ANNUAL REPORT

OF THE

ENVIRONMENTAL PROTECTION AGENCY

TO THE

CONGRESS OF THE UNITED STATES

In Compliance With

Section 202(b)(4)

Public Law 90-148

THE CLEAN AIR ACT AS AMENDED

PREFACE

This report is submitted to Congress in accordance with Section 202(b)(4) of Public Law 90-148, the Clean Air Act, as Amended. Section 202(b)(4) reads as follows:

> "On July 1 of 1971, and of each year thereafter, the Administrator shall report to the Congress with respect to the development of systems necessary to implement the emission standards established pursuant to this section. Such reports shall include information regarding the continuing effects of such air pollutants subject to standards under this section on the public health and welfare, the extent and progress of efforts being made to develop the necessary systems, the costs associated with development and application of such systems, and following such hearings as he may deem advisable, any recommendations for additional congressional action necessary to achieve the purposes of the Act. In gathering information for the purposes of this paragraph and in connection with any hearing, the provisions of section 307(a) (relating to subpoenas) shall apply."

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CHAPTER I: INTRODUCTION

A. Summary

The Clean Air Act as amended charges the Administrator of the Environmental Protection Agency with major responsibilities for the control of motor vehicle emissions. These duties include: establishing emission standards for pollutants which endanger public health and welfare; administrating a number of related activities concerned with vehicle testing, certification and enforcement; regulating the content of fuels; demonstrating the feasibility of low-emission vehicles; monitoring the development of improved devices to control emissions from internal combustion engines; and directing research and development activities related to alternative power systems.

In addition Sections 202(b)(1)(A) and 202(b)(1)(B) require that:

(1) 1975 automobiles achieve a 90% reduction in the emissions of hydrocarbons (HC) and carbon monoxide (CO) which were allowable in 1970, and

(2) 1976 automobiles achieve a 90% reduction in the emissions of oxides of nitrogen (NO_x) from the average levels

measured on 1971 automobiles which were not subjected to any federal or state NO_x emission standards.

Under Section 202(b)(5)(D) the Administrator is permitted to suspend the 1975 and 1976 standards for up to one year, only if he determines that:

"(i) such suspension is essential to the public interest or the public health and welfare of the United States,

(ii) all good faith efforts have been made to meet the standards established by this subsection,

(iii) the applicant has established that effective control technology, processes, operating methods or other alternatives are not available or have not been available for a sufficient period of time to achieve compliance prior to the effective date of such standards, and

(iv) the study and investigation of the National Academy of Sciences conducted pursuant to subsection (c) and other information available to him has not indicated that technology, processes or other alternatives are available to meet such standards."

Since the establishment of the Environmental Protection Agency on December 2, 1970, EPA has completed a number of actions related to the control of emissions from motor vehicles. An initial contract has been signed with the National Academy of Sciences to identify the resources necessary to study the technological feasibility of attaining the 1975 and 1976 standards.

EPA has published an advance notice of proposed rule-making indicating its intention to control or prohibit the use of alkyl lead in motor vehicle gasoline. Detailed studies of scientific, medical, economic, and technological data concerning this matter are currently under review.

In February, the Administrator sent a letter to all domestic and foreign auto manufacturers requesting information about research and testing activities related to the development of emission control systems designed to meet the 1975 and 1976 standards. EPA also conducted two days of public hearings on this subject during May of 1971. Twenty-one representatives of the automotive and related industries, of the academic and scientific communities, and of public interest organizations and groups presented statements and responded to questions.

EPA has published certification test results for 1971 model vehicles and engines. National ambient air quality standards have been promulgated which include motor vehicle related pollutants. Regulations have been proposed defining the useful life of vehicles and requiring the inclusion in owners' manuals of maintenance instructions for emission control systems. Specific numerical standards and test procedures have been established for 1975 and 1976 emissions of HC, CO and NOx.

Demonstration programs relating to low-emission vehicles have been initiated. Three contracts have been signed under the Federal Clean Car Incentive Program whereby manufacturers provide prototype vehicles for government testing and evaluation.

The Low-Emission Vehicle Certification Board prescribed by Section 212 of the Act has been established. The Board held its first meeting in June, 1971, and adopted procedural regulations related to the preferential purchase of low-emission vehicles for use in government fleets.

EPA is also directing a research and development program for low-emission vehicular power systems other than the internal combustion engine.

Chapter 2 of this report includes a brief history of federal and state emission control standards and test procedures. It also contains a more elaborate explanation of EPA's initial accomplishments. Chapter 3 provides an overview of all of EPA's programs and activities related to the control of motor vehicle emissions. While the industry is giving prime attention to the development of add-on devices to enable the internal combustion engine to meet the emission standards prescribed in the law, EPA is also directing research and development programs concerning alternative power systems.

Chapter 4 deals with the health and welfare effects of motor vehicle related pollutants. While vehicular emissions are important sources of pollution, especially in congested urban areas, they are not the only sources of these contaminants. In discussing health and welfare impacts it is important to note that it is ambient air quality, the composition of a local air mass, rather than emission levels from particular sources, which is the significant factor although the two are clearly related.

It is difficult to generalize about the relative importance of various contributions of the same air contaminants to ambient air quality because most air masses undergo lateral movements. Thus relative impacts must be looked at in terms of specific localities reflecting differences in geography, meteorological conditions, traffic patterns and the size and locations of all sources of the same pollutants.

A detailed discussion of the progress reported by industry is contained in Chapter 5. This material describes a number of control devices under development and outlines some of the technical problems facing the industry. This material also reiterates a number of concerns experssed by the manufacturers in their communications with EPA.

The final section of this report, Chapter 6, deals with the costs associated with motor vehicle emission control. It is not yet possible to provide precise estimates of the cost per vehicle of attaining the 1975 and 1976 standards established in the Act. The total cost to the public will, however, include the initial cost of the control system, its maintenance after warranty, and expected increases in fuel consumption and reductions in vehicle performance.

Neither the final control system needed to achieve the 1975 standards nor the technology for attaining the 1976 standards, have yet been identified. Thus, the cost figures contained in Chapter 6 must be considered preliminary and include informal industry estimates of initial costs ranging from $80 to $600 per car for 1975. However, it appears clear that the costs associated with 1975 and 1976 standards will be considerably greater than those experienced in reaching Federal emission standards through 1974.

Information provided to EPA by auto manufacturers revealed a significant increase in emission control systems research and development activity since the passage of the 1970 amendments to the Clean Air Act. During the first six months of accelerated development, industry laboratories have reported the attainment of reduced emission levels. While there are many problems to be overcome to convert laboratory results into reduced emission levels from mass-produced autos, the added industry effort should improve prospects for significant technological improvements.

B. Conclusions

During the recent public hearings industry spokesmen expressed major reservations about the technological feasibility of achieving the statutory emission standards within the time limits prescribed by law. The manufacturers were unanimous in asserting that the levels of reduction required for 1975/76 precluded the substitution of alternative power systems, making it essential that emission control be achieved through an improved internal combustion engine. Industry representatives consistently stated that reaching the 1976 NOx emission levels goes beyond the limits of current knowledge and will require some major technological breakthrough early enough to permit mass production of 1976 models. They also expressed concern about the high cost of attaining the low levels of emissions required by the statute.

At these same hearings representatives of public interest organizations were skeptical of industry statements about their inability to develop the necessary technology to reduce emissions to the required levels. These witnesses pointed to previous instances of resistance by the industrial community to deadlines which were ultimately achieved. Suspicion was also voiced about the vigor of government enforcement concerning interim standards and test procedures. This climate of mistrust makes it important that, to the degree possible, matters related to motor vehicle emission control be given full public exposure.

Motor vehicle emissions are important sources of HC, CO, and NO_x pollutants especially in congested urban areas. However, they are not the only sources of these contaminants.

The specific contribution of vehicle emissions to the degradation of ambient air quality is a complex matter and varies from place to place. These variations are attributable to differences in geography, meteorological conditions, traffic patterns, and the size and location of other sources of these pollutants. More information on these matters is expected with the completion of State implementation plans required under the legislation. These plans are also expected to include a variety of alternative abatement strategies. With additional information about the costs and effectiveness of emission control from all types of sources, it should be possible to undertake detailed cost-effectiveness analyses in order to insure that the ambient air quality standards are achieved at the most reasonable cost to the American people.

One of the unfortunate aspects of motor vehicle emission control is that reducing levels of hydrocarbons and carbon monoxide, which is done primarily through increasing the efficiency of combustion, tends to make more difficult the control of oxides of nitrogen, whose formation is largely a function of the heat of combustion. Thus, a major technological challenge faces the Nation's auto industry in meeting these emission standards.

EPA is moderately optimistic that the 1975 standards can be attained especially since it is expected that unleaded gasoline will be generally available at that time. We are also hopeful that technological developments will enable the manufacturers to reach the 1976 standards. However, the costs associated with achieving these standards may be high. Therefore, the Agency is not recommending any legislative changes at this time, although they may be needed in the future.

CHAPTER 2: Background

A. History of State and Federal Standards

The control of motor vehicle emissions was initiated in the State of California in 1959 with the adoption of standards to control exhaust hydrocarbons and carbon monoxide. This was supplemented in 1960 with standards to control emissions resulting from crankcase blowby. The early generations of California standards were goals requiring the demonstration of feasible technology before the establishment of implementation deadlines. Such scheduling was contingent upon the availability and certification of devices, systems, or modifications which would enable motor vehicles to meet the standards. In 1963, California adopted diesel smoke standards; however, as with the previous standards, there was no immediate implementation schedule. As a result of the certification of appropriate devices and systems, California required a first level of crankcase emission control effective with the 1963 models, improved crankcase emission control for 1964, and control of exhaust hydrocarbons and carbon monoxide in 1966.

The 1965 Amendments to the Federal Clean Air Act gave the Secretary of the Department of Health, Education and Welfare, the authority to control emissions from motor vehicles.

Accordingly, on March 30, 1966, the initial Federal motor vehicle emission standards were adopted to become applicable with the 1968 models. The standards and procedures were similar to those which had been employed by California and required some control of exhaust hydrocarbons and carbon monoxide from light-duty vehicles and one hundred percent control of crankcase emissions from gasoline-fueled cars, buses, and trucks. The term light-duty vehicle refers to self-propelled vehicles designed for street or highway use, which weigh less than 6,000 pounds and carry no more than twelve passengers. Thus, the vehicle population is divided into two groups, light and heavy-duty which generally correspond to cars as opposed to buses and trucks.

