacturers Association, Volume 1, 1977.

vehicles have an average life of ten years, the savings from not having to replace the muffler would only occur once, after five years. The savings would include the cost of material, determined above, and the cost of labor. A survey of local muffler shops shows that typical labor costs are about 25 percent of material costs, as evidenced above in the case of exhaust pipes. Given this, the savings would be $35 (4-cylinder), $44 (6-cylinder) and $52 (8-cylinder). Of course, to compare these values with the initial vheicle price increases, they would have to be discounted at 10 percent over five years, or by 38 percent. With discounting, the savings would be $22 (4-cylinder), $27 (6-cylinder), and $32 (8-cylinder).

General Motors made some comments concerning the cost of the last few components described. One, they stated that the electronic control unit would cost twice as much as EPA's original estimate. General Motors stated that their cost estimates did not include any profit, so their comment should be compared to the $34 cost in Table V-7. This revised cost ($34) is already 55 percent higher than EPA's original estimate ($22). The revised estimate of $34 is based on industry estimates elicited by Rath and Strong. As General Motors did not support their statement nor give any reason why the Rath and Strong estimate should not be used, the revised estimate of $34 should not be changed again. Two, General Motors claimed that EPA did not account for the cost of thermocouples, sensor and a throttle. Actually, $13 was allowed in the original estimate, though it was not mentioned explicitly but implicitly included in the cost of "electronic oxidation control." As General Motors did not present their own estimate and explanation of the costs of these items, the revised estimates shown in Table V-7 should be used. The cost for the sensors includes the cost of two thermocouples, an engine speed sensor and a rack position sensor.

General Motors also states that the muffler would still be required after addition of the trap-oxidizer. The original decision that the muffler (or resonator) could be replaced was based on discussions with General Motors themselves where they spoke of replacing the muffler or resonator with the trap-oxidizer during their tests. More recently, testing of traps by Texaco and EPA have confirmed that these traps are effective silencers.8/,9/ Thus, it appears likely that one of the two standard silencers can be eliminated, and the other can be optimized to reduce what excess noise is left. The credits for the original equipment muffler shown in Table V-7 should be taken in subsequent system cost

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8/ Penninga, T., TAEB, EPA, "Second Interim Report on Status of Particulate Trap Study," Memorandum to R. Stahman, Chief, TAEB, EPA, August 28, 1979.

9/ Alson, Jeffrey, SDSB, EPA, "Meeting Between Texaco and EPA to Discuss Particulate Trap Work," Memorandum to the Record, October 15, 1979.

calculations, as well as the operating cost credit resulting from not having to replace the muffler.

Now that the cost of all the components has been determined, the decision needs to be made concerning which of these components will be needed on any given vehicle. As this is inherently a projection, there will be a number of component combinations which may be able to reduce particulate emissions to 0.2 g/mi (0.12 g/km), but it is also possible that they may not. There will also be variations between models and manufacturers, as is usually the case with a system as complex as a trap-oxidizer.

Four basic combinations appear to have varying degrees of probability in being able to trap and oxidize diesel particulate safely and efficiently. These are shown in Table V-8. At this time, it does not appear likely that a simple trap will be able to perform adequately by itself. Some additional features will be necessary to ensure that the particulate will be oxidized effectively and safely. Systems I, II, and III all include one or two such features. System I includes a trap plus exhaust insulating features to help retain exhaust temperature to promote oxidation. It also includes a throttle to raise exhaust temperature controlled by an electro-mechanical system. This control system would be envisioned to be much simpler than that of a three-way catalyst or electronic fuel injection. The control system would be more on the order of an automatic choke or an odometer-controlled maintenance light (e.g., EGR). The insulation of the exhaust pipe has been omitted primarily because of its cost, which is $34-53. Road tests on a Mercedes-Benz 300D have shown that the temperature drop between the exhaust manifold and the trap inlet is only 15-20° C with an uninsulated exhaust pipe.10/ It would seem that this small decrease in temperature can be made up elsewhere more economically; using, for example, a throttle. Actually, the omission of an insulated exhaust pipe was one of the prime reasons for including a throttle in this system.

System II consists of a trap, a throttle and simple control system, but instead of insulating features uses a coating of noble metals to promote oxidation. System III consists of a trap, a throttle and a sophisticated control system, but uses no insulating techniques or catalytic materials.

Any one or all three of these systems may be able to trap and oxidize diesel particulate successfully. However, there is some chance that more will be needed, which leads to System IV. System IV combines the oxidation-promoting features of Systems I and III,

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10/ Springer, Karl J., "Investigation of Diesel-Powered Vehicle Emissions: VIII. Removal of Exhaust Particulate from Mercedes 300D Diesel Car," June 1977, EPA 460/3-77-007, p. 34.

Table V-8

Components Included in Potential Trap-Oxidizer Systems

System I	System II	System III	System IV
Trap (no noble metals)	Trap (w/noble metals)	Trap (no noble metals)	Trap (no noble metals)
Stainless Steel Exhaust Pipe	Stainless Steel Exhaust Pipe	Stainless Steel Exhaust Pipe	Stainless Steel Exhaust Pipe
Port Liners	Throttle Body and Switch	Electronic Control Unit	Port Liners
Insulated Exhaust Manifold	Mechanical Control	Sensors	Insulated Manifold Exhaust
Throttle Body and Switch		Throttle Body and Switch	Sensors
Mechanical Control			Electronic Control Unit
			Throttle Body and Switch

consisting of a trap, throttle, port liners, insulated exhaust manifold and sophisticated control. This system should be sufficient in any case, and represents an upper bound of necessary technology.

The costs of the four systems are shown in Table V-9. System I is the least expensive, which is to be expected. However, System II, which could be considered less likely to be viable than System IV, is more expensive than System IV. This is primarily due to three assumptions used to estimate the amount of catalytic material on the trap. One, it was assumed that Pt and Pd would be the catalysts used. Two, it was assumed that the catalyst loading would be that found on current oxidation catalysts, around 0.012 gram per cubic inch. Three, it was assumed that this loading would be needed throughout the whole trap. It is possible that expensive catalysts such as Pt and Pd may be avoided and more inexpensive catalysts, such as silver nitrate, may prove sufficient. It is also possible that the loading could be decreased or that the catalyst would only be needed near the inlet to begin the oxidation process, which would proceed thereafter thermally. Any of these changes would lower the costs of System II and could make it competitive with Systems I and III.

It is not possible to place any probability on the possibility of any of these systems being used. It is quite possible that System I will be used on some models, particularly those which may be relatively close to the 1984 standard without a trap-oxidizer. It is also possible that some models will need System IV. Rather than give the systems a probability weighting which would have little basis, the entire range of costs between Systems I and IV will be used hereafter, as it does indicate the range of costs which could occur. The cost of System IV will be taken to be the maximum cost. It will be assumed that System II will be used only if the catalytic material or its loading can be changed to make it competitive with Systems I and III.

The range of system costs (I-IV) of Table V-9 can now be combined with the actual cost to reference cost ratios of Table V-6 to yield the actual cost of trap-oxidizer systems at the production volumes expected. The costs for the trap, port liners, insulated exhaust pipes, and exhaust manifolds, and the throttle body and actuator should be multiplied by the ratios for N equal to 1, 2, and 3 (except for the case of the smallest manufacturer where N is always equal to 1). The costs for the control units and sensors should be multiplied by the ratios for N equal to 1. The results are shown in Table V-10.

During the period between 1984 and 1988, the number of 8-cylinder engines can be expected to decrease due to the need for greater fuel economy. Thus, it should be reasonable to roughly predict that an equal number of each engine size will be produced.

Table V-9

Costs of Four Potential Trap-Oxidizer Systems 1/

	Engine Size		
System	Four-Cylinder	Six-Cylinder	Eight-Cylinder
I	$134	$161	$200
II	179	213	264
III	153	170	200
IV	171	198	237

1/ Assumed production volume of 300,000 units, 1979 prices, includes credit for replacement of muffler by trap.

Table V-10

Estimated Costs of Trap-Oxidizer Systems at Predicted Production Volumes

	# of Engine Cylinders	Fleetwide Average	Largest Manufacturer (GM)	Smallest Manufacturer (IHC)
1984	4	153-190	133-165	---
	6	184-220	160-191	---
	8	229-263	199-228	469-556
	Ave.	189-224	164-195	---
1985	4	132-164	115-142	---
	6	159-189	139-165	---
	8	197-227	171-197	413-490
	Ave.	163-193	142-168	---
1986	4	119-147	104-129	---
	6	144-170	125-149	---
	8	178-204	156-179	375-444
	Ave.	147-174	128-152	---
1987	4	110-136	96-118	---
	6	131-157	115-138	---
	8	164-188	144-165	348-413
	Ave.	135-160	118-140	--
1988	4	104-129	91-112	---
	6	125-149	109-130	---
	8	155-179	136-155	326-387
	Ave.	128-152	112-132	---

The average cost for each year is then an arithmetic average of the costs for the three engine sizes. These are also shown in Table V-8. For the smallest manufacturer, IHC, it was assumed that only 8-cylinder engines would be produced. The fleetwide average cost in 1984 would be $189-224 per vehicle, and this should decrease to $128-152 per vehicle in 1988. The costs for General Motors' vehicles should be somewhat less, $164-195 per vehicle in 1984 and $112-132 per vehicle in 1988. The costs for IHC would be much greater, $469-556 per vehicle in 1984 and $326-387 per vehicle in 1988, if they produced their own trap-oxidizer systems. As these costs indicate, it would be significantly cheaper for a few large suppliers to produce these devices for those manufacturers with low light-duty diesel productions. Given the economics, this would seem likely to occur. Similarly, the credits for reduced maintenance (muffler and exhaust pipe) calculated above could also be averaged across the three engine sizes. The credit for eliminating the muffler replacement would then be $44 and that for the exhaust pipe would be $36. Both of these credits are assumed to occur once in a vehicle's life, after five years.

Chrysler claimed that EPA had underestimated the costs of this system. As the revised costs are roughly $40-100 higher than the original estimates, it would appear that this comment has been accepted.

BMW estimated a cost of $350. They did not elaborate on the breakdown of the cost and qualified their estimate because they were inexperienced in the area. Their engine has 6 cylinders and their cost estimate should therefore be compared to the revised estimate for this engine size. The production volume assumed by BMW, if any, is unknown, however. The estimated cost of the average trap-oxidizer system for a 6-cylinder engine is $185-221 in 1984. The cost for a small manufacturer such as BMW could be somewhat higher if they produced their own units. However, without the details of BMW's estimate, it is not possible to pinpoint the reason for the difference.

General Motors estimated the cost of a trap-oxidizer system to be $470-610. This includes two traps for their larger engines. As two traps are not projected to be necessary to meet the 1984 standards (see Section II, Control Technology), the cost of the second trap should not be included. The size of the trap for an 8-cylinder engine has been increased to 7.3 liters, from the 4.26 liters originally estimated to be necessary. Also, all of the other specific items which General Motors raised have been reconciled in the revised cost estimates. If it is assumed that General Motors used more typical industry production figures and did not consider that costs would decrease with time, their estimates should be compared to a cost of $154-264 per vehicle (fleetwide average, 1984). Since all of General Motors specific comments have been addressed, the reason for this final discrepancy cannot be determined. No furt er revision can be made to EPA's revised estimates without these specific reasons. Thus, the estimated costs as shown in Table V-10 should remain as they are.

To put this cost in perspective, the cost of a three-way catalyst system will be estimated. For simplicity, only the cost of the system for a 6-cylinder engine will be calculated. Again using Rath and Strong, the cost is shown in Table V-11. The total cost of a three-way catalyst system using this methodology is $310 at a production volume of 300,000 units. The comparable figure for a System IV trap-oxidizer system is $198 from Table V-9. Thus, a three-way catalyst is about 57% more expensive than a trap-oxidizer primarily due to noble metal cost.

This estimated cost for a three-way catalyst would not necessarily be the cost of a three-way catalyst on a gasoline-fueled vehicle. The production volume assumed here was that for light-duty diesels, 300,000 units, to isolate technological differences. With a more reasonable production volume of 2,000,000 units, a three-way catalyst would be expected to cost 27 percent less, or $226.

Comments

Chrysler -- claimed that the trap-oxidizer would required maintenance during the vehicle's life.

The Council of Wage and Price Stability -- claimed that the trap-oxidizer would have to be replaced once during the life of the vehicle.

Analysis

EPA assumed that trap-oxidizers would require no maintenance (like current catalysts) and would not require replacement. No other manufacturer joined Chrysler in challenging the first assumption. However, as the designs of trap-oxidizers are becoming better known, it seems reasonable to expect some maintenance to be required. The trap itself should still be maintenance-free, but the oxidation control system may require periodic adjustment. It is also possible that a temperature sensor may also need replacement. It is estimated that this type of maintenance would require about one hour of labor and $10 worth of parts and occur once throughout the life of the vehicle. At a labor rate of $20 per hour, the total cost would be $30. This will be assumed to occur after 5 years of vehicle operation.

The Council based their claim on the belief that a trap oxidizer is analogous to a muffler which is replaced 2 to 3 times during a vehicle's life. EPA does not agree with this analogy. A muffler costs about $20 (retail price equivalent) and is made out

Table V-11

Emission Control System Costs per Engine
6-Cylinder Engine with Three-Way Catalyst 1/

Modifications for Feedback Carburetor		$ 9
Electronic Control Unit		$ 68
Three-Way Catalyst		$217 2/
Oxygen Sensor		$ 3
Stainless Steel Exhaust		$ 13 3/
	TOTAL	$310

1/ "Cost Estimations for Emission Control Related Components/Systems and Cost Methodology Descriptions," Rath and Strong for EPA, March 1978, EPA-460/3-78-002. Production volume of 300,000 units.

2/ Assumes a 250 CID engine with a catalyst volume of 275 cubic inches, a precious metal loading of 40 g/cubic feet with platinum and rhodium in a loading ratio of 9:1.

3/ Includes a $7-10 credit for the steel exhaust pipe which it replaces.

of carbon steel. The trap-oxidizer will cost over ten times that and be made of stainless steel. Since today's catalysts are made of stainless steel and last the life of the vehicle, EPA does not foresee any need for replacement of the trap-oxidizer either. Thus, no replacement cost should be included in the cost analysis.

B. Turbocharging

Comment

Chrysler, the Department of Commerce, the Council of Wage and Price Stability, Daimler-Benz, Fiat and General Motors -- all suggested that EPA underestimated the cost of turbocharging a light-duty diesel.

Analysis

EPA originally estimated the cost of turbocharging to be $145-$185, depending on the size of the engine. Most of those who commented in this area submitted cost estimates of their own. These are shown in Table V-12. In addition, some commenters presented explanations as to why their estimated costs were higher than the EPA's.

General Motors stated that the increased cost was due to the omission of six items by EPA:

1) Engine modifications (additional oil distribution to pistons and rods);

2) Revised fuel control (variable control capability);

3) Turbocharger mounting provisions;

4) Exhaust system design change requirements to operate the turbocharger unit;

5) Increased cooling capacity; and

6) Additional assembly.