On June 4, 1968, revised Federal standards were published which required more stringent control of hydrocarbons and carbon monoxide from light-duty vehicles,of evaporative emissions from the fuel tanks and carburetors of light-duty vehicles, of exhaust hydrocarbon and carbon monoxide emissions from gasoline-fueled engines for heavy-duty vehicles,and of smoke emissions from diesel engines for heavy-duty vehicles. The fuel evaporative emission standards became fully effective with model-year 1971. The other standards applied to 1970 model year vehicles and engines. Thus with the introduction of 1970 models, the industry had reduced hydrocarbon emissions by almost three-quarters and carbon monoxide emissions by about two-thirds.

On November 10, 1970, standards were published applicable to 1972 model light and heavy-duty vehicles and heavy-duty engines. The significant modification in these standards pertained to the method of evaluating the exhaust hydrocarbon and carbon monoxide emissions from light-duty vehicles. Improved methods of test operation, exhaust sampling and gas analysis had been developed so that emissions measurements would be more representative of actual discharges from in-use vehicles.

B. Testing Procedures

Testing procedures are complicated and require some added explanation. Numerical emission standards are meaningful only when related to the specific test procedure employed. As with many other aspects of auto pollution control, test and analytical procedures have undergone modifications and improvements over the years. The initial testing in California and at the Federal level used a 7-mode 7-cycle test procedure. During this type of testing, a vehicle is run through seven driving conditions or modes such as low and high speed acceleration. The resulting emission measurements are representative of the rate of emission during these particular driving conditions, but do not measure total emissions.

In 1970, the Federal Government adopted a Constant Volume Sample or CVS procedure during which the vehicle is run through a test cycle designed to simulate urban driving. The characteristics of the standard test drive were based on an elaborate study of Los Angeles traffic patterns in 1965. All emissions from ignition key-on after a 12-hour storage period to the end of the test cycle are collected and analyzed. The CVS procedures result in measurements which are considered more representative of actual emissions from vehicles as used in urban areas. However, the resulting numerical standards are different from those revealed by earlier test procedures.

EPA has recently announced a further refinement in test procedures to include both a cold start (after a 12-hour storage) and a hot start (after a 10-minute wait) and the computation of a weighted average as a basis for 1975 and 1976 numerical standards. These changes, as well as certain minor modifications in analytical techniques, are intended to make test results more representative of emissions from in-use vehicles. The new test procedures are also expected to be used in connection with the proposed 1973 emission standards.

C. Significant EPA Actions

1) On January 30, 1971, the Environmental Protection Agency published an advance notice of proposed rule-making concerning its intention to promulgate controls or prohibitions on the addition of alkyl lead to gasoline fuels for motor vehicles at the earliest possible date. In accordance with the requirements of Section 211 of the Act, EPA is considering relevant, scientific, medical, economic, and technological data prior to final rule-making in this area. Systems designed to control NO_x emissions to meet standards applicable to 1973 model year cars may require that a low lead gasoline be generally available in late 1972 and the probable use of catalytic converters to achieve the 1975 HC-CO standards makes it imperative that unleaded gasoline be generally available by that time. These developments underscore the need for implementing the President's request for a tax on lead in gasoline to insure that unleaded gasoline will be competitively priced.

2) On February 26, 1971, all domestic and foreign auto manufacturers were requested by the Administrator to furnish EPA with the following information:

1. A description of the basic techniques being explored as a means of meeting the emission standards required under Section 202(b)(1).

2. With respect to the techniques identified and described:

a. An indication of the current state of development and testing, including durability testing of each one.

b. A summary of the emission data derived from any such testing.

c. An assessment of the prospects for perfecting each one to a point at which it could be used on production-line motor vehicles.

d. A description of the major problems that remain to be solved in order to perfect each type of unit.

e. An identification of all other companies participating in the development and testing.

f. A summary of the resources in dollars and professional-technical man years applied during calendar year 1970 and expected to be applied during 1971 to the development and testing of the various units.

3) On April 7, 1971, a notice of proposed rule-making was published concerning the requirement for the preparation of State implementation plans necessary to achieve national ambient air quality standards. Under Sections 109 and 110 of the Act, EPA is required to publish national ambient air quality standards and States are required to prepare specific implementation documents detailing how they propose to attain

the prescribed ambient standards. In this notice, attention was called to the potential need to develop aftermarket strategies to control motor vehicle emissions, which might include vehicle inspection programs, mandatory maintenance, and/or retrofit control systems for the existing auto population. The technology for periodic inspection is being developed and will be evaluated in terms of benefits, costs, and effectiveness.

4) On April 10, 1971, the Federal certification test results for 1971 model year motor vehicles and engines were published.

5) On April 30, 1971, national primary and secondary ambient air quality standards were published as final rule-making, including standards for hydrocarbons, carbon monoxide, and oxides of nitrogen. These pollutants are associated with motor vehicle emissions.

6) Also on April 30, 1971, the State of California was granted waiver of Federal preemption for motor vehicle emission standards more stringent than those currently in effect by Federal regulation. These pertain to:

a. Auto emission standards and test procedures for the 1972 model year.

b. Auto assembly line standards and test procedures for the 1972 model year.

3. Prohibition of the sale of automobiles that require gasoline of research octane greater than 91 effective with the 1973 model year.
4. Gasoline powered truck emission standards and test procedures for the 1973 model year and more stringent standards for the 1975 model year.
5. Diesel powered truck emission standards and test procedures for the 1973 model year and more stringent standards for the 1975 model year.

The waiver was granted on the basis of testimony presented at a hearing held in Los Angeles, California, on January 26 and 27, 1971, additional material provided prior to February 22, 1971, and other related information available to the Environmental Protection Agency. Additional waiver requests were denied at that time but are under review within EPA.

The legal basis for granting this waiver is contained in Section 209 of the statute which concerns Federal preemption of State and local emission standards. However, the law also permits EPA to issue waivers to California if, after public hearing, the Administrator finds that State standards more stringent than the Federal requirements are necessary to meet compelling and extraordinary local conditions.

7) On May 6 and 7, 1971, hearings were held in Washington, D. C. to supplement the industry responses to the Administrator's letter of February 26, 1971. Twenty-one representatives of the automotive and related industries, of the academic and scientific communities, and of public interest groups and organizations presented statements and responded to questions related to meeting the 1975-76 emission standards.

In his introductory comments, the Administrator stated:

"The law itself does not permit traditional conceptions of satisfactory driving performance to stand in the way of whatever changes in vehicle design and power system are needed to control emissions. The same is true with regard to vehicle cost. This hearing is part of the continuing effort by the Environmental Protection Agency to find out just what sacrifices might be needed in cost, in fuel economy, in power, in acceleration and in other historic yardsticks of vehicle performance to produce an automobile that we can live with as a people.

"The low emission car of the future may be a more expensive car. It may not equal today's car in road performance, but this is a price that may be necessary if we are to have and preserve a healthy environment for ourselves and our families.

"As a consequence, we cannot and will not accept anything less than a wide open research and development effort to meet the actual requirements. We will not, for example, find acceptable a manufacturers decision not to explore innovative designs or power systems on the grounds that a vehicle so designed or so powered would be more costly or would not meet traditional performance criteria. We must develop and apply whatever technology is needed to achieve the degree of emission control required by the Act and we must be willing to accept any necessary sacrifices in other areas of vehicle performance."

He further stated a second point concerning, "The specific power conferred upon me by the Clean Air Act to suspend the effective date of an emission standard for one year. Exercise of this power is carefully circumscribed by law. I am required to make a determination relating to good faith and two separate determinations concerning the technological feasibility of meeting the statutory standards."

"I have given serious considerations to the proper construction of the statutory provision for suspension.

It is my present judgment that the required determinations relating to technological feasibility do not permit me to suspend an emission standard in favor of a single applicant or a group of applicants if technical knowledge exists, in the industry or elsewhere, which would enable any member of the industry to mass produce a light-duty vehicle in compliance with the Act."

"It is important that all of the implications of this construction of the law be well understood at the earliest possible time. It means that if any member of the industry could meet the Act's deadlines for compliance, all applications for extension will be denied."

"Any other construction of the suspension provision would be incompatible with the clear intent of the law to require whatever changes in design or power systems are needed to control emissions. Where some manufacturers meet the statutory deadlines by making major changes which substantially increase the cost of the vehicles or which require major sacrifices in vehicle performance, I do not believe that Congress intended to subject such manufacturers to competition from cars produced by other manufacturers who are required to meet a less stringent standard."

"As I read the law, the separate determination concerning good faith becomes applicable where it is not technologically possible for any member of the industry to comply with the Act's requirements. In that event, suspensions for one year would be granted only to applicants who can establish that they made a good faith effort to meet the statutory deadlines for compliance. Here, on the separate issue of good faith, the specific problems which may face a particular manufacturer appear to be pertinent."

8) On May 11, 1971, the proposed definition of useful life for vehicles and requirements for the inclusion of maintenance instructions for emission control systems in owner's manuals were published to implement Sections 202(d) and 207 of the Act.

9) In May, 1971, three contracts were awarded to provide prototype cars for government testing and evaluation under the Federal Clean Car Incentive Program.

10) On June 18, 1971, the Low-Emission Vehicle Certification Board held its initial meeting and approved procedural regulations concerning preferential purchasing of low-emission vehicles for use in government fleets. These activities are prescribed in Section 212 of the Act.

11) On June 29, 1971, the first Federal standards were issued requiring control of oxides of nitrogen emissions and prescribing measurement techniques for this pollutant applicable to 1973 model light-duty motor vehicles.

12) On June 29, 1971, standards were promulgated to prescribe the 1975 exhaust hydrocarbon and carbon monoxide emission requirements, and 1976 oxides of nitrogen emission requirements applicable to light-duty vehicles as required by Sections 202(b)(1)(A) and 202(b)(1)(B). In addition, modifications in test and analytical procedures were included as described in Section B of this Chapter.

In addition, EPA has entered into an initial contract with the National Academy of Sciences to study the technological feasibility of meeting the 1975 and 1976 standards in accordance with the provisions of Section 202c of the Act.

CHAPTER 3: Related EPA Programs and Activities

A. Introduction

The Environmental Protection Agency has been assigned responsibility for a number of programs and activities designed to abate pollution emanating from motor vehicles. Regulations establishing standards, testing procedures, and enforcement practices have been developed and promulgated to guide future actions. Staff and contract personnel from the National Academy of Sciences are assessing the technological feasibility of attaining the 1975 and 1976 standards established in the legislation. EPA is expanding its capability to monitor industry progress which is primarily focused upon add-on devices to clean up the internal combustion engine. Demonstration programs have been initiated concerning the feasibility of low-emission vehicles. EPA is also directing a research and development program for alternative power systems.

B. Establishing Standards

The Clean Air Act as amended establishes specific emission requirements for hydrocarbons, carbon monoxide, and oxides of nitrogen for 1975 and 1976. However, EPA was required to convert these parameters into specific numerical standards related to 1970 and 1971 emission levels. This work has been completed, and the standards for 1975 and 1976 have been published.

In addition, EPA also has responsibility under Section 202(a)(1) of the Act for promulgating emission standards for other exhaust pollutants if they are found to endanger public health and welfare. Due consideration must be given to the availability of appropriate control technology and the cost of compliance. These responsibilities carry EPA into analysis of exhaust materials, research concerning health and welfare impacts of pollutants, assessment of available control technology and studies of the economic impact of alternative abatement strategies.

C. Testing and Enforcement

The enabling legislation assigns EPA responsibility for testing, certification, and enforcement activities concerning emission controls for new motor vehicles and engines. At present these programs generally follow the procedures outlined below: A quantifiable emission standard is promulgated to be met by a set deadline. Manufacturers develop and test prototype vehicles, with some confirmatory testing by EPA. If the prototype design is found to comply with the standard, the group of vehicles represented by that unit is certified for production and sale. In-use vehicles are later tested to determine whether production vehicles continue to meet the standards.

EPA's testing and enforcement procedures require the certification of manufacturers' vehicle and engine product lines based on the satisfactory testing of prototype designs. In formal application for certification, the manufacturer is required to delineate pertinent mechanical characteristics of the vehicles or engines and emission control systems, and the projected sales of each configuration. This information provides the basis for EPA selection of configurations to be tested for establishing eligibility for certification. The actual testing program involves two groups of vehicles or engines. One group is tested to determine emission levels after engine break-in. The second group consists of vehicles or engines which are operated for for extended periods with limited maintenance to simulate the rate of emissions degradation with normal usage. The certificability of a group or engine family is established if the emission value of each engine tested, adjusted by the appropriate deterioration factor, is in compliance with the standards.

Surveillance testing of vehicles in routine service has shown that production vehicles in use do not consistently display the low emission levels indicated in prototype certification testing. Procedures for assembly line testing are under development but they require solutions to serious problems. High volume testing dictates the need for quick test procedures which can be consistently related to the certification test results. Such procedures should ideally provide diagnostic information so that appropriate repairs can be made at minimum expense and with minimum loss of time. An effective quick test procedure could also be useful in expanding the present surveillance programs to determine when manufacturers should institute recall programs. An extensive program is being conducted by EPA to identify appropriate equipment and procedures.

To implement Section 207, manufacturers of new motor vehicles and engines will be required to warrant to the ultimate purchaser that the vehicle or engine is designed, built, and equipped to conform with applicable emission standards, and is free from defects in materials and workmanship which might result in failure to conform to appropriate regulations during its useful life. Surveillance studies will be strengthened and regulations will be promulgated requiring manufacturers to recall vehicles which are found to be out of conformity with standards during the warranty period.

The testing of heavy-duty vehicles entails the application of substantially different procedures than those associated with light-duty vehicles. Heavy-duty engines, both gasoline-fueled and diesel have a broad range of uses in vehicles larger than 6000 pounds. Present procedures, therefore, involve engine testing as opposed to vehicle testing. EPA is currently reevaluating the heavy-duty testing procedures with the objective of assuring that they reflect, as much as possible, the emissions from such vehicles in actual use.

Another important feature of EPA's testing program concerns the verification of new control devices developed by non-automobile manufacturers. Section 206 provides for the testing or any emission control system incorporated in a motor vehicle or motor vehicle engine submitted to the Administrator by any person. If it is determined that the vehicle or engine conforms to appropriate standards, the Administrator shall issue a verification of compliance with emission standards for the system. The manufacturers and the National Academy of Sciences shall be informed of these results which shall also be made available to the public. Hopefully these provisions will accelerate the pace of development of new emission control devices.

D. Monitoring Technological Developments

In order to carry out EPA responsibilities concerning the 1975 and 1976 emission standards for light-duty vehicles, we are expanding our capability to monitor the development of appropriate control technology both within and without the auto industry. As described in Chapter 2 the Administrator has requested specific information from the auto manufacturers and has held public hearings on these subjects. The results of our initial contacts are reflected in Chapter 5.

E. National Academy of Sciences Contract

Section 202(c)(1) of the Act directs that the Administrator "enter into appropriate arrangements with the National Academy of Sciences to conduct a comprehensive study and investigation of the technological feasibility of meeting the emission standards required to be prescribed by the Administrator" (for 1975 and 1976 light-duty motor vehicles). In addition, the Administrator is directed to request the National Academy of Sciences to submit semi-annual reports on its progress to the Administrator and to Congress beginning on July 1, 1971.

Shortly after the passage of the Act, EPA contacted the staff of the Academy concerning this work. A preliminary contract was awarded to the Academy to allow them to assemble the necessary resources, and develop specific plans and budgets for carrying out the work. The involvement of the National Academy of Sciences will provide the Congress and the Administrator with an independent assessment of technological feasibility of meeting the 1975 and 1976 standards.

F. Regulation of Fuel Content

The fuel additive which has received most attention related to auto emissions is lead. It has been well documented that catalytic converters, which are among the devices being developed to remove carbon monoxide, hydrocarbons, and nitrogen oxides from vehicle exhaust, deteriorate rapidly when exposed to fuels containing lead compounds. Lead additives have also been shown by several investigators to contribute to fouling of exhaust gas recirculation systems used for nitrogen oxides control.

As directed in Chapter 4, the health effects of lead emissions are now under serious review. Studies are also being sponsored by EPA to evaluate the economic impact of curtailing or eliminating the use of lead in gasoline. A comprehensive report concerning this matter is expected later this year which will serve as a basis for further discussion and eventual rulemaking.

G. Alternative Power System

In order to meet the 1975-76 standards, the automobile industry is concentrating its efforts on modifications of the conventional internal combustion engine. There is serious question, however, about the ability of the conventional engine to meet long term health and welfare needs of the nation as now perceived. Accordingly, the Environmental Protection Agency has embarked on a program of federally sponsored research and development of alternative engine systems which are inherently cleaner than the conventional engine. This development activity is embodied in the Advanced Automotive Power System Program (AAPSP).

Five types of power systems initially were part of the program when it began in July of 1970. These include Rankine cycle, the gas turbine, heat engine/electric hybrid, heat engine/flywheel hybrid, and all-electric. Two additional systems, the stratified charge engine and the advanced design diesel engine, have been added to the program. Limited privately sponsored research has been underway for some time on all of those systems.

Each candidate system was at a different stage of development when the program began and, depending on technical developments, may enter the hardware phase at a different time. The first 18-month phase of the program is intended to be a period of evaluation wherein complete systems are designed, critical components bench tested, and decisions made on whether to proceed to first generation system hardware.

In the Rankine Cycle Engine, there is an external combustor and an enclosed working fluid which is heated, expanded to do work, then condensed into a liquid, with the fluid being continuously recycled. Three types of Rankine systems are presently in the design and component test phase. Two systems use organic working fluids one with a reciprocating expander, the other with a turbine expander. The third Rankine system is the steam engine. The technical problems confronting the successful development of the Rankine cycle system are understood and are being studied. Major problems appear in the inefficiency of components, and complexity of the control systems. Parallel research and development of components for all three types of engines is currently underway. The first prototype engines are expected to be available for testing in 1972.

More work has been conducted by the domestic auto manufacturers on the gas turbine engine than on any other candidate. EPA sponsored research efforts are being focused on solving specific problems which have made the gas turbine unattractive for use in cars. These problems include the need for reducing the nitrogen oxide emissions in the exhaust, developing manufacturing techniques for mass producing turbines inexpensively, and increasing system reliability. As solutions to these problems become available, it is anticipated that industry will apply them to their own turbine designs.

The hybrid engine candidates include the heat engine/electric and the heat engine/flywheel. The heat engine/electric hybrid consists of a small size low-powered engine (80-100 hp) and an array of batteries. The hybrid system is designed to extract power from the engine alone, or from both engine and battery at the same time. The basic system is compatible with either a conventional internal combustion engine or a small gas turbine. In either configuration the system operates best by running the heat engine at a constant speed with additional power for acceleration supplied from the battery system.

This hybrid concept offers potential advantages. The engine speed range is relatively small with an attendant ease of control of exhaust emissions under such conditions. Good road performance for a standard size American automobile can be obtained with a relatively small and inexpensive heat engine. The basic problems of this system are its relative complexity, higher cost, and the greater space required for the two sources. Development of improved lead-acid batteries to accommodate the rapid charge-discharge characteristics needed for this hybrid mode of operation is now underway.

The heat engine/flywheel system would function in a manner similar to the heat engine/electric with the battery replaced by a mechanical storage device, a spinning flywheel. Research has progressed from the analysis of practical flywheel materials to the design and fabrication of specific flywheels for cars.

The all-electric car engine development has been underway for more than a year at Argonne National Laboratories. It is anticipated that "proof-of-principle" for a high temperature lithium-sulfur system will be demonstrated within the next 8 months. Once proof-of-principle has been achieved, the study will move into a development phase, first with a goal of a 2 kilowatt (kw) battery, then a 5 kw battery and then a 20 kw battery system. Development of the all-electric system will not be completed early enough to meet 1975 standards because the project is still in the fundamental research stage. Moreover, an environmental cost/benefit analysis is yet to be undertaken which would indicate whether there would be a net gain from the environmental viewpoint given the added burdens such a system might place on electric power generation requirements. However, such a low emission vehicle might be highly desirable for conjested urban areas.

The stratified charge engine is a gasoline-fueled internal combustion engine with many hardware characteristics of the conventional engine. Differences appear mainly in the combustion chamber design and the use of fuel injection.