General Motors did not estimate the cost of any of the six items. They appeared to agree that EPA adequately estimated the cost of the turbocharger but omitted the cost of additional items.

Chrysler provided a breakdown of their cost estimate. This breakdown is shown in Table V-12 along with their total estimated cost of $325.

Fiat stated that a number of modifications were required in addition to the turbocharger unit itself. A different injection

Table V-12

Estimated Cost of Turbocharging a Light-Duty Diesel

Source	Cost
EPA	$145-185
General Motors (large engine)	$330
Chrysler	325
Turbocharger	243
Oil line and other plumbing	27
New injection pump configuration	9
Manifold and exhaust transition	46
Fiat	300-350
Daimler-Benz	333-500 1/
Volkswagen	450-500 2/

1/ Estimated cost to consumer buying whole vehicle. Aftermarket cost was reported by Daimler-Benz to be $1,000.

2/ Taken from the comments of the Council of Wage and Price Stability, who quoted Philip Hutchison of Volkswagen, March 23, 1979.

system would be necessary along with a boost pressure element. A waste gate would be required as is a differently-designed piston due to the increased thermal load. Finally, a water/oil heat exchanger would be required for further cooling of the engine oil. As in the case with General Motors, no attempt was made to separate the cost of each of these items.

The only elaboration made on their estimate ($1,000) by Daimler-Benz is that it is the cost of a turbocharger on a replacement engine. As replacement or aftermarket costs are generally 2 to 3 times the allocated cost to the buyer of the whole vehicle, their estimate of $1,000 translates to a $333 to $500 cost to the consumer who buys a turbocharged diesel.

Volkswagen did not elaborate on the breakdown of their cost estimate.

The original EPA estimate was based on a $90 turbocharger unit cost to the manufacturer from the supplier. A factor of 1.6 was used to adjust for mounting, assembly, inventory, etc. In addition, 10-25% ($15-40) was added for additional plumbing and size required for 6- and 8-cylinder engines. It is difficult to revise this estimate using the methodology outlined in the previous discussion of trap-oxidizer costs because of the lack of detailed cost information available to EPA in this area. The manufacturers' estimates do not include the necessary detail to include them easily into such a methodology. Fortunately, the importance of the cost of turbocharging has greatly diminished as EPA no longer expects turbocharging to be widely used as a particulate control technique (see Section II, Technology). However, some effort will still be made to reconcile EPA's original estimate with those of the manufacturers.

The cost of the turbocharger itself from the vendor was $90 in 1978.11/ None of the comments have given sufficient evidence for not accepting this figure. As this is a 1978 cost, it should be adjusted for one year's inflation (8%) to $97. The cost of bolting and connecting the turbocharger to the engine should be minimal, about $1 per engine. This is supported by vehicle assembly costs for manifolds and catalysts, which average about $0.20 per vehicle at the vendor level.12/ Thus, at the vendor level, the turbocharger unit should cost $98. To convert this to a retail cost, it needs to be increased by a factor of 1.277 (see part A, Trap-Oxidizers in this section). At the corporate level, the cost would then be $125 per vehicle. As the original $90 turbocharger cost

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11/ "Ford Buying Garrett Turbos," Automotive News, April 17, 1978.

12/ "Cost Estimations for Emission Control Related Components/ Systems and Cost Methodology Description," Rath and Strong for EPA, March 1978, EPA 460/3-78-002.

was for a 4-cylinder engine, some allowance should be made for higher costs for larger engines. A factor of 1.15 will again be used for 6-cylinder engines, and 1.25 will be used for 8-cylinder engines. This results in costs of $144 and $156 per turbocharger for 6- and 8-cylinder engines, respectively.

With respect to the cost of engine modifications necessary to accomodate the turbocharger, little data is available. General Motors listed some modifications, but did not provide the separate cost of any of them. Chrysler presented essentially the same list of necessary modifications, but did include their individual costs. As EPA agrees that these modifications (see Table V-12) are necessary and no other cost data are available except that submitted by Chrysler, the Chrysler data will be used subsequently. It will be assumed that the Chrysler costs include overhead and profit. Thus, the cost of oil lines and other plumbing, a new injection pump configuration, and modifications to the manifolds and exhaust systems should cost $82 per engine.

The total cost of turbocharging an engine is then $207 for a 4-cylinder engine, $226 for a 6-cylinder engine, and $238 for an 8-cylinder engine. While these costs are still lower than those submitted by the manufactures, the lack of detail of the submitted estimates prevents them from being used to further adjust the above cost estimates.

Comment

The Council of Wage and Price Stability -- claimed that the turbocharger would need to be replaced once during the life of the vehicle.

Analysis

The Council was the only organization to bring up this point. None of the auto manufacturers disagreed with EPA that the turbocharger would last the life of the vehicle. It is actually unlikely that a manufacturer could sell a turbocharged vehicle if their customers knew that they would have to pay at least $500 (aftermarket price) for a new turbocharger after only 50,000 miles. Also, there is no indication from the maintenance schedules of current turbocharged light-duty vehicles (gasoline or diesel) that the turbochargers will not last the life of the vehicle.

The logic used by the Council was that turbochargers are analogous to fuel and water pumps, which typically require replacement once during the life of the vehicle. However, there is not much in common between the devices, except that all are fluid pumps. Fuel and water pumps generally cost less than $20 (retail price equivalent) and their construction, durability, and quality reflect their cost. A turbocharger costs $270, more than 10 times more than the other two pumps. Its quality and durability are reflected by its cost. Thus, EPA should hold to its position that turbochargers will last the entire life of the vehicle.

Comment

Chrysler and General Motors -- stated that the fuel economy benefit of turbocharging was only 4%.

Volkswagen -- stated that turbocharging would increase fuel economy 10%.

Ford and the Department of Energy -- agreed with EPA that turbocharging could increase fuel economy 8% if accompanied by adjustments in the axle ratio.

Fiat -- stated that turbocharging could increase fuel economy particularly if drive line parameters were optimized.

Analysis

It is obvious from the above comments that there is not total agreement on the effect of turbocharging on fuel economy. To determine the best estimate of this effect, it will be necessary to analyze the data made available by these manufactaurers. The manufacturers will be discussed in order of their estimates, beginning with the lowest.

Chrysler did not support their estimate with any test data of their own. They did use a computer model to simulate a turbocharged diesel with drive line optimization. The results were a 3% increase in fuel economy for a large vehicle and a 6% increase for a small vehicle. The latter vehicle configuration included a fifth-gear so extreme that adequate driveability was questionable. They also quote EPA's data on two Mercedes vehicles showing a 5.5% fuel economy increase. Chrysler counters EPA's data on two Volkswagen vehicles (24% fuel economy increase) by quoting data which Volkswagen submitted to the Department of Transportation showing a 2% decrease in fuel economy with turbocharging. This last modification, however, did not increase the maximum fuel rate, nor include any changes to the drive line, and is really not indicative of a turbocharged vehicle as it would be marketed. It also conflicts with the data Volkswagen themselves submitted which will be shown below.

General Motors provided some test results in support of their estimate. The first set of tests examined the effect of adding a turbocharger to an engine with no changes to the drive train of the vehicle. These four vehicles averaged a 3% decrease in fuel economy with turbocharging, but also averaged a 30% decrease in 0-60 mph acceleration time. Thus, the performance of the turbocharged vehicle was greatly improved over those equipped with naturally-aspirated engines.

A second data set of three vehicle sets examined the effect of a turbocharger without modifying either the maximum fuel delivery or the drive train. As would be expected, due to the increased backpressure caused by the turbocharger, the fuel economy decreased 6% with turbocharging. Since vehicles would not likely be marketed with these constraints, this data is of questionable value in this analysis.

A third set consisted of a single test of a vehicle equipped with the naturally-aspirated 5.7-liter diesel and a single test of the same type of vehicle equipped with a turbocharged 4.3-liter diesel. The fuel economy of the turbocharged version decreased 0.5% while 0-60 mph acceleration time improved 6.5%.

The last set of data examined the effect of drive train modifications on the fuel economy of one of the turbocharged vehicles which was tested as part of the first data set. A decrease in rear axle ratio from 4.15 to 3.34 increased fuel economy 4.5 miles per gallon or 13.5%. The data from this data set and that from the first data set is shown in Table V-13. The first step of adding the turbocharger showed a 7% decrease in fuel economy with a 26% decrease in 0-60 mph acceleration time. With the additional change to a 3.34 axle ratio, however, overall fuel economy improved 6% while the 0-60 mph acceleration time still decreased 10%. General Motors identifies this as a reasonable change in axle ratio.

Fiat submitted both data and modeling results indicating the effect of turbocharging on fuel economy. Their data is shown in Table V-14. The actual data compares a naturally-aspirated engine with an axle ratio of 3.2 (standard for that model) to a turbocharged engine with an axle ratio of 2.6. The turbocharged version gave a 5% increase in fuel economy with a 22% decrease in 0-60 mph acceleration time. The computer model predicted an 8% increase in fuel economy. The model was then used to predict an axle ratio reduction to 2.4 for the turbocharged version, which still provided much improved performance over the naturally-aspirated version. This change in axle ratio increased fuel economy an additional 6% or 2.1 miles per gallon.

To obtain the combined effect of turbocharging and axle ratio, the actual data and modeling must be combined. Even though the actual data only consisted of one test, it will be used instead of the modeling results (for the turbocharging step). From Table V-14 then, turbocharging and a decrease in axle ratio to 2.6 improved fuel economy 1.7 miles per gallon. A further decrease in axle ratio to 2.4 improved fuel economy 2.1 miles per gallon. Overall, fuel economy improved 3.8 miles per gallon or 11%, while performance was still improved.

Table V-13

The Effects of Turbocharging and Rear-Axle Ratio on Fuel Economy and Performance

Pre X-Car with Opel Diesel

Engine Configuration	Rear Axle Ratio	Composite Fuel Economy (mpg)	Acceleration Time 0-60 mph (seconds)
Naturally-Aspirated	4.15	35.7	19.9
Turbocharged	4.15	33.3	14.7
	3.74	34.6	17.2
	3.34	37.8	18.0

Table V-14

Effects of Turbocharging and Axle Ratio on Fuel Economy and Performance

Fiat 131 - Modeling Results

Engine Configuration	Rear Axle Ratio	Composite Fuel Economy (mpg)	Acceleration Time 0-60 mph (seconds)	Acceleration Time 1 Km 1/ (seconds)
Naturally-Aspirated	2.8	37.9	18.1	39.6
	3.0	36.4	17.9	39.5
	3.2 2/	35.0 (34.6) 3/	17.7	39.4
Turbocharged	2.4	39.8	13.9	36.1
	2.6	37.7 (36.3) 3/	13.8	35.9
	2.8	35.7	13.7	35.9

1/ Standing start.
2/ Standard configuration.
3/ Actual data.

Ford presented one data set from their own testing which compared the fuel economy effect of turbocharging without a change in the axle ratio. These tests on an Opel showed a 2% increase in fuel economy while performance was not measured. They quote Volkswagen data on a Rabbit showing a 10% increase in fuel economy with turbocharging and a decrease in axle ratio from 3.9 to 3.6. They also quote the Fiat data, which has already been discussed. Finally, Ford quotes a study performed by Ricardo on a Mercedes-Benz 300D. The fuel economy decreased 7.5% with no change in the axle ratio. As the commercial Mercedes-Benz 300SD has consistently shown 5-6% better fuel economy than the 300D with a heavier vehicle and improved performance, this last result appears anomolous and will not be considered any further.

The Department of Energy submitted no data to substantiate their estimate. They only stated that they had examined the data available at that time, which was likely most of what is being shown here. They did add the qualification to their 8% estimate that it would include a weight reduction due to the use of a smaller (though more powerful) turbocharged engine.

Finally, Volkswagen did not submit any data in addition to that quoted by Ford.

To summarize all this data, it will be important to be consistent in the hardware changes which are affecting the fuel economy. Because a turbocharged diesel can be equipped with a lower axle ratio to improve fuel economy, without a degradation of performance below that of the naturally-aspirated engine, that is the configuration that will be compared. It is recognized that the axle ratio does not have to be lowered, and that a performance improvement can result. However, it is difficult to put a value on performance so the maximum fuel economy case is most appropriate for this discussion. Table V-15 shows the estimates of the various groups and the results of their data.

The single datum, representing the lower limit of the range of General Motors' data, shows no improvement with a smaller turbocharged engine at equal performance and appears quite suspect in the midst of all of the other data. At the same time, the largest improvements have all occured on small vehicles (VW, Fiat). Noting that the improvement on a Mercedes 300D (4000 pounds) was 5.5%, a reasonable average should be between 5.5% and 10-11%. A simple arithmetic average would be 7.75-8.25% or about 8%. Since this was EPA's original estimate, no change should be required in this area.

Comment

The Council of Wage and Price Stability -- suggested that EPA use a 5% discount rate for fuel costs rather than not discounting these costs at all.

Table V-15

Fuel Economy Improvements Due to Turbocharging

Organization	Estimate	Result of Data
Chrysler	4%	3 - 6%
General Motors	4%	0 - 6%
Fiat	--	11%
Department of Energy	8%	--
Ford	8%	10-11%
Volkswagen	10%	10%

1/ Quote of Fiat and Volkswagen data.

The Department of Commerce -- suggested that EPA's projection that fuel prices would rise 10% faster than the general price index was 'draconian'.

Analysis

A 10% discount rate was used in the Draft Regulatory Analysis for all costs and savings except those involving petroleum-based fuel; in this case, diesel fuel. It was projected that diesel fuel prices would rise 10% faster than the general price index per year, and to account for this , no discount rate was used.

Adjusting discount rates is a shorthand technique to account for cases where inflation is not expected to occur equally for every item under consideration. A technique which is perhaps more straightforward, but which requires more computation would be to inflate the fuel costs or savings first, by the difference between the projected inflation rate for fuel and that for all other goods, and then discount all costs by the same discount rate, in this case 10%. To illustrate the difference between the two techniques, an example is given below.

Example: The annual inflation rate of most goods is assumed to be 5% over the next 15 years. Fuel prices, however, are assumed to increase 12% per year over the next 15 years. A man owns a tractor and expects to have maintenance fees of $100 per year (1979 dollars) in 1979, 1980, and 1981. He also expects to spend $600 per year for fuel (1979 dollars) over the same three years. He desires to determine the present value (1979) of these expenditures. A 10% discount rate will be used. The maintenance costs can be discounted directly and added to receive the total, $273.55. The fuel costs should first be inflated to $600 (1979), $640 (1980) and $682.67 (1981) using the ratio of the inflation rates of fuel and other items (1.12/1.05). These inflated costs can then be discounted back to 1979 and added to equal $1,746.01. Adding the maintenance and fuel costs yields $2,019.56.