Much of the initial work on this engine was sponsored by the U.S. Army Tank-Automotive Command. The measured exhaust emission levels for an experimental stratified charge engine installed in a small military vehicle and employing a catalytic muffler are below the standards for hydrocarbons and carbon monoxide set for 1975. Further work must be conducted to reduce the nitrogen oxide emissions to attain the 1976 standards. Several generations of development have been funded by the Army with some assistance by HEW. EPA's work on this engine has emphasized the reduction of nitrogen oxide emissions. Testing of this system in a fleet of vehicles is now being contemplated. However, there are many problems to overcome to convert experimental engines into mass produced vehicles with similar emission characteristics.

The diesel engine is not commonly used in American made automobiles because it is heavier and more expensive than the conventional automobile engine. Emphasis is being directed toward the development of a low compression diesel with high-swirl injection and a modified prechamber design. Exhaust emission levels for hydrocarbons and carbon monoxide lower than the 1975 standards have been shown for this type of engine without the need for a catalytic converter. The measured nitrogen oxide levels of the first generation engine are relatively low although above the 1976 standards. Studies are concentrating on nitrogen oxides reduction and on performance, durability and driveability testing.

H. <u>Federal Clean Car Incentive Program</u>

The Federal Clean Car Incentive Program (FCCIP) is designed to foster private development of new types of low emission vehicles related to the 1975 and 1976 emission standards. In the first stage of the program the developer leases to the Government a candidate prototype vehicle which is subjected to rigorous evaluation. After successfully passing stringent emissions and performance testing on the leased prototype car, 10 additional vehicles may be purchased for more comprehensive testing. The government may later buy up to 100 vehicles for further evaluation. If the low emission levels are maintained and road performance is found to be satisfactory, the car is then eligible for certification as a low-pollution vehicle under the program described in the next section of this report.

This program began in January, 1971, with approximately 20 initial proposals from industry. Ten different vehicle systems have been accepted into the program. In May of this year three contracts were approved to provide prototype cars for testing. The Incentive Program is expected to provide valuable information about the feasibility of reaching the 1975-76 emission standards.

I. Low-Emission Vehicles Purchase Program

Section 212 of the Act provides for the creation of a Low-Emission Vehicle Certification Board (LEVCB). EPA initially certifies vehicles which discharge significantly less pollutants than required by current Federal regulations. The LEVCB identifies the class of vehicle for which the selected cars are considered suitable substitutes taking into consideration factors such as performance and cost of maintenance. Certified vehicles may be purchased for use in government fleets at premiums of up to 100% over the prices normally paid by the government for equivalent vehicles. The non-statutory members of the Board have been named by the President and its first meeting was held on June 18, 1971. At that time the board adopted initial procedural regulations.

CHAPTER 4: Health and Welfare Effects

A. Emission Levels and Ambient Air Quality

Motor vehicle emissions are important sources of air pollutants especially in our congested urban areas. The following figures indicate EPA's estimate of the relative contribution of vehicle emissions of HC, CO, and NO_x.

% of National Emissions in 1969

Source	CO	HC	NO_x
Motor Vehicles	64.7	45.7	36.6
Other forms of transportation	9.0	7.2	10.5
Fuel Combustion in stationary sources	1.2	2.4	42.0
Industrial Processes	7.9	14.7	0.8
Solid Waste Disposal	5.2	5.3	1.7
Miscellaneous	12.0	24.7	8.4
	100.0	100.0	100.0

In addition, emissions of HC and NO_x from motor vehicles and other sources undergo complex chemical reactions in the atmosphere and contribute to the formation of photochemical oxidants associated with urban smog.

While the proportions indicated above hold true nationally, the relative contributions of vehicle emissions to ambient air quality varies among communities. These variations result from differences in geography, meteorological conditions, traffic patterns, and the size and location of other sources of the same pollutants. Thus in discussing health and welfare impacts the key factors are ambient air concentrations resulting from emissions from all sources, rather than emissions from any particular source.

In accordance with Section 109 of the Clean Air Act, EPA has published national primary and secondary ambient air quality standards for a variety of air pollutants. Primary standards define levels of air quality which the Administrator judges to be necessary, with an adequate margin of safety, to protect public health. Secondary standards reflect concentrations judged necessary to protect public welfare from any known or anticipated adverse effects. Of interest to a discussion of motor vehicle emissions are the ambient air quality standards for photochemical oxidants, hydrocarbons, nitrogen dioxide, and carbon monoxide which are shown in Table 1.

Table 1

NATIONAL PRIMARY AND SECONDARY AMBIENT AIR QUALITY STANDARDS
For Motor Vehicle Related Pollutants
(Concentrations not to be exceeded more than once per year)

Pollutant	Concentration Limit: Micrograms Per Cubic Meter	Concentration Limit: Parts Per Million	Averaging Time
Photochemical Oxidants	160	0.8	1 hour
Hydrocarbons (Methane free)	160	0.24	3 hours
Nitrogen Dioxide	*	*	*
Carbon Monoxide	10,000	9	8 hours
	40,000	35	1 hour

For the above pollutants, adverse welfare effects have not been observed to occur at levels below those judged necessary to protect the public health. Accordingly, the secondary standard has been set at the same level. Pursuant to the Act, primary ambient air quality standards must generally be achieved by June 1, 1975.

*Standards for short-term exposure rates for nitrogen dioxide have not been promulgated. EPA has established safe annual exposure rates of 100 $\mu g/m^3$ or 0.05 p.p.m.

Related to the establishment of national ambient air quality standards are the provisions of Section 110 of the legislation, which require that States prepare implementation plans indicating how they will attain the national ambient standards within their boundaries by 1975. These documents, which are to be submitted to EPA by January 30, 1972, will indicate the relative contribution of motor vehicle emissions to ambient air quality for communities in many parts of the Nation. They are also expected to include a variety of abatement strategies and contribute greatly to our understanding of the significance of motor vehicle emissions control.

B. Photochemical Oxidants, Hydrocarbons, Carbon Monoxide, and Oxides of Nitrogen

Detailed discussions of the effects of photochemical oxidants, hydrocarbons, nitrogen oxides, and carbon monoxide may be found in their respective Air Quality Criteria Documents. The following is a summary of the more important effects of these pollutants in ambient air masses coming from all sources and not just motor vehicles.

Photochemical oxidants result from a complex series of atmospheric reactions initiated by sunlight. When reactive organic substances and nitrogen oxides accumulate in the atmosphere and are exposed to the ultraviolet components of sunlight, the formation of new compounds, including ozone and peroxyacyl nitrates, takes place.

Photochemical oxidants may adversely affect vegetation, human health, animals, and certain man-made materials. They can cause injury to many important species of plants such as beans, tobacco, petunias, peanuts, and pine trees. Injury to sensitive species has occurred after exposure of 4 hours to 0.05 ppm of photochemical oxidants. In southern California hundreds of acres of pondercsa pine forest have been affected by photochemical oxidants.

The principal human effect associated with photochemical oxidants include impairment of athletic performance and an increase in attacks among asthmatics, the latter effect having been observed when oxidant levels reached 0.15 ppm for one hour. Although eye irritation has been associated with oxidant levels of 0.10 ppm in Southern California, it has not been shown conclusively that any particular species of photochemical oxidants is responsible.

Rubber, fabrics, and dyes are particularly sensitive to photochemical oxidants as evidenced by rubber cracking, reduced strength in cellulose fabrics, and the fading of certain dyes after exposure.

Hydrocarbons represent the major class of reactive organic matter in the atmosphere that is responsible for photochemical smog. Through their reaction intermediates and photochemical oxidation products, they are directly responsible for the eye irritation associated with photochemical smog and much of the characteristic vegetation damage. Hydrocarbon oxidation products are also believed to be important contributors to the atmospheric aerosols responsible for the reduced visibility associated with photochemical smog. In addition, ethylene, a specific hydrocarbon, is directly responsible for certain forms of plant injury--orchids are especially sensitive.

The presence of nitrogen oxides in the atmosphere is essential to the photo-oxidation of hydrocarbons and the development of photochemical oxidants. Sufficiently reduced levels of either NO_x or HC alone in the air tend to alleviate the formation of photochemical oxidants, but the exact relationships are extremely complex.

Nitrogen dioxide, a type of oxide of nitrogen, is also a specific air pollutant associated with increased incidences of acute bronchitis in infants and school children and acute respiratory disease in the entire faimily group. Nitrogen dioxide has also been associated with damage to vegetation and corrosion of electronic components. Increases in the incidence of respiratory disease were associated with nitrogen dioxide levels ranging from 0.06 ppm to 0.08 ppm over a 6-month period.

Carbon monoxide is well known for its poisonous effects at high concentrations. It is absorbed through the lungs and reacts primarily with the hemoglobin of red blood cells. As an air pollutant, carbon monoxide represents a potential danger to human health and safety. It decreases the oxygen carrying capacity of the blood and reduces the availability of oxygen-transported to vital tissues by the blood. Carbon monoxide concentrations of 10 ppm produce blood carboxyhemoglobin levels of 2% in non-smokers. This carboxyhemoglobin level has been associated with impaired time interval discrimination.

Carbon monoxide concentrations of 30 ppm for 8 to 12 hours have been associated with impaired psychomotor performance and reduced visual acuity in normal subjects and with increased physiological stress to patients with heart disease.

C. Other Pollutants

1. Lead

Evaluations of available evidence are presently underway to determine the specific health effects of lead particulate matter emanating from auto emissions. These evaluations should be completed in the near future. It is already known that lead is a biologically nonessential metallic element which is clearly toxic under conditions of prolonged and excessive exposure (e.g., ingestion of paint containing lead). Furthermore, lead accumulates in persons exposed to high atmospheric concentrations. Lead is absorbed primarily through the gastrointestinal and respiratory tracts.

As noted in Chapter 3, in addition to health effects, lead in gasoline has been found to greatly reduce the effectiveness of catalysts and therefore the availability of unleaded gasoline is needed if these devices are to be used on production vehicles.

Since about 96 percent of the lead particulate matter found in the atmosphere results from gasoline-fueled engines, the reduction or elimination of lead from gasoline should significantly reduce the incidence of lead particulate matter in the future.

2. Other Substances

The significance of the relationship between auto emissions of the materials listed below and the health or welfare dangers has not been established. Medical and biological investigations of the following items are underway:

(1) Particulate materials--both organic and inorganic.

(2) Aldehydes and other carbonyl compounds.

(3) Nitrogen compounds other than nitrogen oxides, such as ammonia.

(4) Miscellaneous organic materials, such as polynuclear aromatic hydrocarbons.

CHAPTER 5: Industry Progress

A. Basic Technology

The gasoline-fueled internal combustion engine is the best understood and most reliable propulsion system currently available. The auto industry maintains that it is also the only prospect for mass production in 1975-76. Unfortunately, it is also an inherently high-emission propulsion system. These high emissions are caused, to a major degree by the fuel itself and relate to the difficulty in supplying thermodynamically ideal air and fuel charges to the cylinders and bringing about complete combustion over the full range of vehicle operating requirements.

The problem is maximized at low engine start-up temperatures and when the humidity and temperature of the air supply vary widely. Additionally, variability in fuel density and viscosity are factors which inhibit precise metering of the fuel. Gasoline in the liquid state will not burn and thus the higher boiling point hydrocarbons do not vaporize and burn when the engine is cold. Cold engine starts require extra amounts of gasoline to produce enough vaporized fuel to provide a combustible mixture at the spark plug. The excess non-vaporized portions then pass through the engine unburned.

The problem is reduced as the volatility of the gasoline is increased and the boiling range reduced. The importance of the fuel volatility factor is dramatized by the emission performance of the internal combustion engines when operated on natural gas or liquified petroleum gas (LPG). Typically, such changes in fuels result in lower emissions of HC and CO.

While efforts aimed at leaner air-fuel mixtures tend to reduce hydrocarbons and carbon monoxide, they tend to increase emissions of nitrogen oxides. This occurs because improved combustion results in higher temperatures which in turn promote the union of nitrogen and oxygen. Efforts to control nitrogen oxides to high levels within the engine tend to negate the improvement gained in HC and CO control. Thus NOx control will probably require other measures to reduce peak combustion chamber temperatures and/or the addition of an external control system.

B. Typical Control Concepts and Devices

Engine modifications designed to reduce emissions during the combustion process represent the principal approach used for compliance with motor vehicle exhaust emission standards now in effect. Such modifications, refined to promote even more efficient combustion, will continue to be a fundamental part of the systems approach leading to compliance with future standards. However, add-on devices such as thermal reactors and catalytic converters will most likely be required to complete the system.

Modification in gasoline composition, such as the elimination of lead and, possibly, changes in volatility characteristics, may also be required in order to facilitate the use of certain control techniques and optimize the potential of others. A review of the emission control techniques, components and concepts, known to be under development by industry for gasoline fueled motor vehicle follows:

1. Modification of Combustion Chamber Design

A major source of hydrocarbon emissions from automobiles is unreacted fuel-air mixtures expelled through the tailpipe. This occurs primarily because the very thin layer of gaseous mixture which makes contact with the relatively cool combustion chamber surfaces does not burn. By modifying the combustion chamber design to reduce the surface-to-volume ratio and by minimizing crevices, more nearly complete combustion of the full cylinder charge is promoted.

2. Modification of Induction System

Carbon monoxide in the exhaust results from insufficient oxygen in the fuel-air mixture and consequent incomplete combustion. Incomplete combustion is also an important source of hydrocarbons. Leaner air-fuel mixtures to assure more complete combustion can be accomplished by converting more of the liquid gasoline into the vapor form and by providing for improved fuel-air mixing and distribution among the cylinders. Air-fuel induction systems can be adapted to provide heated intake air for more uniform carburetor inlet temperatures thus allowing leaner fuel-air mixtures to be used. Air temperature can be maintained by a thermostatically controlled mixing valve in the air cleaner. Intake manifold heating tends to provide more uniform fuel distribution. Intake ports can also be re-designed to give improved induction turbulence and mixing. More uniform distribution of the fuel-air mixture to the cylinders can likewise be accomplished through design changes. Unfortunately, modification of induction systems which improve combustion and reduce HC and CO emissions also raise temperatures and worsen NOx control.

3. <u>Carburetor Modifications</u>

The carburetor is a key element in effective emission control by virtue of its role in metering the fuel in proper proportion to inlet air. Precise fuel metering, in accordance with changing engine requirements, makes possible operation with lean air-fuel mixtures. Carburetors can be designed with stronger fuel metering signals and closer calibration tolerances to assure better fuel mixing preparation. Fuel injection systems can provide more accurate metering and deliver fuel under pressure for maximum atomization. Electronic fuel metering could also allow for altitude compensation and more precise mixture control.

4. <u>Choke Modifications</u>

Gasoline in liquid form does not burn. Consequently, when an engine is started cold, an extra amount of gasoline is needed in order to obtain enough vaporized hydrocarbons to mix with air and provide a combustible mixture at the sparkplug. The function of the carburetor choke is to supply the added fuel. However, the unvaporized hydrocarbons pass through the engine unburned. By tailoring choke action to car requirements, enrichment during starting and warm-up can be made compatible with satisfactory driveability over a wide temperature range. Modification of the fuel to achieve greater vaporization could obviate the need for the choke or drastically reduce its periods of actuation.

5. Ignition System Modifications

Ignition systems optimized to initiate combustion in accordance with engine operation and emission control requirements, support improvements in fuel metering and mixture control. Spark retardation can be employed to reduce emissions of hydrocarbons and nitrogen oxides. Electronic ignition systems have been developed which will improve control of spark timing at all engine operating conditions greatly facilitate adjustments of spark timing on vehicles in consumer use, and improve system reliability. Retarding ignition timing results in more fuel being burned during the exhaust phase of the combustion cycle. Accordingly, some loss in power and fuel economy results and demands on the engine cooling system are increased.

6. Lower Compression Ratio

The use of high compression ratios improves engine efficiency and results in more power output for a given amount of fuel. Combustion temperatures are high, however, causing high emission of nitrogen oxides. The octane requirements of high compression ratio engines are high, necessitating the use of lead or expensive fuel modification. The presence of lead in gasoline severely limits the effectiveness of catalytic converters and reduces the life of other emission control system components. For these reasons, compression ratios of new cars are being reduced to curtail NOx emissions and promote the removal of lead additives.

7. Air Injection

Exhaust port air injection is one of the oldest concepts used for controlling motor vehicle exhaust emissions. Increased oxidation of hydrocarbons and carbon monoxide is achieved by pumping air into the exhaust ports and manifold. Major revisions to the cylinder head and exhaust manifold are required. Since NOx control during the combustion process has tended to increase HC and CO emissions, interest in exhaust port air injection is reviving. Air injection pumps are also helpful for effective operation of catalytic converters and thermal reactors.

8. Exhaust Gas Recirculation

Recirculation of a portion of the exhaust gas into the air-fuel mixture causes a reduction in the peak combustion temperature and a reduction in the formation of oxides of nitrogen. Dilution of the fuel charge with inert gases has the secondary effect of reducing engine octane requirements, but with some loss in power. Extreme dilution causes misfiring and deterioration in driveability. This can be compensated for by increased throttle openings and providing richer carburetion mixtures, but with some loss of fuel economy. Improved systems provide for proportioning the recirculated exhaust gas to the air flow demanded by the engine. Sensitive induction system components can be corroded and plugged by acid condensate and dirt in the recycled exhaust. The removal of lead and associated scavengers from gasoline is expected to moderate these problems.

9. Thermal Reactors

A thermal reactor functions as a combustion chamber outside the engine and normally appears in the form of an oversized exhaust manifold. Thermal reactors receive the hot exhaust gas from the engine, retaining as much heat as possible with insulation. Additional heat is generated by oxidation of carbon monoxide in the exhaust gases. High carbon monoxide concentrations are obtained by operating the engine with rich fuel mixtures. Such reactors are known as "rich thermal reactors." Supplementary air is required and it is necessary to create appropriate mixing and provide adequate residence time for the combustibles present to react with the oxygen. When designed for rich fuel-air mixtures to promote NO_x control, there is a substantial fuel penalty. In a "lean thermal reactor" system the carburetion is set lean so that the exhaust is inherently oxidizing and a secondary air pump is not required. Emissions are generally higher than from "rich" reactors.

Because of the extremely high temperatures that can be reached, the selection of suitable materials to give satisfactory durability is a major challenge. Special protective systems will be needed to prevent overheating which could damage the engine or create a general safety hazard for the vehicle occupants.

10. Afterburner

The afterburner is designed to oxidize unburned hydrocarbons and carbon monoxide in the exhaust gas.

It includes a precombustion chamber in which secondary air and fuel are sparkignited to provide thermal energy for the associated reaction chamber. Over-temperature problems present a serious handicap to its use.

11. Catalytic Converters

Catalytic converters are devices designed to receive exhaust gases and foster chemical changes associated with reducing levels of undesired pollutants.
The catalyst bed generally consists of an inert support material on which the active material is deposited in a thin layer. Alumina is the most common support whereas platinum, or platinum group metals, and transition metal oxides are the most common active materials. Catalysis may be used for oxidizing the hydrocarbons and carbon monoxide or reducing nitric oxide. The basic construction of reducing catalysts is similar to that for oxidizing catalysts. Reasonable effectiveness can be obtained for both reactions with identical catalysts under ideal conditions.

The catalytic converter is a relatively low-temperature device and need not be located in the engine compartment with attendant space problems. Underbody modifications may be required, however, for heat insulation and adequate ground clearance. It has a high heat capacity, requiring a relatively long time to reach activation temperature, but by the same token, it remains warm longer. A catalyst and thermal reactor combination represents an attractive system for controlling vehicle emissions. The thermal reactor increases the exhaust gas and catalyst temperatures and provides improved control during cold-start and warm-up. Deterioration tends to occur as a result of cyclic exposure to a high temperature environment. As with thermal reactors, fail-safe over-temperature controls are required to prevent permanent damage resulting from unit or engine malfunction.

Oxidizing and reducing catalysts may be used in combination but some mixture enrichment is needed to provide the necessary reducing atmosphere in the reducing stage, and supplemental air may be required for the oxidation stage. Warm-up problems in the second stage are accentuated in "dual catalytic converters." Good driveability and minimal economy loss is possible with this concept. However, reducing catalysts with good endurance are not yet available.

C. Industry Concerns

Various industry representatives have expressed a number of concerns about the prospect of meeting the 1975 and 1976 standards. While no one speaks for "the industry," there is enough commonality in content to identify a number of major concerns shared by many of the manufacturers. It has been asserted that the proposed standards cannot be attained with available technology, would be far too expensive compared to their effectiveness on air quality and include deadlines that provide the industry with insufficient lead time. A number of manufacturers have also expressed concern over increases in costs and reductions in fuel economy and driveability after modification to meet the 1975 and 1976 standards.