The shorthand technique would combine the excess inflation rate of fuel and the discount rate to arrive at a special discount rate for fuel. This can be done in one of a few ways. For complete accuracy, the discount rate, plus one (1.10) can be divided by the inflation rate for fuel plus one (1.12) and then multiplied by the general inflation plus one (1.05). Subtracting one yields a special discount rate for fuel of 3.125%. Now calculating the present value again, the total maintenance costs remain at $273.55. The fuel costs of $600 in 1979, 1980, and 1981 are now discounted at a rate of 3.125%. The result is a present value of total fuel costs of $1,746.01, or the same value as that calculated above.

An ever simpler method, though slightly less accurate, is to subtract the excess inflation rate (determined by subtracting the general inflation rate from the inflation rate for fuel) (7%) from the discount rate (10%). This method yields a special discount rate of 3%. The difference between the two shorthand techniques is only 0.12% per year in this case (1.03125/1.03). For the purposes of this analysis and the Regulatory Analysis, the latter shorthand technique will be used.

The Council of Wage and Price Stability believed that a 10% difference between the inflation rate of diesel fuel and the general inflation rate was too high. They performed an analysis of these two inflation rates between February 1973 and February 1979. This analysis showed the price of diesel fuel to be rising about 3% faster than the general price index (10.8% compared to 7.9%). The Department of Commerce simply stated that it was "draconian" to assume that the price of diesel fuel would rise 10% faster than the general price index, but gave no support to their statement.

The Council's analysis and recommendation appears to be very reasonable. Since the conclusion of that analysis, however, the price of diesel fuel has risen from $0.527 per gallon (February 5, 1979) to $0.869 per gallon (June 25, 1979).13/ Incorporating this time period into the Council's analysis results in a 19.0% annual compounded inflation rate. If a 1% per month inflation rate for the general price index since February 1979 is assumed, the annual inflation rate for the general price index between February 1973, and July 1979 is 8.2%. The difference between inflation rates now becomes 10.0% (1.19/1.082). This is an increase of over 7% averaged over the 6.5-year period due to the increase in fuel prices over the last five months.

From their analysis, the Council had suggested a 5% difference between the general discount rate and that for fuel. From the results of the last paragraph, the 10% difference may be justified after all. However, the latter analysis does include a period of extremely-high inflation of fuel costs right at the end of the period in question. This has a tendency to overemphasize that period if the trend does not continue. It is unlikely that the Council did not foresee the most recent price increases, but still believed that over the long term a 5% difference would be the most accurate. Given that it is a compromise between the 2.7% difference through February 1979 and the 10% difference through July 1979, EPA will accept their suggestion. The Regulatory Analysis should use a 5% discount rate for fuel costs and a 10% discount rate for all other costs.

C. Other Engine Modifications

13/ Barbara O'Connor, Interstate Commerce Commission, June 27, 1979.

Comment

General Motors -- claimed that EPA's estimate of $1 per vehicle for minor combustion chamber modifications is very optimistic.

By minor combustion chamber modifications, EPA means small changes to the chamber geometry, nozzle configuration, piston configuration, etc. None of these changes should require the addition of any items or hardware to the engine, only the redesign of existing items. As such, EPA does not expect the cost of the redesigned item to be any more than the existing item, with the exception of the research, development and tooling costs involved in making the change. These costs (per vehicle) are very dependent on the number of years over which they are amortized. It would be convenient to amortize the cost over the three model years which have to meet the 0.6 gram per mile standard. Even though these engine modifications will likely continue past 1983, it will simplify the cost calculations to have the costs paid off by the time the second standard becomes effective.

With two or three year's production over which to amortize the costs, the cost per vehicle should be no more than $10. This would provide General Motors over $6 to 9 million in 1980 for research, development, and retooling, depending upon the implementation dates of the standards and assuming a discount rate of 10 percent and that funds obtained from a model year's sales are not available until December 31 of that year. The sales figures used were those outlined in part c) of the Environmental Impact section of this document with an annual increase in sales assumed to be 2% over 1978 sales.

As General Motors did not present an estimate of the cost themselves, the $10 per vehicle estimated in the above paragraph should be used in the Regulatory Analysis.

D. Test Equipment and Testing

General Motors -- "Facility modification costs are five times higher than predicted by EPA...GM's estimated costs are as follows:

Facilities Modification Costs .

CFV-Tunnel System		$62,500
600 cfm CFV	$53,000	
Dilute Exhaust System	$ 9,500	
. Particulate Sample System		20,000
. Computer System Modification		95,000
. Gaseous System Modifications		13,000
Cost per Site		$190,500
. Particulate Weighing Facility and Equipment		42,000

Additional Cost Per Facility	42,000
Cost to General Motors - 24 Sites at 13 Facilities	$5,118,000"

Analysis

A close review of the site cost numbers would indicate General Motors' intent to highly automate their particulate sample system. This is especially apparent from their cost estimate of the particulate sample system ($20,000) and the computer system modification ($95,000). This is further confirmed by their proposal to use a regulated or servo-controlled particulate sample system. Such sophisticated automation and control will quickly add cost to a test site, and are really discretionary costs. Further, there is no justification for the $13,000 gaseous system modification to be attributed to particulate-related modifications.

EPA cost estimates were for a more basic system without substantial automation. Using this philosophy, the General Motors cost estimates would reduce to the following:

Facilities Modification Costs

. CFV-Tunnel System		$62,500
600 cfm CFV	$53,000	
Dilute Exhaust System	$ 9,500	
. Particulate Sample System		10,000
. Computer System Modification		--
. Gaseous System Modifications		--
Cost Per Site		$ 72,500
. Particulate Weighing Facility		42,000
Additional Cost Per Facility		42,000
Cost to General Motors - 24 Sites at 13 Facilities		$2,286,000

These revised per-site costs and per-facility costs are more in line with EPA's own updated cost estimates. These updated cost estimates are as follows:

. CVS (600 cfm) including heat exchanger plus	$38,100
. Dilution Tunnel	10,000
. Particulate Sample System	7,000
Cost Per Site	$55,100
. Microgram Balance	10,000
. Weighing Chamber	20,000
Cost Per Facility	$30,000

EPA concludes from these revised and updated cost estimates that while General Motors may intend to spend $190,500 for each site and $42,000 for each facility, much of the expense is discretionary. General Motors could only make these expenditures because the manpower requirements for testing would be reduced to the point that overall costs would be minimized. Over a longer period of time, an automated system will actually lower the overall cost of testing. However, this savings has not been reflected in any of the above equipment costs. If GM does not believe these extra expenditures will not pay for themselves eventually, EPA can only assume they will not actually proceed with the extra features.

Comment

International Harvester -- "EPA's Draft Regulatory Analysis dated December 22, 1978, indicates that these regulations will add $562.69 to the cost of our diesel-powered Scout as follows:

	1981-82	1983-85
One Durability Vehicle	$156,000	$156,000
Three Data Vehicles	63,000	63,000
Test Facility	42,300	
	$261,300	$219,000
Cost Per Unit (Five Years)	$90.10	44.69
Hardware Costs 1981	180.00	180.00
1983	--	338.00
Total	$270.10	$562.69 "

International Harvester has also requested that assigned deterioration factors (DFs) be made available for exhaust particulates for low-volume manufacturers.

Analysis

The comment on assigned deterioration factors for low-volume manufacturers has been included in this section because it is coupled to International Harvester's overall cost of testing through their estimate of $156,000 for one durability vehicle in the table.

International Harvester, in the past, has applied for and received assigned deterioration factors (DFs) for gaseous emissions under §86.078-24(e)(4) and §86.078-24(f). Because of the general applicability of §86.078-24 to all regulated exhaust emissions, it was intended that particulate emissions would also be handled under this section. No proposal has been made to revise this section. Hence, International Harvester, or any other manufacturer should be able to continue to apply for assigned DFs under §86.078-24.

It should be noted that International Harvester also requested that EPA consider revising the definition of a low-volume manufacturer from one that estimates a production volume of less than 2,000 units to one that estimates production of less than 10,000 units. This request is beyond the scope of the light-duty diesel NPRM and therefore cannot be treated here. This request will be considered when EPA reviews these provisions of the regulations. As implied earlier, the requirement to run a durability vehicle is not connected to these particulate regulations. If IHC's diesel Scout production exceeded 2,000 units per year, the requirement to run a durability vehicle would exist whether or not this particulate regulation was promulgated. Thus, the cost of running a durability vehicle should not be connected with this regulation.

The only exception could be the first year of the second standard, 1984, when a change in the particulate standard might necessitate the running of a durability vehicle. Even this requirement hinges on IHC's diesel Scout production being over 2,000 units per year. As can be deduced from IHC's calculations above, they have used a 3-year production total (1983-85) of 4,900. This total should not result in a requirement to run a durability vehicle and the $156,000 cost should not be included. In Part A of this section, however, EPA did project IHC to produce about 8,000 vehicles over this 3-year period, which would require a durability vehicle. However, the cost would then be spread out over more vehicles and the cost per vehicle would be less. The certification and test facility costs under both these situations are shown below. The costs being used are those from the NPRM unless modified in previous sections.

	Low Sales	High Sales
1982-83		
Three Data Vehicles	63,000	63,000
Test Facility	85,000	85,000
1984-85		
One Durability Vehicle	--	156,000
Three Data Vehicles	63,000	63,000
Total Cost	$211,000	$367,000
Total Sales (5 years)	8,000	21,000
Cost Per Unit	26	17

As can be seen, neither of these costs is very high, likely being less than 0.5 percent of the price of a Scout. After the 5-year payout period is over, these costs will decrease to zero.

Further, the $338.00 that IHC attributed to 1983 hardware costs is really the total of the 1981 and 1983 hardware costs. The 1983 line should have read $158.00 (estimated for trap oxidizer) and IHC's hardware costs become the same as those for the other manufacturers. From the analysis in the previous three parts of this section, it is evident that all of the projected costs of the two standards should be adjusted for the final analysis. However, this does not change the outcome of the analysis above. IHC's costs per vehicle should be very close to those for the other manufacturers. The only exception could be the trap-oxidizer cost (see Part A of this section) if IHC decided to produce its own traps. However, given the economics and that IHC does not produce its own catalysts for its gasoline engines, which have a higher sales volume, this is unlikely. Thus, EPA concludes that International Harvester has substantially overestimated the additional cost to the Scout and that their costs are not out of line with those of other manufacturers.

E. Cost Effectiveness

Comment

The Council of Wage and Price Stability -- stated that the marginal cost effectiveness of the 1983 standards appears to be too high compared to that of other control techniques.

Analysis

The Council submitted the following table (Table V-16) showing the marginal costs of control of the diesel particulate standards and other control strategies. As can be seen, the 1983 diesel particulate standard is more expensive per ton of particulate reduced than all the others.

EPA believes that the past practice of using a simple cost per mass of pollutant reduced is insufficient to accurately discriminate between choices of control strategies. As the Council's table shows, it is getting expensive to further control particulate emissions. EPA needs to ensure that its programs are positively affecting the health of the nation. To do this, we need to ensure that: (1) ambient pollutant levels being breathed by people are being reduced, and (2) we are controlling emissions which are harmful to health. The simple dollar per ton figures will not allow this to be done.

First, a measure is needed to determine the impact of a regulation on those people living and working in areas affected. This measure should include the number of people affected and the reduction in ambient pollutant levels experienced by those people. The height of the stack or exhaust coupled with the size and density of the particles will affect how long these particles remain aloft and available for inhalation. The height of the stack or exhaust will also affect the impact of that source on air quality. These factors need to be taken into account, but the question remains of how to do it. Two possible methods will be outlined below.

Table V-16

Marginal Costs per Metric Ton of Controlling Particulates (1978 dollars)

Diesel Light-Duty Vehicles		
1981 Standards:	EPA's estimate	$ -160
	CWPS estimate #1	$1,720
	CWPS estimate #2	$4,470
1983 Standards:	EPA's estimate	$3,200
	CWPS estimate #1	$5,500
	CWPS estimate #2	$7,650
Electric Utilities 1/		
NSPS, Eastern Coal:	100 MW Steam Electric	$1,931
	1,100 MW Steam Electric	$2,203
Medium-Size Industrial Boiler, NSPS 2/		$614-1,199
Sewage Incinerators, NSPS 3/		$1,335-2,205
Electric Arc Furnaces, NSPS 3/		$2,095
Kraft Pulp Mills, NSPS 4/:		
Recovery Furnace		$385-781
Smelt Tank		$259-344
Lime Kilns, NSPS 5/:		
New		$3,120
Retrofit		$1,750

1/ PEDCO, "Particulate and Sulfur Dioxide Emission Control Costs For Large Coal-Fired Boilers," Reported prepared for EPA, OAWM, OAQPS, Research Triangle Park, N.C., February 1978.

2/ Industrial Gas Cleaning Institute, "Particulate Emission Control Costs for Intermediate-Sized Boilers," Report prepared for EPA, SASD, EAB, Research Triangle Par, N.D., February 1977.

3/ "Draft Regulatory Analysis," p. 88

4/ EPA, OAWM, OAQPS, "Standards Support and Environmental Impact Statement, Vol. I: Proposed Standards of Performance for Kraft Pulp MIlls," September 1976.

5/ EPA, OAWM, OAQPS, "Standards Support and Environmental Impact Statement, Vol. I: Proposed Standards of Performance for Lime Manufacturing Plants," April 1977.

The first method is an ideal one. It assumes that all necessary information is available. While this is never the case, this method will serve to outline the important features of calculating a true cost effectiveness for the more practical method to follow. The primary principle to keep in mind is that we should be measuring an improvement in people's living and working environment. The state of that environment (for our purposes) is determined by the ambient concentration of harmful pollutants which exist there. From this basic premise, a good measurement of the effectiveness of a regulation can be determined. Assuming linearity holds in the above statements, a figure such as person-concentrations would fulfill the requirements. An illustrative example is given below.

Example: Regulation A will reduce ambient TSP levels by 5 micrograms per cubic meter (annual geometric mean), in areas containing one million people. The effectiveness of this regulation would be 5.0 million person-micrograms per cubic meter (1 million person x 5 micrograms per cubic meter).

This type of analysis would require a good population exposure data base, both before and after regulation to both the source in question, and to TSP levels from other sources in aggregate. Since this information is rarely available, the question is now how to best estimate it, using the information that is available.

This leads us to the second method, which is practical, but approximate. Three factors must be accounted for: source location, height and particle size. Source location is important because it determines how many people are exposed to the source's emissions. Source height is similarly important since it determines the magnitude of the impact on ambient levels. Particle size is important since it determines how long a particle stays aloft where it can be breathed. All of these factors could then be applied to emission reductions, which alone are not a good measure of air quality benefit.

After accounting for these factors, the second step is to adjust for particle characteristics which affect health. The bulk of health effects work now shows that it is the inhalable particles (diameter less than 15 micrometers) that affect health, with the fine particles (less than 2.5 micrometers diameter) probably the most dangerous.14/ Given this knowledge, it is not difficult to see that reducing the ambient level of particulate larger than 15 micrometers will not improve public health nearly as much as an equivalent reduction of inhalable or fine particulate.