Various manufacturers have pointed out that the law requires them to solve two very different technical problems almost simultaneously. Hydrocarbon and carbon monoxide controls needed for the 1975 standards dictate more complete combustion in an oxidation atmosphere while controlling oxides of nitrogen necessitates lower combustion temperatures and/or a reduction atmosphere to convert these emission to nitrogen and oxygen gases.

A number of officials of both domestic and foreign producers indicated that achieving the 1976 NO_x standards takes them beyond existing knowledge and will require some technological breakthrough.

D. Exchange of Technical Information

Several manufacturers have complained about present limitations on exchange of technical information concerning vehicle emission control. These problems relate to the civil antitrust action brought by the Department of Justice in early 1969. The Government's complaint alleged that the Automobile Manufacturers Association and the four major United States manufacturers of motor vehicles, conspired to eliminate competition among themselves in the development and installation of motor vehicle air pollution control equipment. The Government charged specifically that the defendants had agreed to restrict public knowledge of research and development efforts related to control of motor vehicle emissions, that the defendants had delayed installation of control equipment, and that the defendants had deliberately misinformed California regulatory officials about the technical feasibility of reducing motor vehicle emissions. On September 11, 1969, the defendants, without admitting the truth of these allegations, entered into a consent decree which, among other things, prohibits each defendant from agreeing with any other defendant, or with any manufacturer of motor vehicles, to exchange unpublished technical information for developing, improving or lowering the cost of motor vehicle air pollution control equipment.

The consent decree expressly permits the defendants to continue to exchange "basic research," as distinquished from "applied research," and defines "basic research" to include "theories of control of motor vehicle emissions..., "as well as information pertinent to gaining a fuller knowledge or understanding of the presence, nature, amount, causes, sources, (or) effects... of motor vehicle emissions in the atmosphere." The decree also permits the defendants to exchange information that relates primarily to the "testing or measurement" of control equipment and information that results from testing or measuring "advanced stage" production prototypes. In addition, the decree expressly permits the defendants to exchange information that is made public through disclosure to news media or at meetings where persons other than employees of motor vehicles manufacturers are permitted to be present.

The decree contains other provisions which specifically allow the defendants to purchase from each other or from other motor vehicle manufacturers "specific commercial products," "specific existing patent rights," and "specific existing..." information or "engineering services" related to vehicle emission control. Finally, the decree does not prohibit any defendent from entering into or performing an agreement to which the Department of Justice consents in writing.

A number of manufacturers of motor vehicles, including most foreign manufacturers who sell motor vehicles in the United States, contend that progress in emission control technology is best achieved through unrestricted information sharing. The smallest of the major United States manufacturers claims that exchange of technical information is essential to permit it to design engine systems that are compatible with components that it must continue to purchase from other manufacturers. In general, the smaller manufacturers contend that their resources are inadequate to support an independent research and development program which encompasses more than a few areas of technological promise. They contend that only the large vehicle manufacturers are able to seek answers simultaneously to all of the interdependent engineering and scientific challenges that are encountered in attempting to mass produce vehicles that perform adequately and meet statutory emission standards.

While industry-wide research programs have been effectively deterred by restrictions imposed on the major United States manufacturers through the consent decree, the Department of Justice has approved certain limited arrangements involving specific research projects in which participation from related industries is regarded as particularly important or involving vehicle manufacturers who must purchase essential engine components from other manufacturers. Pursuant to the decree, the Department has consented to annual renewals of an inter-industry research program which includes the Ford Motor Company, certain foreign vehicle manufacturers, and a group of oil companies.

The "Inter-Industry Emission Control Project" is specifically limited to five or six defined research topics, and it is understood that the vehicle manufacturers participating in the project undertake substantial research and development activity independent of the project. Foreign particpants are: Fiat, S.P.A., Mitsubishi Heavy Industries, Ltd., Nissan Motor Company, and Toyo Kogyo Company, Ltd. In addition, Volkswagenwerk A.G. and Toyoto Motor Company, Ltd., have more recently purchased rights of access to the project's technical work. However, these two additional foreign manufacturers are not full participants in that they do not themselves provide the other project members with technical information. The Justice Department has also permitted American Motors to purchase certain emission control engineering services from General Motors.

In general, the Environmental Protection Agency agrees with the Department of Justice that technological progress in automobile emission control is best assured through primary reliance on competition and independence in research and development efforts conducted by manufacturers. At the same time, it must be recognized that the emission reductions required by law present a technological challenge that may severely strain the resources of smaller manufacturers and may raise special problems in the case of manufacturers who must continue to purchase major engine components from other manufacturers.

It is also possible that a vehicle emission control system or device could be independently discovered which, if not generally known to members of the industry in time to make necessary modifications in production facilities, could radically affect existing competitive relationships in the industry and could significantly reduce the number of independent manufacturers. The possibility that severe competitive dislocation could result from independent research and development activity is a matter of major concern. The compulsory licensing provisions contained in Section 308 of the Act may not obviate this problem because it applies only to patented devices. The Environmental Protection Agency will closely monitor research and development activities conducted by each member of the industry. In addition, the Agency will urge the Department of Justice to continue to approve limited arrangements between particular manufacturers that may be needed to meet special problems.

CHAPTER 6: Costs

A. Cost of Attaining the 1975 and 1976 Standards

Precise estimates of the cost of attaining the 90% reductions in HC, CO, and NO_x required by the Clean Air Act amendments of 1970 cannot be made at this time. The total cost to the public will, however, include the initial cost of the control system, its maintenance after warranty, and expected increases in fuel consumption and reductions in vehicle performance.

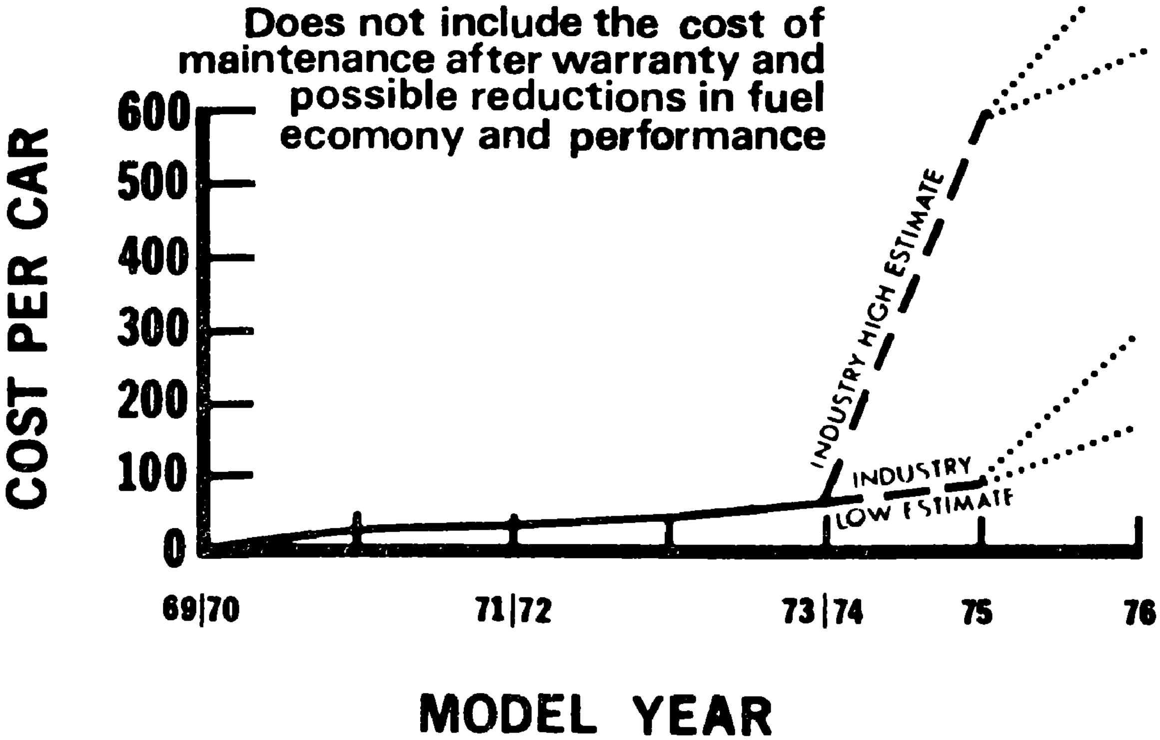
Preliminary estimates of the cost of the 1975 HC and CO control systems have been made by the manufacturers. However, no final decision on the control system to be used has yet been made. Since the technology for achieving the desired levels of NO_x control for 1976 is not now available, estimates of the related costs are even more speculative. However, it appears that costs associated with 1975 and 1976 standards will be considerably greater than those experienced in achieving Federal emission standards through 1974.

A variety of control systems are under development for meeting the 1975 HC and CO standards. Figure 1 indicates the estimated cost per car of achieving control standards through 1975. Costs through 1974 are derived from estimates published in EPA's Cost of Clean Air report of March 1971. Estimates of the cost of 1975 vehicles were provided informally by manufacturers and range from 80 to 600 dollars per car. Thus far, EPA has not been able to develop an independent estimate for 1975 costs. As indicated above, precise cost estimates cannot be made for 1976 standards.

Also included on Figure 1 is a table showing the percent reductions in emissions for the various model years compared to those emanating from uncontrolled vehicles. As explained in Chapter 1, the legislation requires that 1975 vehicles include a 90% reduction in HC and CO emissions compared to the levels permissible in 1970, and that 1976 vehicles include a 90% reduction of NO_x from the levels observed in 1971 uncontrolled autos. Since the 1970 baseline vehicles included some emission controls of HC and CO, the 1975 standards for these emissions require very high levels of control when measured against uncontrolled vehicles. It should also be noted that the cost per car indicated in Figure 1 covers only the initial production costs and does not reflect any costs for maintenance after warranty or increases in fuel consumption or reductions or vehicle performance.