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

It is true that the NAAQS for particulate matter is based on measurements of TSP, but this does not affect the results of the above argument. If we know that the fine and inhalable fractions cause the health problems, then bringing the entire U.S. into compliance with the NAAQS by simply reducing levels of particulate larger than 15 micrometers would be complyng with the letter of the law, while providing little, if any, benefit to public health. Thus, the effectiveness of a control strategy should be measured only on an inhalable or fine particulate basis. There is little danger that a disproportionate share of inhalable particulate will be controlled with respect to TSP since the larger particles are almost always the easiest to control, and will be reduced with the smaller ones.

Returning to the comments of the Council of Wage and Price Stability, their table shows the marginal cost effectiveness of a number of particulate standards. As they have added the marginal costs of a few more standards to those that were included in the Draft Regulatory Analysis, they have improved our ability to compare the light-duty particulate standards to other regulations. As they have not incorporated the factors discussed above into their submittal, the table cannot be used as it now stands to compare regulations. The adjustment factors mentioned above will need to be incorporated before any comparison can be made.

Since it is one of the primary purposes of the Regulatory Analysis to perform such comparisons, the adjustment of these values should be left to that document. There, a new cost effectiveness of the final diesel standards should also be calculated, reflecting the comments contained in this document.

Comment

The Council on Wage and Price Stability -- presented a much cheaper alternative control strategy than diesel particulate regulations: more frequent and more thorough cleaning of city streets.

Analysis

The Council cites two reports when discussing this alternative in their comments to the EPA.[15/],[16/] When calculating the cost effectiveness of this alternative, the Council assumes that cleaning streets twice as often will reduce emissions by 50%. A search of these two reports shows that neither one discusses the effect of cleaning on emissions. It is acknowledged that to determine a cost effectiveness that would be comparable to the cost effectiveness of

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15/ "Guidelines for Development of Control Strategies in Areas with Fugitive Dust Problems," U.S. EPA, October 1977, EPA 450/2-77-029.

16/ "Control of Reentrained Dust from Paved Streets," PEDCo Environmental, July 1977, EPA 907/9-77-007.

other strategies listed in the draft Regulatory Analysis, the Council was likely forced to make this type of assumption. The effect on emissions, however, could be as low as zero which will be shown below.

The PEDCo study,17/ included field studies of five cleaning techniques. In the "Summary of Control Measure Evaluations," the report states:

> The relationship between cleaning and subsequent emission rates appears to be complex: emission rates are not directly related to the percent of street surface loadings removed from the traffic lanes (just as emission rates were not found to be closely related to the street surface loadings). Also, the street cleaning studies with streetside samplers tended to show a positive effect from cleaning operations, while those using regional network samplers in general failed to show an impact from street cleaning.

It appears that only flushing (with water) had any consistent positive effect, but then only on the day of flushing. No effect was found on the day after cleaning. The reduction on the day of cleaning averaged 16 micrograms per cubic meter for the two studies in which this was effective. From the above paragraph, this is taken to be a streetside effect, and not a regional effect. Flushing was ineffective in two other studies.

Flushing has an undesirable side effect of increasing the amount of material carried into the sewer, increasing the load on the local water treatment plant. it would seem reasonable to estimate that any reduction in emissions to the atmosphere would result in an equal increase in water pollution. The study did not deem this insignificant. Attempts to sweep the gutters after flushing were ineffective.

The latest EPA report in the area confirms these findings.17/ In its summary on relative effectiveness, it rates street cleaning poor and costly. The earlier EPA study15/ acknowledges that intuitively this technique should reduce reentrained dust, but up to now is still unproven. It advises caution be taken before undertaking any studies and that small pilot-scale projects be tested in each city considering this technique to accurately predict its effect. It also mentions that the interest and full support of the local public works department is necessary if any street cleaning problem is to be successful.

17/ "Particulate Control for Fugitive Dust," U.S. EPA, April 1978, EPA-600/7-78-071, pps. 28 & 51.

In summary, it appears that there are still significant problems with street cleaning as a control technique. Its effect on regional TSP concentrations is doubtful. At the same time, there is evidence that if performed correctly in certain areas, it could reduce roadside concentrations significantly. Any decision to move ahead in this area would have to be made at the state and local levels. As such, it is outside of the realm of this regulation or any other nationwide EPA regulation. Due to its lack of effect on a regional scale, and other associated problems, it is not an effective alternative to this rulemaking action, and will not be considered further.

E. Recommendations

The following changes should be made as a result of comments on the economic impact of this proposed regulation:

1) The estimated cost of a trap-oxidizer should be increased to \$189-224 (1984) and \$128-152 (1988) from the original estimate of \$114-157, plus a \$30 maintenance fee and an \$80 maintenance credit (exhaust pipe and muffler) occurring after 5 years.

2) The estimated cost of turbocharging should be increased to \$207-238 per vehicle from \$145-185 per vehicle, and the fuel economy improvement due to turbocharging should remain unchanged at 8 percent.

3) A 5 percent discount rate should be used for fuel costs, and a 10 percent discount rate for all other costs.

4) The estimated cost of minor combustion chamber modifications should be raised to \$10 per vehicle, from \$1 per vehicle.

5) The estimated cost of test equipment modifications should be increased to \$55,000 per test cell plus \$30,000 per facility, from \$40,000 per test cell plus \$8,000 per facility.

6) The simple dollar per ton measure of cost effectiveness has been shown to be inadequate for the area of particulate emissions. A comparison of the cost effectiveness of appropriate alternative strategies should be performed in the Regulatory Analysis using more sophisticated techniques.

7) Street cleaning should be rejected as a cost-effective alternative control strategy because of questionable effectiveness and cost on a regional scale.

VI. Alternative Regulatory Approaches

In the NPRM, EPA invited interested parties to comment on alternative regulatory approaches.

A. Smoke Standards

Comment

American Motors -- "Because of the complexity, cost, and leadtime associated with this procedure, other alternative methods should be explored such as smokemeters which could serve as an interim standard and satisfy the CAA requirements for the 1981 model year."

Analysis

The Clean Air Act explicitly mandated control of particulate emissions. While smoke standards would likely result in some control of diesel particulate, EPA does not consider smoke opacity to be a good indicator of particulate emissions. The smoke opacity of an exhaust stream is primarily a function of the optical properties of the particulate, rather than of the mass or quantity of the particles in the exhaust stream. It has been shown, for example, that while particulate is emitted under all engine operating conditions, smoke opacity is generally very low except under full load conditions. Smoke opacity is a measure of the visible particulate, and as such is appropriate for a standard based on aesthetic considerations. It is not a valid parameter for a standard based on total particulate emissions and public health considerations.

B. Corporate Average Particulate Standard (CAPS)

Comments

General Motors -- "[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."

Council on Wage and Price Stability -- "This [EPA] form of standard has the following major drawback: if a manufacturer produces different diesel models which have different costs of meeting an established standard, this form does not permit any trading-off of low cost means of control against high cost means of control across different vehicles....Regardless of the level of stringency chosen for the diesel particulate standard (in terms of grams per mile), a sales-weighted average approach means lower costs of compliance as compared to the EPA's proposed approach; the sales-weighted average approach would always be more cost-effective....Our recommended sales-weighted approach is currently applied in the automotive fuel economy area; it is also analogous to the bubble concept for consolidated facilities that EPA has put forth in recent months.... We believe that diesels are different enough from gasoline powered cars that the standard and CAPED [Corporate Average Particulate Emissions from Diesels] should be limited to diesels."

Volvo -- "In principle, Volvo supports the "bubble" concept of emission standards exemplified by the General Motors "CAPS" proposal....Volvo would expect to be able to comply with the GM CAPS scheme."

Ford -- "[GM's proposal contains] some potential sources of problems which should be carefully assessed and resolved before taking any action. For instance, the GM CAPS proposal could be interpreted to require exhaust particulate determination for all vehicles, including those powered by gasoline engines; such an interpretation would result in an unacceptable increase in certification workload. [It] might introduce difficulties associated with "mix management" of a manufacturer's total product offerings. At any rate, if the proposals were accepted, for the sake of consistency, consideration must also be given to the adoption of an equivalent averaging scheme for the currently regulated HC, CO, and NOx emissions."

Department of Energy -- "Averaging of particulate emissions over a number of vehicles (new and in-use, gasoline and diesel) as proposed by one manufacturer and discussed in the hearings has a number of economic, legal, and environmental implications which would require greater exploration prior to any adoption of this approach....If such a proposal is considered, it would require a new rulemaking procedure to allow all interested parties an opportunity to comment specifically on that proposal."

Volkswagen -- "Volkswagen wishes to emphasize the following: a) Introduction of a CAPS-concept would result in a restriction of the diesel-content in the fleets sold by all manufacturers. We strongly believe that such a restriction is clearly beyond EPA's statutory authority. While Congress authorized EPA to set up technologically feasible standards for particulate emissions, certainly it did not authorize EPA to limit the percentage of diesels sold by a manufacturer; b) The CAPS concept starts from the assumption that particulate emissions from gasoline-fueled vehicles are zero. This assumption is known to be incorrect. We believe that EPA cannot issue certificates of conformity based upon such false assumptions; c) The CAPS concept is anticompetitive because it favors big manufacturers with large gasoline-fueled fleets. Smaller manufacturers selling the same number of diesel vehicles as a big manufacturer would have to apply more advanced technology on their diesel vehicles just because they [sell] fewer gasoline-vehicles."

Peugeot -- "In principle, we cannot agree to this approach for the following reason: For 1977 calendar year, our market share in the U.S. for diesel vehicles was 52% and was 66% in 1978. We have no reason to believe that this percentage will decrease in the next years. In those conditions, in 1981, to meet GM CAPS of 0.2 gpm, Peugeot diesel vehicles would have to be lower than 0.33 compared with 0.6 gpm in the NPRM of EPA. In 1983 to meet the GM CAPS of 0.1 gpm, Peugeot would need to be lower than 0.17. If that proposal is adopted, Peugeot diesel vehicles will be excluded from U.S. market, even though particulate levels of our cars will be lower than those of GM... We feel our position is probably the same that any manufacturer with a high sales percentage of diesel vehicles."

Associate Professor Edward J. Farkas, University of Waterloo -- "In my opinion the corporate overall standard approach is very undesirable for several reasons: 1. It does not meet the elemental criterion of fairness. It means that certain motorists will drive dirtier cars than other motorists. If motorists see the dirtier cars as more desirable, or if it is more expensive, it means that what are in effect privileged motorists will be driving the dirtier cars. 2. Surely the enforcement of a corporate overall standard is much more complex, both for the manufacturer and for the EPA, than a standard that simply says that each vehicle must emit a certain number of grams per mile or less."

Citizens for Clean Air, Inc. -- "We concede that the fleet averaging concept would allow the manufacturers some flexibility in marketing. However, it would also allow for the possibility of concentrated operation of high-emitting diesel vehicles in densely populated urban areas such as mid-town Manhattan. There would be an immediate economic incentive for diesel taxis and jitneys if a 1 gpm standard were adopted and full-sized diesel vehicles became readily available for this application."

Natural Resources Defense Council -- "Under the GM proposal, its light-duty diesel vehicles would have average particulate emissions of 1.0 gpm by 1981, 0.5 gpm by 1985, and 0.2 gpm by 1990. This would allow light-duty diesel vehicles to emit 66% and 150% more particulate in model years 1981 and 1983 respectively than would be allowed even under the EPA standard as proposed... Section 202 of the Clean Air Act Amendments of 1977 states that the regulations are to require the greatest degree of control achievable through the application of technology available in the model year to which the standard would apply. A lesser degree of control such as that proposed by GM to ensure greater flexibility to the manufacturers is clearly not acceptable under the Act."

Analysis

There are two primary advantages of an emission averaging 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 having to design each engine family so that it can certify at or below the emission standard, the manufacturer only has to conform to the requirement that its sales-weighted average emission level is 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 able to optimize its control technology strategies with respect to economics; as the Council on Wage and Price Stability pointed out, it may quite likely be more cost-effective for the manufacturer to control one engine family to a very low emission level while controlling a second engine family correspondingly less, than to control every engine family to the very same level. Two different averaging approaches were proposed during the comment period. General Motors suggested a plan whereby the sales-weighted average of a manufacturer's diesel and gasoline fleet would have to be equal to or less than the Corporate Average Particulate Standard (CAPS). Volkswagen suggested a similar plan but which would incorporate only diesel vehicles; this Diesel Average Particulate Standard (DAPS) is discussed later in this section.

We agree with GM that an additional positive aspect of the CAPS proposal is that it would put a "lid" on diesel particulate emissions. Once a manufacturer reached approximate equilibrium with the CAPS, any increase in the number of diesels sold by that manufacturer would have to be accompanied by a corresponding reduction in particulate emission 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.

As the above comments indicate, there are many concerns about the CAPS proposal. Volkswagen and Peugeot both pointed out that the concept allows manufacturers who produce larger quantities of gasoline-fueled vehicles to market higher particulate-emitting diesels than manufacturers who sell fewer gasoline-fueled vehicles. Mercedes (who expressed opposition to CAPS at the public hearings) and Peugeot would be the manufacturers most affected as both manufacturers presently sell about 65 percent diesels; for these two manufacturers GM's proposal would be much more stringent than the standards EPA is promulgating. GM suggested two possible solutions to this dilemma in its comment: 1) a period of exemption from the standards for certain manufacturers and 2) a provision allowing these manufacturers to "obtain" additional particulate emission tonnage from other manufacturers not using their allotments. We find neither of these solutions to be promising at this time.

Citizens for Clean Air commented that GM's maximum particulate ceiling of 1.0 gpm (0.62 g/km) could allow the possibility of localized particulate impact problems in certain cities, neighborhoods, or roadways which might have an unusually high concentration of high particulate diesels. One likely possibility here would be the dieselization of the New York City taxi fleet.

Associate Professor Farkas commented that enforcement would likely be complicated under an averaging approach. Our preliminary analysis of this issue confirms his suspicion. The approach that has been recommended by GM would involve 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 the CAPS to the manufacturer's projected corporate average particulate level. Thus, if the CAPS was 0.10 g/mi (0.062 g/km), and the manufacturer's projected corporate average particulate level was 0.08 g/mi (0.050 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 the appropriate 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 enforcement on an engine family basis 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 manufacturer's projected sales. Yet any final determination of the safety factor would not be possible until the end of the model year, when the actual 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 the manufacturer's production distribution, 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 be exceeding the CAPS. A changing production distribution, and thus a changing safety factor and enforcement level, could also portend the scenario where an engine family would be declared to be in compliance immediately following an SEA test, but could be in noncompliance later in the model year. These two examples briefly illustrate the difficulties inherent in attempting to enforce on an engine family basis when the standard is fixed only on a fleet-wide basis.

Volkswagen and the Natural Resources Defense Council (NRDC) both claimed that the CAPS approach could not be promulgated within the authority given to EPA by the Clean Air Act. Volkswagen asserted that CAPS would restrict dieselization and the NRDC felt that CAPS would not provide the "greatest degree of emission reduction achievable." Finally, Volkswagen and Ford commented on the problem of how to handle gasoline-fueled vehicles under a concept which averages together the particulate levels of both diesel and gasoline-fueled vehicles. All of these concerns are being scrutinized.

EPA is seriously evaluating GM's CAPS proposal and is analyzing the various concerns delineated above. A more complete evaluation of the concept should appear in the final Regulatory Analysis. Regardless of the final evaluation, we agree with the Department of Energy that should EPA decide to support an averaging approach, a new rulemaking procedure would be necessary. EPA certainly could not finalize what it has not officially proposed.

C. Diesel Average Particulate Standard (DAPS)

Comments

Volkswagen -- "This VW proposal suggests a standard applicable to the average diesel particulate emissions of each manufacturer's fleet of all diesel light duty vehicles. We suggested calling this standard the Diesel Average Particulate Standard (DAPS). It is similar in design to the Average Fuel Economy Standard. 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."

Council on Wage and Price Stability -- "One specific program that merits consideration is the following: whatever the standard EPA chooses would be established as a Corporate Average Particulate Emissions from Diesels (CAPED) standard. We believe that diesels are different enough from gasoline powered cars that the standard and CAPED should be limited to diesels. At the completion of the certification testing of the 50,000 mile durability fleet, each manufacturer (or EPA) would establish a limited number (say, five to ten) of categories of diesel cars for the purpose of particulate emissions control and would establish a separate particulate standard for each category. Each model assigned to a given category would not be allowed to exceed the standard established for that category. The 4000 mile emissions data fleet could be certified in this fashion. EPA's Selective Enforcement Auditing of assembly line vehicles would use these category standards, as would any warranty or recall action. At the end of the model year, compliance would be judged by whether the manufacturers' CAPED--the sales-weighted average of emissions (sales in each category multiplied by that category's emissions standard, divided by total corporate diesel automobile sales)--was at or below the overall standard. If the CAPED exceeded the standard, the manufacturer would be declared to be out of compliance for that model year, and the penalties of Section 205 of the Clean Air Act could be invoked."

Peugeot -- "As a principle we favour the DAPS concept since it allows a manufacturer a better flexibility as he may find the best compromise between several requirements: emissions, particulates, fuel economy, without any overall change of the total emission impact of the particulates upon air quality. However, before giving our final comment we wish to know the detail of this proposal."

Volvo -- "[W]e do not consider the DAPS and DIPS approach, suggested by Volkswagen, to be acceptable for a manufacturer such as Volvo."

Analysis

As mentioned above, the primary difference between GM's CAPS proposal and VW's DAPS/DIPS proposal is that the latter averages the particulate emissions from diesel vehicles only while the former averages particulate values from diesel and gasoline-fueled vehicles. Otherwise the two proposals share the same philosophical underpinnings, and thus the DAPS/DIPS proposal shares many of the same advantages and disadvantages of the CAPS approach discussed above. It would give the manufacturers more flexibility in complying with the particulate standards, and would permit them to comply in a more cost-effective manner. Alternatively, there are the same concerns about possible localized impact and enforcement problems of the DAPS/DIPS proposal, and the same question of whether such an averaging approach is permissible under the Clean Air Act mandate of the "greatest degree of emission reduction achievable."

We agree with VW that one advantage of their proposal, which only averages diesel particulate levels, is that it is more equitable to those manufacturers who produce significant percentages of diesels. Regardless of how many gasoline or diesel vehicles a manufacturer sells, each manufacturer would have to comply with the same diesel average particulate level. This very characteristic also means that the DAPS/DIPS approach does not put a "lid" on diesel particulate emissions, however, as the CAPS proposal does.

The Council on Wage and Price Stability (CWPS) agrees with VW that an averaging approach should involve diesel vehicles only, but their proposal involves a slightly different enforcement mechanism. While VW proposed an enforcement program very similar to the one suggested by GM, CWPS suggests that the manufacturer or EPA set a limited number of particulate "categories" (apparently not necessarily synonymous with engine familes), each with a separate, fixed particulate standard. These categories would be sales-weighted and averaged at the end of the model year to determine fleet-wide compliance. CWPS suggests that these category standards could be used for SEA as well. The advantage of this approach is that the SEA enforcement levels are fixed, and are not dependent upon the manufacturer's sales distribution or safety margin. It is still possible for a manufacturer to be complying with all of its category standards, however, while being in noncompliance with the fleet-wide average, due to greater than projected production of certain model lines. Still, the CWPS suggestion does eliminate one of the uncertainties involved in the engine family enforcement approach (the likelihood of a changing safety factor) and thus is a contribution to the analysis of the various averaging approaches.

D. Recommendation

EPA should continue to evaluate the various averaging approaches proposed during the comment period, and should include a complete evaluation of them in the final Regulatory Analysis. It must be emphasized again that should EPA decide to propose such an approach, a new rulemaking package would be required to give interested parties the chance to comment on any specific proposal. EPA does not consider smoke standards to be a legitimate alternative approach to diesel particulate standards.

VII. Test Procedure

This section contains the summary and analysis of comments that deal with the proposed test procedure. While General Motors' comments were quite comprehensive, overall relatively few comments were received under ths general subject area. Comments on the major test procedure related items, such as the sample zone temperature specification, hydrocarbon sample temperature specification, filter acceptance criteria, etc., are presented first in the standard format of this document. The more minor items, plus editorial and correcton comments are presented in an abbreviated form at the end of this section (Part M).

A. General Comments

Comments:

General Motors -- "Because of the timetables for test equipment acquisition, we recommend that EPA immediately initiate dialog to finalize the technical details of the proposed measurement system."

Analysis

Dialog concerning the light-duty diesel measurement system was initiated when the Draft Recommended Practice was issued in March, 1978, and continued through the close of the comment period for the proposed regulations. The industry was invited to submit comments on the recommended practice. Comments received were analyzed, and a revised test procedure was issued in October, 1978 in order to provide maximum leadtime in this area. In addition, in January 1979, EPA technical staff requested* General Motors to submit relevant data on several topics related to the diesel test procedure. The light-duty diesel rulemaking process, especially the public hearings (March, 1979) continued the dialog on the measurement system. However, only relatively few comments concerning the measurement system were submitted through these latter mechanisms, even though the industry had from October, 1978 through April 19, 1979, (when the comment period officially closed) to prepare comments on the measurement system. A letter outlining the changes expected to be made to the test procedure in the final regulation was mailed to the industry on July 25, 1979. EPA technical staff concluded that an adequate dialog has been maintained.

Recommendation

None required.

Comments

B. Hydrocarbon Double-Counting

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* Letter from Charles L. Gray, Director, ECTD to Thomas Fisher, Director, Automotive Emission Control, GM Technical Center, dated January 9, 1979.

General Motors and International Harvester -- have commented that the temperature specifications cause some hydrocarbons to be counted both as a particle and as a gas.

Analysis

General Motors' comment emphasized that the temperature specifications are the problem. However, the real issue centers around EPA's intent to measure both total hydrocarbons and total suspended particulates. The temperature specifications are naturally the result of this intent, and not the problem.

The intent to measure both total hydrocarbon and total suspended particulate material results from the fact that each is regulated for a different reason. Hydrocarbon emissions standards are intended to reduce the atmospheric photo-oxidant smog level; standards for total suspended particulates are intended to reduce the respiratory health hazard associated with these fine materials.

Therefore, the proposed measurement practice as specified in §86.110-81(b) should be continued until it can be conclusively proven that particle-bound hydrocarbons do not leave the particle while suspended in the atmosphere, and hence do not first constitute a respiratory health hazard and later contribute to the atmospheric photo-oxidant level.

General Motors submitted thermogravametric (TGA) data to EPA as evidence that the particle-bound hydrocarbons do not leave the particle and become free in the atmosphere. While interesting, this data falls short of being conclusive because TGA does not closely simulate real atmospheric conditions, and therefore does not answer the question of what really happens in the atmosphere.

It must be emphasized that since the standards have been based on a baseline allowing some double-counting, and because the standards are technology-based, the double-counting does not affect the stringency of the standards. Halting the double-counting would necessitate a new baseline, a new technological review, and a lower set of standards.

Recommendation

No change to the temperature specifications should be made at this time.

C. Sample Zone Temperature Specification

Comments

General Motors, Daimler-Benz, Ford and Chrysler -- have commented that the 125°F particulate sample zone temperature limit is arbitrary and without technical foundation.

Analysis

From the outset of diesel particulate measurements and published practices, a 125°F limit on the sample zone temperature has been used and specified (§86.110-81(b)(1)-(2) and (6)). Both industry and EPA agreed that some limit was necessary in order to prevent a loss of hydrocarbons by thermal desorption. The limit was set at 125° to be sure that little hydrocarbon would be thermally desorped. Further, this limit was considered a maximum that would realistically occur in the atmosphere. It also permits reasonable dilution ratios in the sample system.

Data now available indicates that the 125°F limit on the sample zone temperature was a reasonable choice.

Data generated at the Ann Arbor EPA lab indicates that particulate losses begin to occur at temperatures slightly below 125°F (see Figure VII-1). Further, Ricardo Consulting Engineers developed data (under EPA Contract No. 68-02-2751) which indicates that the hydrocarbon content of the particles decreased at filter temperatures exceeding 140°F. With an allowance for initial desorption temperature, the 125°F limit is considered very reasonable.

General Motors submitted temperature effects data from which they concluded that the 125°F limit is not necessary. EPA has reviewed this data, and does not agree with the GM conclusion. Their submittal presented six sets of data (including repeat testing) in which particulate emissions from an Oldsmobile were graphed as a function of the maximum sample zone temperature (see Figure VII-2). In four out of the six sets, the particulate emissions decreased with increasing temperature (maximum sample zone temperature ranged from 106° to 160° F). Similar data was presented for an Opel, and again, four out of the six sets indicated lower particulate emissions with increasing sample zone temperature (maximum sample zone temperature ranged from 95° to 135° F). This data therefore, does not substantiate a change in the sample zone temperature.

It should be noted that the 125°F sample zone limit will require CVS units with pump capacities higher than those in current use, especially for the larger engines (greater than a 3L). This means that gaseous exhaust samples with lower concentrations will be collected in the bags. However, the concentrations experienced will still be within the sensitive range of present day analyzers. Testing of various engine sizes with a single CVS size currently requires that analyzer ranges be selected according to concentration. Therefore, lower concentrations are not expected to be a major problem.

Recommendation

The maximum sample zone temperature limit should not be raised.

FIGURE VII - 1

PARTICULATE AS A FUNCTION OF TEMPERATURE

EPA MEASUERMENTS

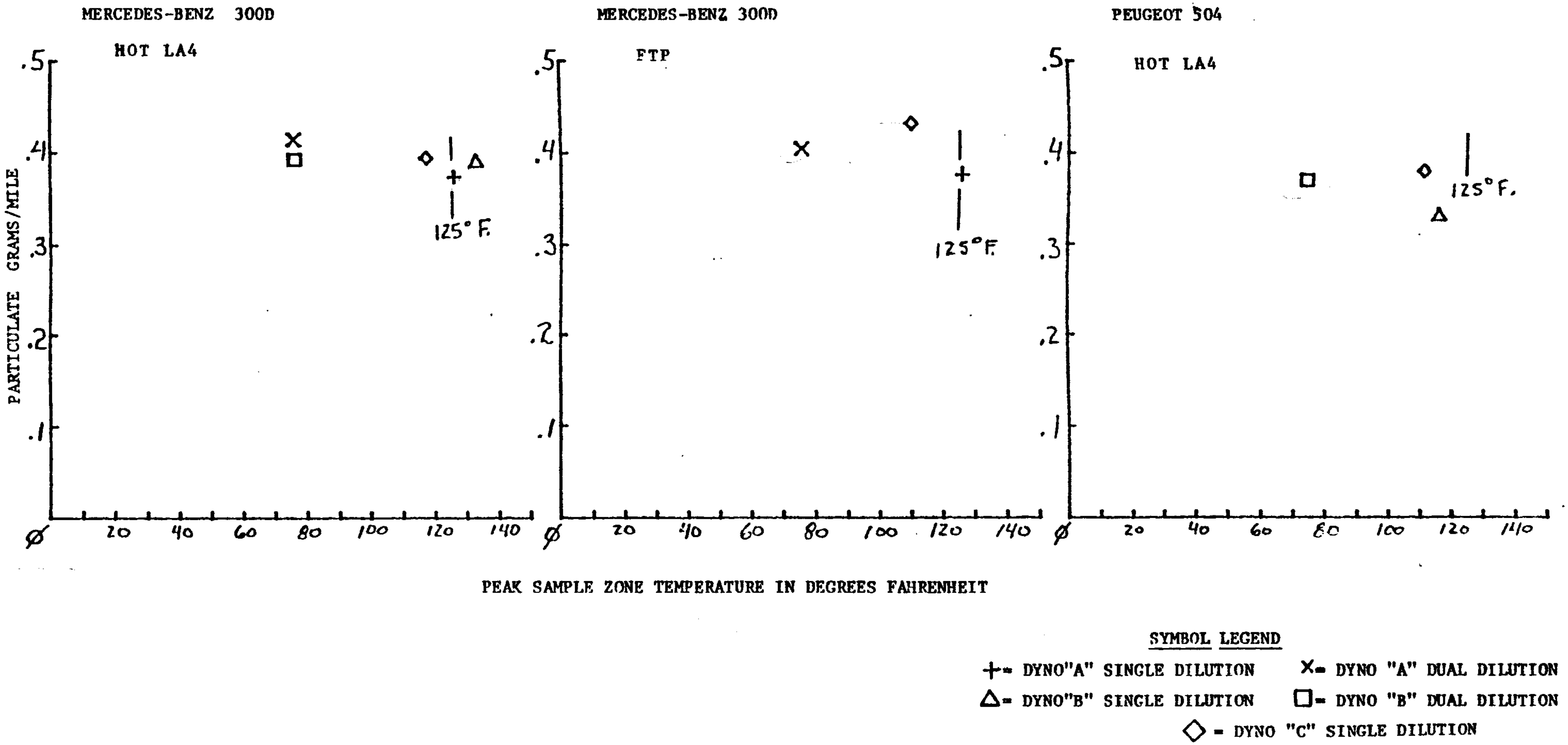
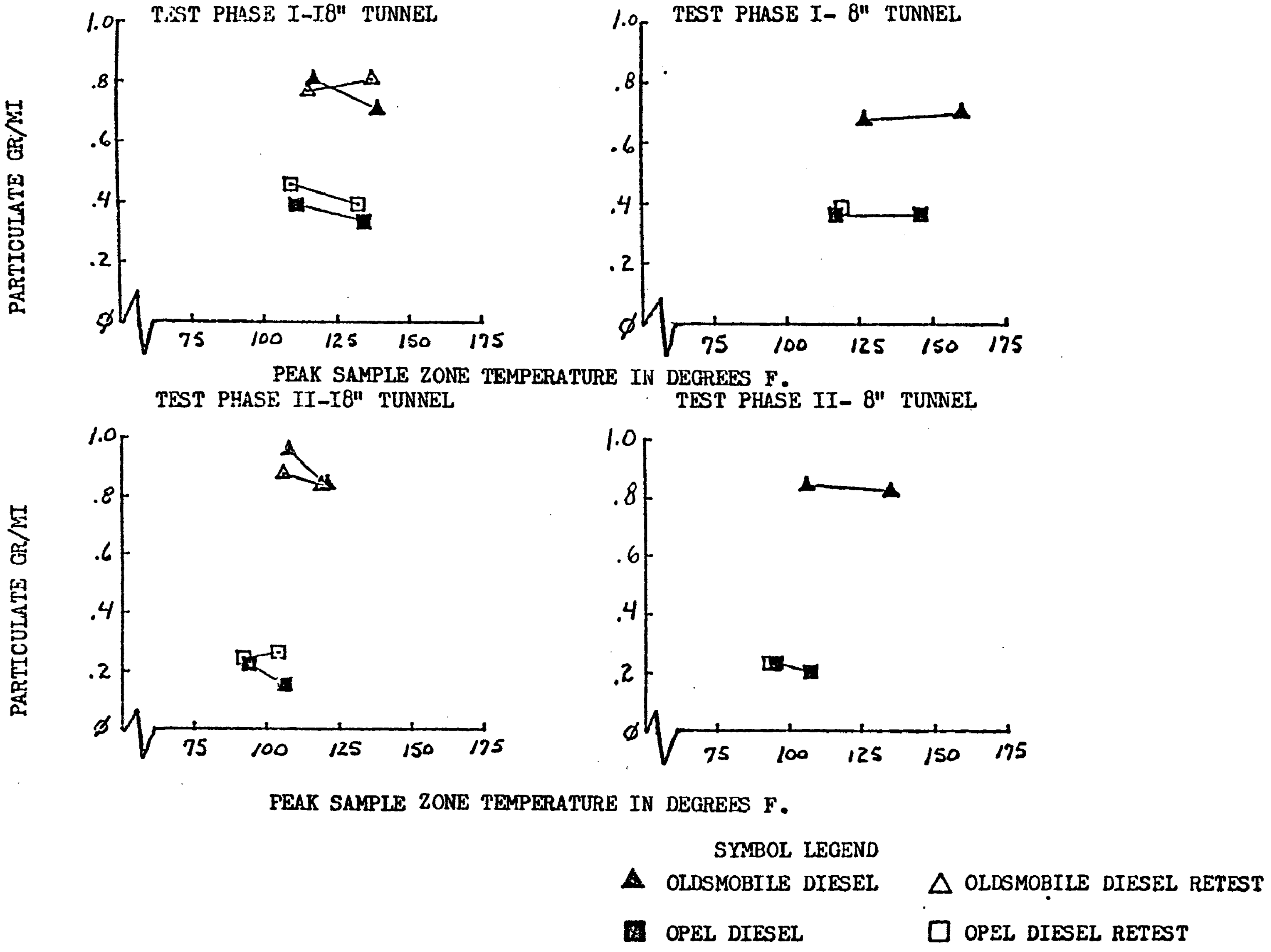