Figure 2 was prepared by the Department of Commerce on the basis of informal information obtained from automobile industry sources. This graph depicts the estimated increases

INITIAL COST PER CAR OF EMISSION CONTROL SYSTEMS



% REDUCTIONS OF POLLUTANTS REQUIRED BY FEDERAL STANDARDS COMPARED TO UNCONTROLLED VEHICLES

70/71	72/74	75	76
73	80	98	98
62	69	97	97
0	25	25	90

FIGURE 1

ESTIMATED COST PRICE PER CAR TO CONTROL AUTO EMISSIONS

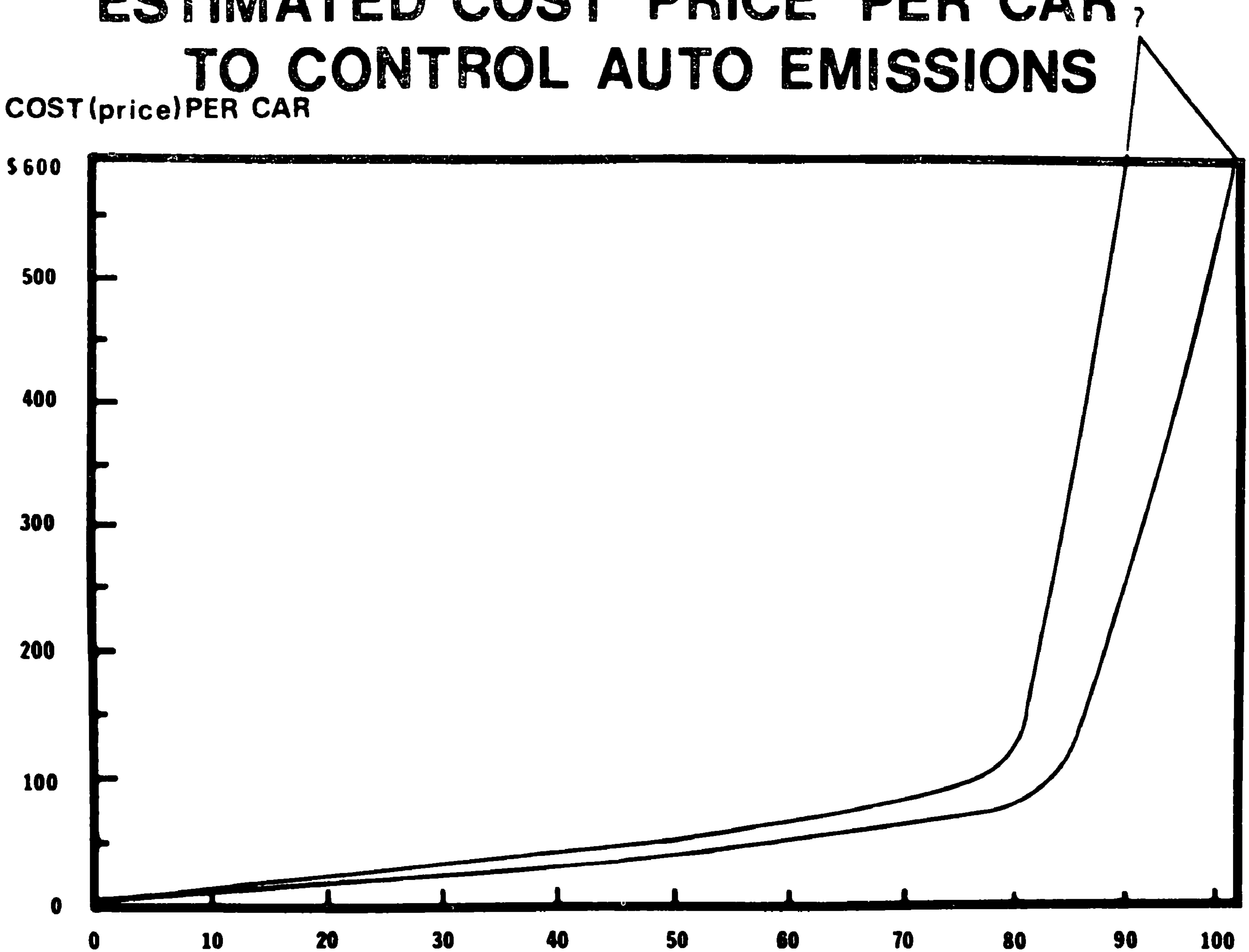


FIGURE 2 Percent AUTO EMISSION CONTROL June 1971

Source Generalized from manufacturers' private estimates prepared by the Department of Commerce in production costs per car in the 1976 model year of controlling HC, CO, and NO_x at various levels of emission reduction--assuming that all three pollutants would be controlled at the same level. Since all three pollutants will not be reduced by the same amount from the baseline of uncontrolled vehicles, this graph is merely illustrative of the principle that costs of control are expected to rise steeply as emission reductions move beyond some point. The thrust of this illustration is that the last 5-10% is likely to be much more costly to remove than the first 5-10%, but these figures are not known with certainty.

B. <u>Cost-Effectiveness of Motor Vehicle Emission Control</u>

Under Section 312(a) of the Act, the Administrator of EPA is required to report to Congress on January 10 of each year concerning the economic impact of achieving air quality standards. Among other things, that report is intended to provide a basis for evaluating the program and costs for achieving air quality standards. Accordingly, future reports submitted under Section 312(a) will address some of the key economic issues involved. In the public interest, ambient air quality standards should be achieved at the least cost possible. Since knowledge of effects of air pollution and of technology for controlling emissions is constantly improving, it will be necessary to periodically review the effectiveness and costs associated with alternative approaches of meeting ambient air quality standards and thus protecting the Nation's health and welfare.

As indicated in Chapter 4, the control of auto emissions is an important element in achieving the ambient air standards for HC, CO, NO_x, and photochemical oxidants. However, the relationships between automobile emissions control and the achievement of national ambient air quality standards is extremely complex. For example:

a) Motor vehicles are not the only important sources of HC, CO, and NO_x. Other sources are identified in the table on page 4-1.

b) The significance of auto emissions upon ambient air quality varies from place to place, and therefore so does the effectiveness of auto emission controls compared to controls over other sources.

c) The cost of HC, CO, and NO_x control for motor vehicles are interrelated since some types of HC and CO control make it more difficult to reduce emissions of NO_x.

d) Meeting the 1975/76 standards will have a cumulative impact over time on air quality as new controlled vehicles replace older models in the automobile fleet. This can be seen on Figures 3, 4, and 5, which depict EPA estimates of future national levels of NOx, HC and CO emissions from gasoline-fueled motor vehicles assuming all future Federal standards are achieved. The graphs do not reflect the possible impact of modifying used vehicles to attain emission reductions.

Considerations such as these are particularly important in attempting to find the least cost means of achieving ambient air quality standards, since the impact of achieving various reductions in automobile emissions will influence the costs of reducing pollutants from other sources. Other sources of particular pollutants (e.g., NO_x from power plants) may be so important in some areas that the reduction of automobile emissions will contribute relatively little to meeting ambient standards in that area.

C. The Relationships between Costs and Effectiveness in Reducing Air Pollution

As suggested earlier in this chapter, many of the relationships between costs and effectiveness are not yet well understood. All of these factors require further study

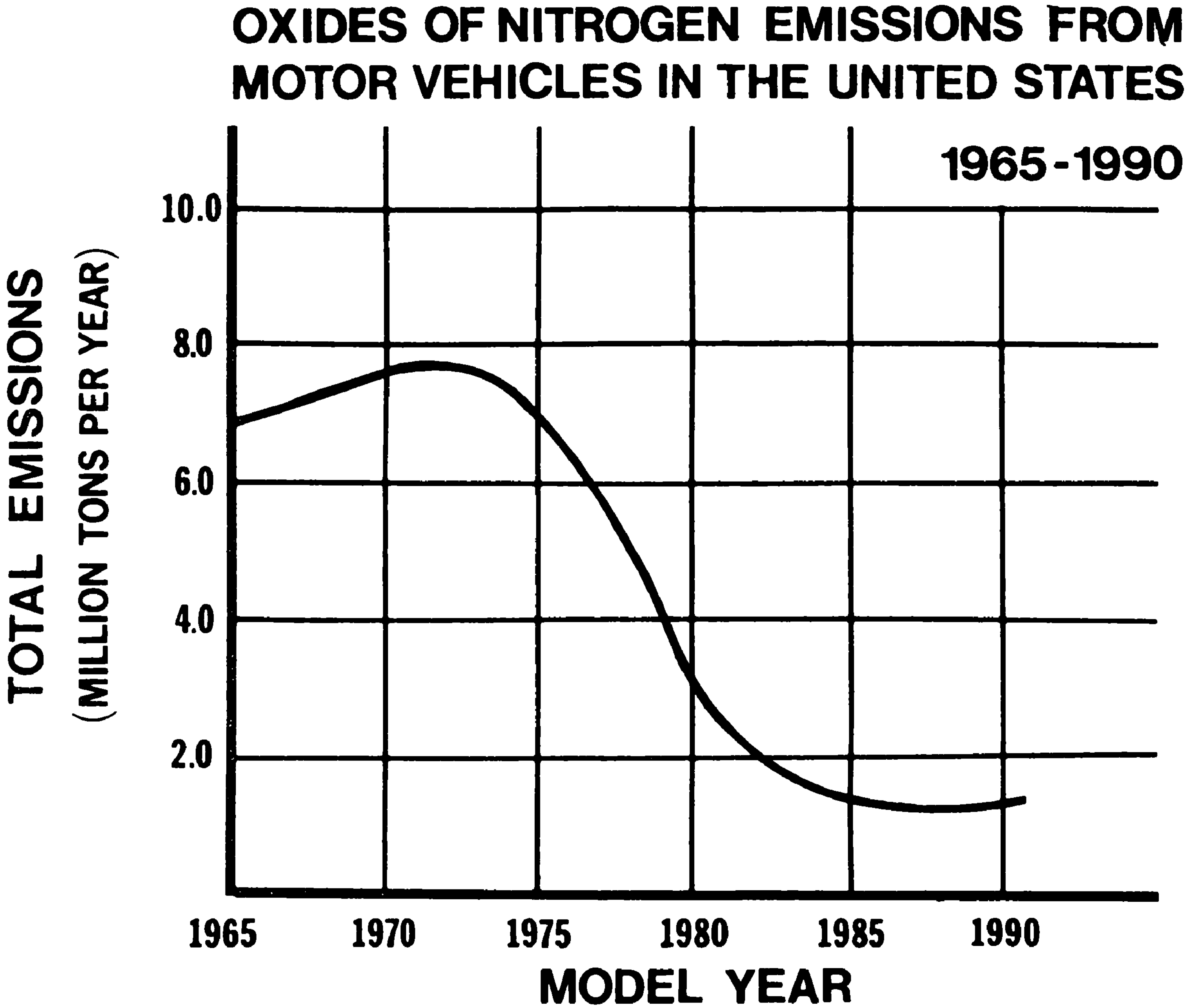


FIGURE 3

PROJECTIONS BASED ON ACHIEVING ALL FEDERAL EMISSION STANDARDS

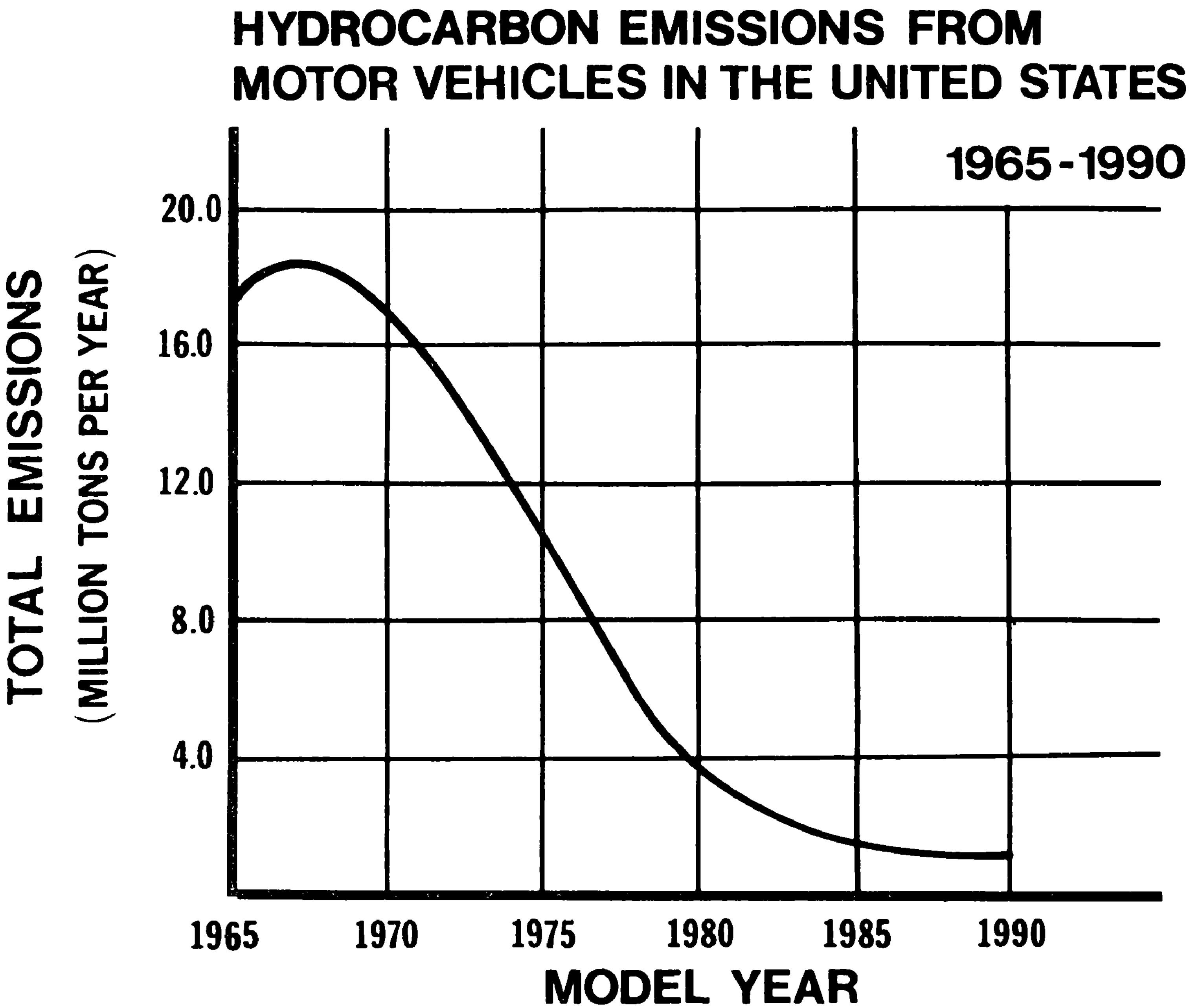


FIGURE 4 PROJECTIONS BASED ON ACHIEVING ALL FEDERAL EMISSION STANDARDS

CARBON MONOXIDE EMISSIONS FROM MOTOR VEHICLES IN THE UNITED STATES

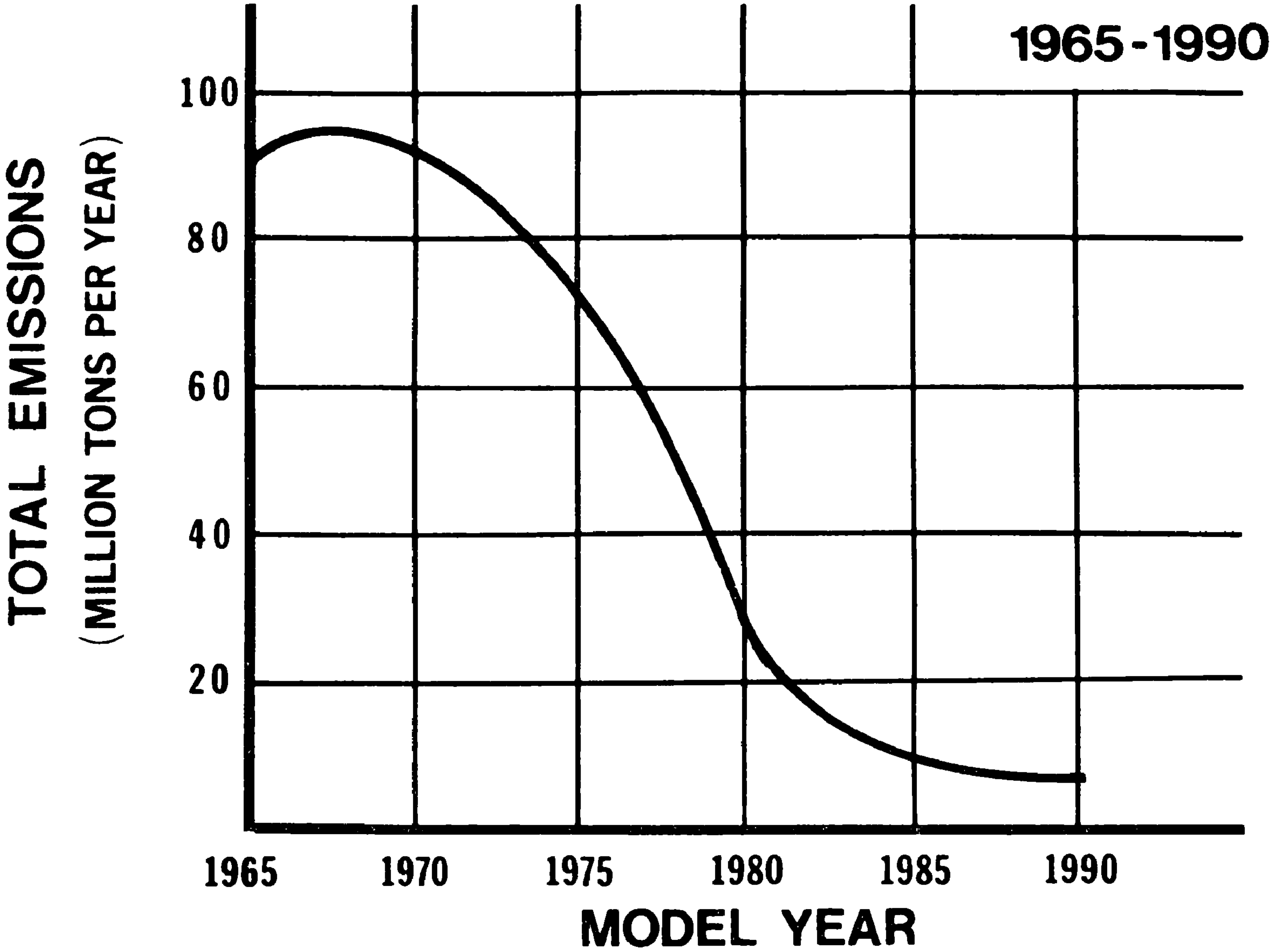


FIGURE 5 — PROJECTIONS BASED ON ACHIEVING ALL FEDERAL EMISSION STANDARDS

to ensure that desirable levels of air quality are achieved at the most reasonable level of costs to the American people. Knowledge today is simply not adequate to identify specific numerical values for costs and benefits.

However, even without the specific data, some conclusions can be drawn. Beyond some point, costs will increase more rapidly as successively greater reductions in emissions are achieved. However, in some situations, the last increment of impurity in the air will be less important to remove than the earlier increments. Thus it will be important to consider both the cost and value of incremental improvements in air quality.

A great deal of the knowledge required to assess the cost-effectiveness of various alternative pollution control strategies is expected from the review of State implementation plans which must be prepared during the coming months. These implementation plans will provide considerable information on the sources and amounts of emissions. This knowledge will increase further as monitoring and surveillance programs are improved and expanded. In addition, EPA's research programs are designed to improve knowledge of the health and other effects of various pollutants. This information, together with economic analyses that will be carried out or supported by EPA should provide an improved basis for future program decisions.

D. Industry Sponsored Research and Development

In response to the Administrator's letter of February 26, 1971, the industry supplied EPA with information concerning their expenditures for developing and testing emission control systems. These responses indicated industry-wide costs of nearly $250 million in 1970 with a one-third increase projected for 1971. This information also revealed that about six thousand professional and technical personnel were engaged in emission control research and development programs for the manufacturers in 1970, with a similar one-third expansion projected for 1971. Thus, there has been a significant increase in industry resources devoted to emission control programs since the passage of the 1970 amendments to the Act.

The information supplied by the industry appears to lack total comparability due to the variations in definitions and allocations of cost figures. In addition, much of this information furnished was indicated as being confidential by the manufacturers who alleged that it related to "trade secrets." Section 208 of the Act allows the Administrator to keep information confidential if he finds that it does in fact relate to "trade secrets." EPA does not agree that all of the information so indicated relates to "trade secrets." Work is underway to develop appropriate protocols to permit the collection of data on the magnitude of the industry's emission control efforts on a fairly consistent basis. This information should be available for public distribution at some time in the future.