FIGURE VII - 2

PARTICULATE AS A FUNCTION OF TEMPERATURE - SUMMARY OF G.M. MEASUREMENTS



D. Filter media

Comment

Ford -- has commented that fluorocarbon-coated glass fiber filters should not be required.

Analysis

This comment can best be addressed by stating the EPA position on the filter media. The fluorocarbon-coated glass fiber medium has been recommended (§86.110-81(c)(4)) as optimum for collection of diesel particles for three prime reasons: (1) there is less interaction with high molecular weight gaseous organics than the uncoated glass fiber options, (2) less hygroscopic and more mechanically sound than the uncoated glass fiber options, and (3) lower pressure drops than the teflon membrane options. This position remains unchanged.

Ford further commented that this type of filter is known to cause chemical degradation of some samples. It is acknowledged that this may happen, but it is not considered to be important in the present certification application, because appreciable total particulate mass changes do not result. Chemical composition changes could be important to the assessment of health effects, however.

Nevertheless, if a manufacturer desires to use an alternate fluorocarbon-based filter media, this should be allowed as long as the filter meets the acceptance criteria specified in the final regulation.

Recommendation

Revise §86.110-81(c)(4) to include fluorocarbon-based filters, as well as the fluorocarbon-coated glass fiber filters already required.

E. Filter Efficiency

Comment

General Motors, Volkswagen and Fiat -- have commented that the procedure for assessing the collection efficiency of the filter is not acceptable.

Analysis

The filter efficiency test specified in the NPRM (§86.110-81 (c)(1)(i)-(v)) is intended to establish a filter and sample system acceptance criteria with respect to diesel particulate material. To do so requires the involvement of the driving cycle, the vehicle, filter loading, sample system, etc. As noted by Kittelson, Dolan and Kadue in CAPA-13-78 Progress Reports 8 and 9 (dated June 6, 1979) on Laboratory and Field Studies of Aerosols Produced by Diesel-Powered Vehicles "...there is some disagreement between the laboratory (DOP) and field characterization of these (T60A20) filters." [Parenthesis added]

Data presented by General Motors indicates that filter efficiency increases with loading (see Pallflex T60A20 unheated and Pallflex TX40HI20WW data in Table VII-1). This is consistent with the results of the other researchers in this regard. Data generated at EPA indicates that filter efficiency will have to be optimized as a function of the vehicle, i.e., filter efficiency results seem to be somewhat vehicle dependent (see Table VII-2). A standard procedure such as the General Motors recommended DOP (ASTM D-2986) does not consider these variables, and therefore does not provide a satisfactory acceptance criteria for diesel particulate filters. Further it provides no check on the sample system.

General Motors indicated that the efficiency test does not perform as intended, apparently because initial tests (at GM) failed to find a passing filter. However, data presented by General Motors (Table VII-1) indicates that they ultimately achieved 98 percent efficiency (EPA calculation) by optimizing their sample flow rate and loading. This is exactly the result that the efficiency test is intended to achieve.

Fiat commented that a more correct approach to the definition of filter efficiency requires that the back-up filter be a quasi-absolute filter such as electrostatic precipitator. This may be a good recommendation from an ideal procedure point of view, but would be difficult to put in place for day-to-day testing.

Comment

Ford, Volkswagen and Fiat -- have commented that the 98 percent filter efficiency (EPA procedure) requirement is too high.

Analysis

Data now available indicates that universal compliance with the 98 percent filter efficiency requirement (86.110-81(c)(1)) will be difficult to achieve with fluorocarbon-coated glass fiber filters (see Table VII-2). Ford commented that a collection efficiency greater than 95 percent should not be required.

This comment is consistent with the analysis and conclusion stated in the EPA Technical Report "Particulate Measurement - Efficiency of Pallflex T60A20 Filter Media" (SDSB-79-22 dated July 1979), except for one slight modification: the report concluded that for those vehicles in which 95 percent filter efficiency cannot be achieved the combined weight of the first filter and the back-up filter must be used in calculating particulate emissions.

Table VII-1

Filter Efficiency Test Data

GM Results

Filter	Flow Rate (cfh)	1st Filter mg	2nd Filter mg (Eff)*	3rd Filter mg (Eff)**
Fluorocarbon coated glass fiber filters				
Pallflex T60A20	10	0.815	0.050 (94.2)	0.035 (89.6)
	30	2.167	0.062 (97.2)	0.043 (95.2)
	50	3.101	0.051 (98.4)	0.044 (96.9)
Pallflex TX40HI20WW (>99% efficiency claimed on the DOP test)	10	0.897	0.039 (95.8)	0.026 (92.8)
	30	2.087	0.042 (98.0)	0.031 (96.5)
	50	2.782	0.046 (98.4)	0.029 (97.3)
Pallflex T60A20 (filters located inside heated (375°F) oven for test)	20	0.838	-0.004 (100.5)	---
	30	1.635	-0.011 (100.7)	---
	50	2.465	0.009 (99.6)	---
	60	3.380	0.039 (98.9)	---
Glass fiber filters				
Gelman A/E	20	1.829	0.087 (95.2)	

$$*\text{Efficiency} = \left(1 - \frac{\Delta W_2}{\Delta W_1 + \Delta W_2}\right) 100\%$$

$$**\text{Efficiency} = \left(1 - \frac{\Delta W_2 + \Delta W_3}{\Delta W_1 + \Delta W_2 + \Delta W_3}\right) 100\%$$

NOTE: While GM did not indicate filter size, 10 cfh and 0.815-0.897 mg are below the specified flow rates and filter loading for even the minimum specified filter size. It cannot be expected that the filter would perform as required.

Table VI 2

Pallflex T60A20 Filter Efficiency Test Data

EPA Results

Peugeot 504D

Filter Batch	Filter Efficiency* - Percent	
	Bag 1	Bag 2
3991E2	92.0	91.7
1092B	91.4	93.7
4009E2	90.7	93.5

Oldsmobile 350D

Filter Batch	Filter Efficiency* - Percent	
	Bag 1	Bag 2
3991E2	98.0	98.4
1092B	99.1	99.1
4009E2	99.0	99.2

---

*Filter efficiency determined per Section 86.110-81(c)(1)(iv).

It should be noted that Fiat's filter efficiency comment is based on measurements in which a glass fiber back-up filter was used. Such efficiency measurements will be erroneously low because of hydrocarbon adsorption by the glass fiber media. The back-up filter will indicate a particulate net weight increase that is too high because of this HC adsorption.

Recommendations

On the basis of the above analyses, it is recommended that §86.110-81(c)(1) be revised as follows:

1. Rename the efficiency test and call it "Filter Acceptance Criteria."

2. Require the back-up filter during actual certification testing.

3. Calculate the ratio of weights as indicated in the NPRM.

4. If the ratio is greater than 0.95, determine paticulate emissions on basis of first filter net weight.

5. If the ratio is less than 0.95, determine particulate emissions on basis of combined net weights of the first filter and the back-up filter.

F. Filter Flow Rate and Loading

Comment

General Motors -- has recommended that the required flow rate provision be dropped and that a reasonable filter weight gain be kept. However, the recommended weight gain window is tighter than needed for good measurement accuracy.

Analysis

It is agreed that the specified filter flow rates can be dropped. The requirement for constant sample flow rate during the test is a sufficient flow requirement to assure good measurements. However, the specified 2 mg minimum loading (on a 47 mm filter) is necessary to achieve high efficiency. GM's own data indicates this (see Table VII-1). Higher loadings can be left to the manufacturer's own discretion.

Recommendation

It is recommended that the specified filter flow rates be dropped, and that only the minimum 2 mg filter loading be required.

G. Post-Test Filter Stabilization Period

Comment

General Motors -- has requested that the regulations be changed to require a one-hour minimum filter stabilization period after a vehicle test. GM further commented that there is no need for the 56-hour maximum time limit on the filter stabilization period.

Analysis

EPA has no objection to shortening the minimum post-test stabilization period specified in §86.139-81(e). General Motors indicates that using a one-hour post-test stabilization period instead of a 24-hour stabilization results in an 0.5 percent increase in measured particulates. General Motors is requesting the one-hour lower limit in order to minimize any interference with mileage accumulation. They feel that the penalty of accepting the higher particulate measurement is outweighed by the advantage of speeding up the certification process. However, for best accuracy, it is recommended that EPA use a minimum 24-hour stabilization period (used in baseline testing) for certification testing. Some correlation problems may result with manufacturers that use a very short period, but this is at the manufacturer's own risk and at their option.

It should be noted that the 56-hour specification is the upper limit of a range that currently varies from 8 to 56 hours. The upper limit was specified to cover weekend operations at various test facilities. This is reasonable because, as GM stated, additional time (assumed beyond 8 hours) has no effect on filter stabilization.

Recommendation

It is recommended that §86.139-81 be revised to allow a one-hour minimum post-test filter stabilization period. The upper limit of 56 hours should remain as proposed.

H. Heat Exchanger Requirements

Comments

General Motors -- has commented that the specific requirement for a heat exchanger (with the CFV sampler) should be replaced by a general requirement for flow proportionality.

Analysis

Conceptually, this statement is correct because the function of the heat exchanger in the CFV/diesel particulate application is to provide for proportional sample flow by compensating for varying gas temperature in the dilution tunnel. However, a change to the test procedure cannot be recommended because no confirmatory data, specifications or schematic diagrams of the proposed alternate sample system were provided with the comment. As stated in §86.110-81(a)(5), other sampling systems may be used if shown to yield equivalent results and are approved in advance by the Administrator. Confirmatory data and system diagrams are among the necessary items needed to receive approval.

Confirmatory data is necessary in order to show equivalency between the alternative measurement system being proposed and either of the specified systems (§86.110-81(b)(1)-(2)). Stated another way, evidence that the alternative is practical and works must be submitted to EPA. Diagrams and specifications are required for inclusion in the Federal Register so that any testing laboratory can duplicate the system.

For the record, it should be noted that General Motors has proposed to compensate for temperature by using a critical flow sample probe. They further propose to put the filter ahead of the nozzle to prevent contamination. However, placing the filter in this position introduces another problem: particulate material collected on the filter alters the upstream sample nozzle pressure which in turn results in non-proportional flow. General Motors would eliminate this problem by using a back pressure regulator or servo-controlled valve that keeps the sample venturi inlet pressure proportional to the CFV inlet pressure, and thereby maintain proportional sample flow. They further recommended a tolerance on the proportionality of ± 2 percent at all times during testing.

While this is certainly an interesting sampling technique that may have potential, it cannot be accepted without knowing the practical working details.

Recommendation

It is recommended that the General Motors proposal not be adopted at this time.

I. Tailpipe Connector Specification

Comment

General Motors -- has commented that the tailpipe connector specification is too rigid.

Analysis

The current tailpipe connector specification (§86.110-81(b)(3)) of a maximum length of twelve feet of smooth (non-flexible) pipe is considered by General Motors to be a serious handicap to facility design. General Motors has submitted data which indicates that particulate measurements made using 17 feet of four-inch flexible pipe are equivalent to measurements made using 7 feet of two and one-half-inch smooth pipe over a hot start LA-4 cycle. EPA data (memo from Thomas Penninga to F. Peter Hutchins entitled "Diesel Particulate Exhaust Collection Configuration Study - A Preliminary Look at the Data," dated March 29, 1979) indicates that this equivalency may be due to several competing effects taking place in the GM pipe comparison. This EPA data from a Mercedes 300D and from an Oldsmobile 350D indicates that particulate measurements increase with pipe diameter (7% to 12% in going from two and one-half inch to four-inch diameter), and decrease with connector length (-2% to -4.5% in going from 12 feet to 20 feet) and roughness (-4% to -13% in going from smooth to convolute pipe).

The EPA data further indicated that insulating the pipe could result in an increase in particulate measurements of up to 16 percent (smooth pipe). Increased heat loss could also be a factor in the particulate measurements taken with 17 foot (GM) and 20 foot (EPA) lengths of pipe. The specific particulate loss mechanism related to this heat loss may be thermal precipitation.

From the above discussion it is apparent that a more thorough understanding of the tailpipe connector effects on particulate measurements is needed. EPA is therefore planning to conduct more testing in the area of tailpipe heat loss effects. Specifically, particulates will be measured using a 20 foot length of smooth insulated pipe. These measurements will be compared to measurements taken with a similar 12 foot insulated pipe, and also measurements taken with a 12 foot uninsulated pipe (the baseline reference pipe). EPA will allow the longer alternative if the data indicates that this is reasonable.

Efforts will be made to place the most practical solution into the final rule. If this cannot be done, then a technical amendment will have to be issued.

Recommendation

It is recommended that no change be made to the tailpipe specification until EPA testing has been completed.

J. Flow Measurement

Comment

General Motors -- has commented that gas meters are a burden. Equivalent flow measurement devices which can be operated automatically should be allowed.

Analysis

It is agreed that gas meters are a burden. It was never intended that the test procedure would eliminate automatically-operated flow instrumentation.

Recommendation

It is therefore recommended that a more general term such as "flow instrumentation" be used in addition to the words "gas meter."

Comment

General Motors -- has commented that the ±5 percent tolerance on sample flow rate is too large. They suggest a tolerance of ±2 percent.

Analysis

It is agreed that a tolerance of ±2 percent is more desirable as it will reduce the sample error. However, it is not certain that every laboratory can comply with this tolerance because of the possible extra cost. No other manufacturer commented that a tighter tolerance be adopted. Therefore, this suggestion of a ±2 percent tolerance should not be adopted unless it can be proposed and commented on by all of the manufacturers.

Recommendation

It is recommended that the ±5 percent tolerance or flow rate be retained.

K. Heated Lines (HC sample system)

Comment

General Motors -- "Commercially-available heated lines cannot meet the proposed temperature specifications."

Analysis

Apparently, General Motors has not realized the distinction between probe wall temperature specifications and dilute exhaust gas temperature specifications. It should be specifically noted that the temperature specifications in §86-110-81(b)(11) and (12) apply to the probe wall, while the temperature specification in §86-110-81(b)(13) applies to the dilute exhaust gas.

General Motors' comment seems to be based on dilute exhaust gas temperature profiles measured (by GM) over the entire length of heated line. These measurements are not necessary. The exhaust gas need only be measured before the heated filter (§86-110(b)(13)(i) and before the HFID (§86.110(b)(13)(ii)). General Motors' own data (Figure VII-3) indicates that the exhaust gas temperature specifications can easily be met at these two locations by using at least two feet of heated line.

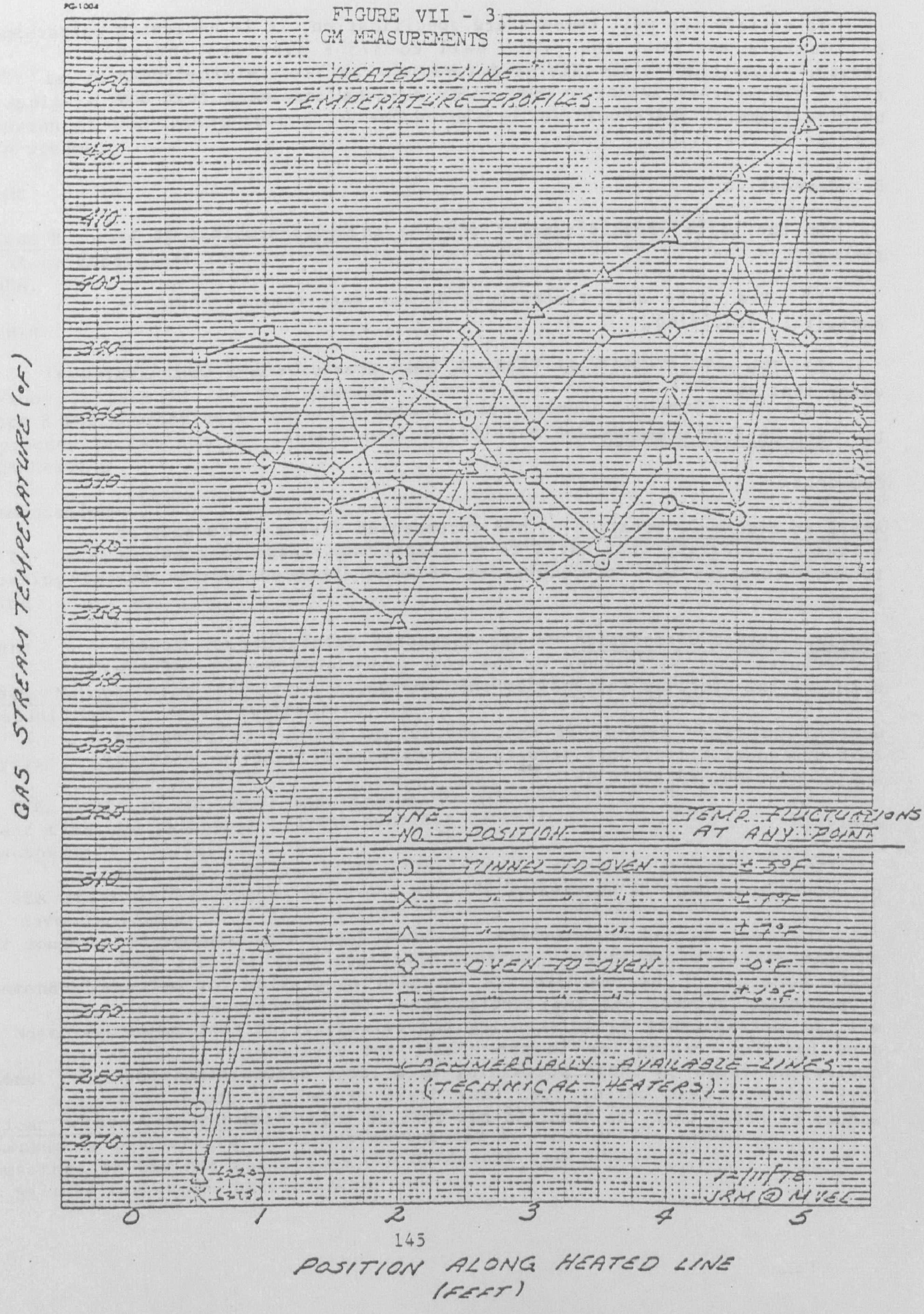


FIGURE VII - 3
GM MEASUREMENTS

To satisfy the wall temperature specification, it is necessary to insulate and heat the probe wall to 375°F over its entire length. Compliance with this specification can be determined by a single temperature sensor. The sensor must be insulated from any heating elements and should be located on the section of probe wall outside of the dilution tunnel.

Recommendation

On the basis of this comment and the analysis provided it is recommended that:

1) The probe wall temperature sensor requirement should be explicitly specified.

2) The words "wall" and "exhaust gas" should be emphasized by using italics.

L. SEA Related Comments

Comments

American Motors Corporation -- has recommended that a discussion of evidence indicating that there is no compelling reason to continue to have separate test procedures for SEA be included in the preamble.

American Motors Corporation -- has suggested tabulating the specific changes that will occur in the test procedures because of the NPRM, giving specific reasons for each change.

General Motors -- recommends that §86.608 be amended to recognize test procedure differences between prototype certification vehicles and production SEA vehicles.

Analysis

These comments indicate that clarification of the SEA test procedure amendment is necessary.

The test procedure amendment is not intended to change the current SEA test procedure. Current procedure will in fact continue to apply. The amendment is intended to provide for better coordination between SEA and certification test procedures. This will be accomplished by referencing the certification test procedure for SEA testing (as in the NPRM), and including a list of deviations (such as those pertaining to mileage accumulation test fuel, diurnal heat build, fuel tank drain procedure, etc.). It should be noted that the NPRM did not include this list.

Recommendation

It is recommended that a list of test procedure deviations that apply to SEA testing be included in the final regulation. A discussion of the intent of the SEA amendments should be included in the preamble.

Comment

American Motors Corporation and General Motors -- have requested that it be made clear that only exhaust emissions will be measured for SEA.

Analysis

It is agreed that there is no intent to measure evaporative emissions as part of the SEA program. Hence, the sections from Subpart B which describe evaporative emission measurement equipment and procedures (except the diurnal heat build) are not applicable to SEA testing.

Recommendation

It is recommended that a statement be added to Subpart G indicating that evaporative emission tests are excluded from SEA testing.

Comment

American Motors Corporation -- has recommended Subparts A, B, and G be republished in their entirety at the time of final rulemaking.

Analysis

MVEL staff in Ann Arbor are responsible for Subparts A and B. Current time and resources prevent complete republication of these two subparts.

SEA staff in Washington D.C. are responsible for Subpart G. They have indicated that this subpart will be republished when other soon-to-be-proposed amendments are finalized.

Recommendation

None required.

Comment

American Motors Corporation -- has recommended that the added cost of measuring particulate emissions during SEA be considered. AMC claims that it was not clear from the NPRM that only diesel vehicles will be tested for particulate.

Analysis

The added cost of measuring diesel particulate emissions during SEA testing was considered in the cost analysis. No cost analysis of particulate testing of gasoline-fueled vehicles was made because particulate emissions from gasoline-fueled vehicles are not intended to be measured. (Section 86.127-81(a)(2) clearly indicates that particulate emissions are measured from diesel vehicles only.)

Recommendation

None required.

Comment

General Motors -- has recommended that a more general term such as "flow measurement instrumentation" be used instead of "gas meter".

Analysis

This comment was covered in Part J of this section of the Summary and Analysis of Comments. It was recommended that the more general terminology be used, as well as the specific "gas meter" terminology.

Recommendation

None required.

Comment

Volkswagen of America -- "It is, from our point of view, completely impossible to set an SEA standard at the certification level because 50 percent of the cars must fail if you are perfect."

Analysis

This would be true if in fact the certification vehicle is a "mean emission" vehicle and emission levels are distributed normally. If the distribution of particulate emissions follows a pattern similar to that for gaseous emissions, that is a distribution skewed toward the high end, then the failure rate would be less than 50 percent. In the case of gaseous emissions, experience indicates that about 40 percent of the vehicles exceed the mean value.

Recommendation

None required.

M. Miscellaneous Comments

Comment

General Motors -- "The use of the term CVS applied to the CFV is objectionable because it leads some to believe that it is indeed a constant volume sampler without the addition of the heat exchanger."

Recommendation

Replace the phrase "Critical Flow Venturi-Constant Volume Sampler" with "Critical Flow Venturi Sampler."

Comments

General Motors -- has recommended rewording the second sentence of §86. 109-81(b)(2) to: "The gas mixture temperature variation during the entire test shall be within ±10°F of the average temperature for the test."

General Motors -- has recommended rewording the second sentence of §86.110-81(b)(2)(iii) to: "The gas mixture temperature variation during the entire test shall be within 20°F of the average temperature for the test."

Analysis and Recommendation

While both the current and the GM wording specify the same limit on the gas mixture temperature relative to a reference temperature, the average temperature for the test is unknown until after the test is finished, and therefore the heat exchanger set point to unknown. Hence, no change to the wording of the cited sentence is recommended.

Comment

General Motors -- "The requirement for the temperature measuring system to have an accuracy and precision of ±1.8°F (1°C) excludes the use of "J"-type thermocouples. By changing this requirement to ±2°F (1.1°C), precision "J"-type thermocouples would be acceptable."

Recommendation

It is recommended that a ±2°F (1.1°C) accuracy and precision on the temperature measuring system be specified. The specification of 1.8°F was due to inadvertant round-off in converting metric units to engineering units.

Comment

General Motors -- has recommended rewording §86.109-81(c)(2) to add the underlined words: "...(as measured by hot silicone oil or equivalent)."

Recommendation

No change to the cited wording is recommended because equivalent measurement techniques are handled under §86.109-81(a)(4).

Comment

General Motors -- has recommended that separate filters and filter holders for each test phase be used, so that filter changes during the soak period are not required. (See Figures B81-3 and B81-4.)

Analysis and Recommendation

It was intended that separate filters and filter holders for each test phase be allowed, as well as the two filter/filter-holder combination diagrammed. Therefore, it is recommended that a note indicating this intent be placed on Figures B81-3 and B81-4.

Comment

General Motors -- "The cyclonic separators shown in these figures (B81-2 and B81-4) for the CFV system should be deleted. The inclusion of these separators are not required for valid emissions tests." (Parenthesis added.)

Analysis and Recommendation

It is agreed that the cyclonic separator is not required in Figure B81-4. However, it is required in Figure B81-2 because catalyst vehicles are tested with this system. It is recommended that: 1) Figure B81-2 remain as diagrammed, and 2) the cyclonic separator in Figure B81-4 be indicated as optional.

Comment

General Motors -- "The development of turbulent flow is not enough to ensure that particulate stratification does not occur. Upon initial setup of the tunnel, uniform mixing should be demonstrated through an experiment designed by the user."

Analysis and Recommendation

It is agreed that good engineering practice requires that the user demonstrate to himself that uniform mixing is taking place. It is recommended that a note suggesting this be included.

Comment

General Motors -- "This requirement, that the probe face upstream, is related to isokinetic sampling and, as such, is unnecessary. A downstream facing probe also eliminates any chance of the test being incorrect due to sampling particle of particulate trap material or a large chunk of material dislodged from the tunnel wall."

Recommendation

It is recommended that the upstream facing probe be retained for the following reasons:

1) This requirement is consistent with keeping the probe inlet free from the influence of wakes or eddies produced by the hydrocarbon probe (or any other obstruction).

2) EPA data (Technical Report LDTP 78-14 "Particulate Measurement - Dilution Tunnel Stabilization" dated November, 1978) infers there is very little buildup of particulate material on a tunnel wall, and hence dislodged particulate material should be a negligible problem.

3) Particulate trap material, if retained by the filter, fits the current definition of particulate material, and hence should be measured.

Comment

General Motors -- "The centerline location of the probe should be approximate, to allow for individual probes for the various test phases."

Recommendation

It is agreed that the centerline probe location can be approximate because of the requirement for well-mixed flow. It is recommended that probe location be specified as "approximately on the tunnel centerline."

Comment

General Motors -- has recommended rewording §86.112-81(a)(2) for clarity as follows: "...maintained to within 10% relative humidity of a set point such that deviations from a 50% relative humidity set point could range from 40% to 60% relative humidity."

Recommendation

It is recommended that no change to the wording of the cited sentence be made. The GM statement is less clear than the current statement, and it is apparently more restrictive than necessary.

Comment

General Motors -- "It is recommended that reference filters be weighed only once each day of testing. The meaning of a conditioning period is not obvious."

Recommendation

It is agreed that with the fluorocarbon based or fluorocarbon coated glass fiber filters a reference filter weighing of once each 24-hours is sufficient as long as the humidity is maintained within specification. Therefore, it is recommended that only 24-hour weighing of the reference filters be required, and that a continuous recording of weighing room humidity be maintained.

Comment

General Motors -- "The meaning of "micrometer" in this context is not clear." GM is referring to §86.112-81(b).

Recommendation

Delete the word "micrometer" because it currently appears in parenthesis along side the word "readability" (i.e., the word "micrometer" was intended to clarify).

Comment

General Motors -- has recommended that §86.120-81(f)(1) be replaced with: "Determine the new calibration flow constant for the flow measurement instrumentation."

Recommendation

It is recommended that no change to §86.120-81(f)(1) be made since: (1) some laboratories will be using gas meters, and (2) §86.120-81(f)(2) already provides for a calibration curve to be used if no adjustments are made to the flow instrument.

Comment

General Motors -- "The FID optimization method presented is outdated. The practices recommended in SAE paper 770141, "Optimization of a Flame Ionization Detector for Determination of Hydrocarbon in Diluted Automotive Exhausts," by Glenn D. Reschke should be substituted."

Analysis and Recommendation

It is recommended that no change be made to the FID optimization method presented in §86.121-81 of the NPRM. This recommendation is based upon the following analysis.

The recommendations presented in SAE paper 770141 were specifically aimed at Beckman Model 400 FIDs. There is no assurance that these recommendations are applicable to the several other available FIDs. Hence these recommendations may not be universal enough for publication in §86.121-81 which is intended to apply to all FIDs. Consistent with this intent, no part of the general procedures outlined in §86.121-81 prevent a Beckman user from following the specific recommendations of SAE 770141.

Comment

General Motors -- has recommended that the underlined words be added to the last sentence of §86.127-81(b): "...using a constant volume (variable dilution) sampler or a critical flow venturi."

Recommendation

It is agreed that the above statement is more technically correct, and should be adopted. It is therefore recommended that this revision be made.

Comment

General Motors -- has commented that with respect to §86.137-81(b)(5)(i): "It is not clear what gaseous samples are referred to: The stated 0.17 cfm is too high for the FIDs."

Recommendation

It is recommended that the following clarification be made:

1) Specify that 0.17 cfm is the minimum flow rate for all NOx, CO and CO_2 measurements.

2) Specify a minimum FID and HFID flow rate of 4 cfh (0.067 cfm).

Comment

General Motors -- has suggested rewording §86.137-81(b)(7) as follows: "...sample filter into each of the filter holders..."

Recommendation

It is recommended that the above rewording be adopted to be consistent with the comment on filter holders.

Comment

General Motors -- has recommended rewording the last sentence of the NOTE in §86.137-81(b)(11) to: "...rerun with a lower flow rate, or larger diameter filter, or both."

Recommendation

It is agreed that the above rewording is more proper than the current wording of this sentence. It is therefore recommended that the above wording be used.

Comment

General Motors -- has commented that it is not clear what humidity measurement is required in §86.142-81(i).

Recommendation

Reference to humidity measurement is a typographical error. This section should read as follows: "Recorder charts: Identify zero, span, exhaust gas, and dilution air sample traces."

Comment

General Motors -- has commented that there is no need to obtain a record for the pressure drop across a CFV as required by §86.142-81(e).

Analysis and Recommendation

No change to §86.142-81(e) is recommended because the pressure drop record is needed to insure that critical flow was maintained. Other methods of critical flow determination may be available, but monitoring the pressure ratio is the most direct and also is easiest.

Comment

General Motors -- "The background particulate level, even though low at EPA, contributes to measured vehicle particulate level and should be subtracted in all cases."

Analysis and Recommendation

No change to the proposed handling of the background correction is recommended. This correction depends upon an accurate measurement of the dilution ratio during the test. This in turn requires an accurate measurement of the volume of dilute air (or exhaust) since the emissions-based to dilution-ratio formula specified in the Federal Register is not valid for diesel vehicles.

Dilute air flow measurements are very difficult and expensive to make, and therefore is not considered worthwhile in view of the very low background particulate levels in most laboratories.

Comments

General Motors -- "The equations in (b)(6) and (b)(7) [§86.145-81] assume that a gas meter will be used for the flow measurement device. We recommend removing this text and replacing it with 'calculate the particulate flow using the proper equations for the flow instrumentation which is used. In the case of a gas meter, perform the following calibration technique.'"

Analysis and Recommendation

It is not agreed that the referenced equations assume that gas meters will be used. The equation assumes only that a volumetric flow measurement will be made. Use of a gas meter is just one way to obtain this type of flow measurement. A time integration of the output of a constant volume flow rate instrument is another way to obtain the desired flow measurement. Therefore, no change to the equations in §86.145-81(b)(6) or (b)(7) should be made.

Comment

Ford -- "The proposal ignores the difficulty introduced by specifying a three-bag FTP with a filter collected for each bag. The probability of consistently acquiring three valid filters consecutively in vehicle testing is low, except in the hands of personnel trained to a degree not feasible for widespread use of the method."

Analysis and Recommendation

It is recommended that the three-filter procedure be retained. This three filter procedure is necessary so that the cold start and hot start particulate measurements can be properly weighted. The only alternative to this procedure is to use the four-bag/2-filter proposed in the Draft Recommended Practice published in March, 1978. There was widespread industry objection to this procedure because of the extra time involved in driving two complete LA-4 cycles, and also because of the substantial computer reprogramming that would be required. Most manufacturers recommended keeping the particulate measurements consistent with the gaseous measurements.

The training of technicians is not considered to be any more extensive than that required for gaseous emissions. Measurement experience at EPA indicates that test-to-test variability is generally less than 5 percent of mean measurements using the three filter procedure. This compares very favorably with the variability of the other regulated emissions.

Comment

Ford -- "The requirement on page 56 of the proposal for ±1 microgram filter weighing accuracy cannot be justified for sample weights of 2 to 7 mg."

Analysis and Recommendation

No change to the balance specification is recommended. The one microgram specification is intended to provide the capability to keep the contribution of the filter associated weighing and stabilization (mainly humidity) errors to one percent or less. To do this requires the capability of detecting day-to-day reference filter weight changes of ±20 micrograms (1 percent of the minimum filter loading). This in turn requires a balance with at worst one microgram capability. The ±10 mg accuracy recommended by Ford will not provide the necessary capability.

Comment

Chrysler -- "In addition, a new test requirement for fuel drain, refuel, and preconditioning is added which will double or triple the per-test costs."

Analysis

This comment is not clear and therefore no meaningful response can be given.

VIII. Miscellaneous

All of the major issues of this specific rulemaking have been examined in the previous sections. This section includes the many general comments received about the light-duty diesel vehicle, as well as some minor specific comments that were not covered in the previous sections.

A. Advantage of the Diesel Engine

Comments

Council on Wage and Price Stability -- "Because the proposed standards may discourage the development and spread of diesels, we wish to point out the advantages of diesels -- some of which are well known, others of which are less so -- and hence indicate why this possible discouragement of diesel usage concerns us. Perhaps best known is the superior fuel economy aspect of the diesel.... Overall, the general rule is that a diesel vehicle will have a 25-30% fuel economy advantage over a comparably performing gasoline engine vehicle....A second advantage of the diesel lies in the environmental area and should be of particular interest to EPA. Diesels emit far less hydrocarbon (HC) and carbon monoxide (CO) in the exhaust than do comparable gasoline engine vehicles. This is due to the lean-burn characteristic of diesels....Another favorable environmental aspect of the diesel which is less widely known is that its use and fueling involve much less HC evaporative emissions than occurs with gasoline engine vehicles. Diesels have no carburetors, and diesel fuel is much less volatile than gasoline. These reductions in evaporative emissions are substantial....A third favorable aspect of the diesel, which seems to have been neglected, it is superior safety in the event of a crash. Since diesel fuel is less volatile, the likelihood of a fire in the event of a crash is much reduced."

Department of Energy -- "The EPA Draft Regulatory Analysis and the Notice of Proposed Rulemaking contain little discussion of the energy conservation aspects of diesel engine use. However, this is one of the criteria under Section 202(a)(3)(A)(iii) which must be considered. Questions by the EPA hearing panel members during the public hearings seem to indicate that EPA anticipates little energy savings due to introduction of diesel engines. This belief appears to be based on the assumption that the use of diesel engines will simply displace other fuel saving technology (particularly in large cars) since the Department of Transportation (DOT) analysis has shown that diesels will not be required to meet the corporate average fuel economy (CAFE) 27.5 mpg standard in 1985. This overly simple view of the conservation impacts of diesels ignores a number of facts:

- Manufacturers of diesel-powered cars are presently above the

CAFE requirements, in part due to the use of diesel engines. Thus, energy savings are already being derived by the use of diesels.

- Diesel engines, particularly in large cars, may be a lower cost way of making fuel economy gains thus leaving the manufacturer resources that can be devoted to other fuel economy improving technologies....
- Significant improvements in light-duty truck fuel economy will be dependent in part on the use of diesel engines.
- The setting of standards requiring fuel economy improvements beyond 1985 will also be dependent, in large part, on diesel engines.
- For a given level of EPA measured fuel economy, the actual on-road mpg performance for a diesel will be higher than a gasoline-powered equivalent car. The latest DOE analysis indicates that the shortfall between EPA and on-road fuel economy for diesels is about one-half that of a gasoline-powered vehicle. This means a car with an EPA rating of 27.5 mpg is getting 24.8 mpg on-road for diesels compared to about 21.5 mpg for gasoline cars. This differential represents energy savings directly attributable to diesels even under the assumption that current fuel economy standards remain unchanged.

In view of the above, we believe that overall energy conservation considerations require that these particulate standards not limit the use of diesel engines, particularly in larger cars or in light trucks. These two vehicle types are precisely the areas where the largest energy conservation gains can be made."

Congressman John D. Dingell -- "[I]n view of the fuel economy standards, the large diesel engine currently is the only means readily available for manufacturers to continue to offer through the mid-1980's the family size, although down-sized, six-passenger cars. The need for six-passenger vehicles will continue, even if such new vehicles are not available. In that case, the public will simply extend the life of existing six-passenger vehicles, vehicles which are far less fuel efficient and somewhat less clean burning in terms of controlled emissions. I am sure it is obvious to you that many families can only afford one vehicle for family daily use and weekend or vacation travel. In several cases this requires the full or intermediate sized vehicle for carrying family members and equipment. In several additional cases, the use of such vehicle is required for towing trailers, boats, or other recreational equipment....It is, therefore, most important that your review of the statements on the proposed standards be cautious."

Analysis

EPA agrees that there are definite advantages of the diesel engine. Since it has been established that most manufacturers intend to meet the CAFE standards and not greatly exceed them, regardless of the breadth of the dieselization programs, dieselization will not provide a 25 to 30% fuel savings on a fleetwide or national basis. Still, as the Department of Energy (DOE) and others have pointed out, the diesel does provide fuel conservation benefits due to its smaller shortfall between EPA projected fuel economy and in-use fuel economy, and the likelihood that some manufacturers will exceed the CAFE standards to some extent. Diesel do emit lower levels of CO and evaporative HC emissions, but they are not expected to emit any less exhaust HC emissions; all light-duty vehicles must meet a 0.41 g/mi (0.25 g/km) exhaust HC standards beginning with the 1980 model year. It is also accepted that diesels are far less likely to catch fire during crashes due to the lower fuel volatility. On the other hand, there are also disadvantages of the diesel in addition to the considerably greater particulate emissions. It appears to be more difficult to meet the statutory 1.0 g/mi (0.62 g/km) NOx standard with diesels, and they have greater noise, odor, and smoke problems than do gasoline vehicles.

EPA has not considered the general question of the societal desirability of the light-duty diesel vehicle, because, as discussed in Section IV, the diesel particulate standards will not restrict light-duty diesel production. They will only force light-duty diesel vehicles to meet the particulate level achievable by the highest-emitting light-duty diesel utilizing the best available control technology. We have considered the specific effects that the particulate standards would have on fuel economy, other emissions, and safety.

It is ironic that Congressman Dingell advises EPA to be "cautious" with regards to the diesel particulate regulations. Although we have consciously abstained from any overall judgment of the diesel, EPA has recommended caution to the light-duty manufacturers until the results of the many diesel health effects research programs have been analyzed. The possibility that diesels might pose a carcinogenic threat demands caution. Nevertheless, EPA has kept these recommendations independent of the diesel particulate regulations.

B. Investment Decisions

Congressman Andrew Maguire -- "Automakers ought to proceed carefully. It makes little sense to spend immense amounts of capital on conversion to diesel, nor does it make much sense to retrain mechanics or reequip service stations to handle a new technology when this may cause major damage to the nation's efforts to clean up its air and may require as a result further restrictions."

East Michigan Environmental Action Council -- "[W]e are seeing an incredible line of reasoning which suggests that the careful approach would be to go slow with diesel regulations, so as not to 'kill' the diesel. Again, we would like to make clear that perhaps and 'early abortion' would be more palatable now than a 'therapeutic euthenasia' later, once 'sufficient evidence' has accumulated. It is obvious that the industry is poised on the brink of a huge investment, an investment which would surely work against future attempts to be objective about the diesel. We maintain that the 'careful' approach would be to delay the investment rather than the standards."

Analysis

As has been emphasized many times, EPA has not made the final decision as to the acceptability of the light-duty diesel vehicle; such a decision must await the completion of the many diesel health effects programs now underway. The diesel particulate regulations will not force any diesel models out of production, unless the manufacturer is unwilling to reduce the particulate emissions of a model to an acceptable level. We have advocated caution on the part of the diesel manufacturers, since there is a possibility, once the health effects data are in, that a decision will be made to restrict diesel production.

C. Anti-competitive Standards

Comment

Volvo -- "Volvo believes that the very low particulate standards proposed by EPA will be anti-competitive in nature because they favour the largest manufacturers with a wide model range, and create extraordinary difficulties for the smaller manufacturers with a limited model range."

Analysis

EPA disagrees with Volvo on this issue. The manufacturer with a wide model range would have a greater advantage under an average particulate standard because it could take full advantage of the extra flexibility by trading-off one model's low emissions for another model's higher emissions. EPA maintains that the advantage of a wide model range is minimized by individual vehicle standards, since such trading-off is not possible. Volvo's support for the CAPS proposal (see Section VIB) and opposition to the individual vehicle standards would seem to be more a function of the numerical stringency of the two approaches than of their effects on competition.

D. Higher Standards Due to Test Procedure

Comment

Fiat -- commented that the 1981 standard ought to be increased to account for the higher efficiency filters that would be required to be used in certification testing, Fiat claimed the EPA baseline test data were obtained with lower efficiency filters.

Analysis

Fiat's claim has no basis in fact. The 1979 certification particulate baseline data were all taken with fluorocarbon-coated glass fiber filters, the type that will be used by EPA for certification. The low efficiencies that Fiat obtained for its fluorocarbon-coated glass fiber filters, which cause Fiat to comment as it did, were due to its usage of glass fiber back-up filters and thus were erroneously low. This issue is dealt with further in Section VIIE.