AN ANALYSIS OF ALTERNATIVE MOTOR VEHICLE EMISSION STANDARDS

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MAY 19, 1977

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The analysis contained herein assesses the air quality, health, cost, fuel economy and economic consequences of specific auto emission control alternatives currently before Congress. The alternatives are:

A. Administration proposal with 0.4 gpm NOx.

B. Administration proposal with 1.0 gpm NOx.

C. Dingell/Broyhill proposal with 2.0 gpm NOx.

D. Dingell/Broyhill proposal with 1.0 gpm NOx.

E. Senate Committee Proposal.

The specific emission limitations and schedule for each of these alternatives are provided below.

Model Year	Hydrocarbons					Carbon Monoxide					Nitrogen Oxides				
Emission Schedule	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
1978	1.5	1.5	1.5	1.5	1.5	15	15	15	15	15	2.0	2.0	2.0	2.0	2.0
1979	.41	.41	1.5	1.5	.41	9	9	15	15	3.4	2.0	2.0	2.0	2.0	2.0
1980	.41	.41	.41	.41	.41	9	9	9	9	3.4	2.0	2.0	2.0	2.0	1.0
1981	.41	.41	.41	.41	.41	3.4	3.4	9	9	3.4	1.0	1.0	2.0	2.0	1.0
1982	.41	.41	.41	.41	.41	3.4	3.4	9	9	3.4	1.0	1.0	2.0	1.0	1.0
1983	.41	.41	.41	.41	.41	3.4	3.4	9	9	3.4	.4	1.0	2.0	1.0	1.0
1984	.41	.41	.41	.41	.41	3.4	3.4	9	9	3.4	.4	1.0	2.0	1.0	1.0
1985	.41	.41	.41	.41	.41	3.4	3.4	9	9	3.4	.4	1.0	2.0	1.0	1.0

This report has been prepared by EPA, FEA and DOT in order to provide information on these alternatives, including the Administration's recommendation.

I. Summary and Conclusions

Broad segments of the population now live in areas where ambient concentrations of photochemical oxidants (Ox) (population 96 million), carbon monoxide (CO) (population 66 million) and nitrogen oxides (NOx) (population 30 million) exceed the Federal ambient air quality standards.

Automobile emissions produce about 70 percent of the CO in areas where the National Ambient Air Quality Standards (NAAQS) are exceeded. Autos produce about 20 percent of the hydrocarbons (HC) and NOx nationally, and over twice that percentage in some urban areas (HC and NOx are precursors of photochemical oxidants).

Since autos are not the only sources of HC, CO, and NOx, stringent emission standards for autos will not, by themselves, eliminate "auto related" air pollution but they will certainly reduce that pollution and its attendant effects on public health.

Therefore, the Administration recommends that automotive emission standards of 0.41 grams per mile (gpm) hydrocarbons, 3.4 gpm carbon monoxide and 1.0 gpm nitrogen oxides be implemented as rapidly as possible to protect the public health. Public health may require that the NOx standard be set at the more stringent 0.4 gpm level. Studies currently underway should enable EPA to resolve this issue by 1980.

Air Quality Benefits of Alternatives

National Ambient Air Quality Standards will probably be exceeded in some places for each of the auto related pollutants through the year 2000. Rapid imposition of stringent auto emission standards will reduce the severity and frequency of NAAQS violations and the attendant effects on public health.

Table 1 summarizes the projected effects of the auto emissions standards alternatives on selected air quality indicators. Such projections must rely on assumptions concerning future growth and expected levels of stationary source control. Consequently, the projections should be used as comparative indicators of the air quality impact of alternatives rather than as absolute predictions.

TABLE 1

LONG RANGE AIR QUALITY PROJECTIONS

Pollutant	CO		NOx/NO2			HC/Ox
Emission Schedule	C,D	A,B,E	C	B,D,E	A	A,B,C,D,E
Final Emission Level	9.0	3.4	2.0	1.0	0.4	0.41
Percent Change in Air Quality By 2000	-45 to -60*	-60 to -70*	+13	+8	-5	-45 to -50*
Number of AQCR's with NAAQS Violations in the year 2000	12* to 16	5* to 12	7	7	4	26* to 31
Number of NAAQS violations 1980-2000	3300* to 14,000 1/	2000* to 6000 1/	135 2/	115 2/	90 2/	62,000 3/* to 79,000

1. Violations of the 8 hour CO standard projected for only 30 AQCR's
2. Violations of the annual NO2 standard for only 14 AQCR's
3. Violations of the 1 hour OX standard for only 48 AQCR's

*with Inspection/Maintenance

Hydrocarbon/Oxidants

There is general agreement that 0.41 gpm for HC should be imposed as rapidly as possible to mitigate the pervasive photochemical oxidant (smog) problem. The seriousness of the problem is shown in Table 1. Even with 0.41 gpm auto emission control, a strong program of vehicle inspection/maintenance and stationary HC source control, the NAAQS for Ox is projected to be exceeded in 26 or more AQCR's in the year 2000.

There is a one year difference between the several alternatives in the timing of 0.41 HC. That one year delay is projected to cause about 4 percent more violations of the 1 hour oxidant standard between 1980 and 1990.

Carbon Monoxide

Both the severity and frequency of violations of the 8 hour NAAQS for CO are expected to decline through 1990. However, even the rapid imposition of 3.4 gpm together with an I/M program will not eliminate the projected violations. A CO standard of 9 gpm would leave more AQCR's in violation of NAAQS in the year 2000 than would 3.4 gpm. The less stringent standard is projected to result in 65-130 (with and without I/M, respectively) percent more NAAQS violations between 1980 and 2000.

The more rapid attainment date for 3.4 gpm contained in Schedule E would reduce the cumulative number of violations of NAAQS by about 25 percent between 1980 and 1990.

Nitrogen Oxides

Nitrogen dioxide concentrations are projected to increase in the near future due to general growth of mobile and stationary NOx sources. That projected increase could be stopped or reversed toward the end of the century by stringent control of NOx from both mobile and stationary sources.

Based on limited air quality monitoring data, at least six of the country's most populous urban areas are projected to be in violation of the annual average NO2 ambient levels in the year 2000 if a 1.0 gpm emission standard is implemented rapidly. If the standard stays at 2.0 gpm, annual average air quality levels will be 4% worse in 1990 and 5% worse in 2000. Reducing the NOx standard to 0.4 gpm would improve air quality by 9% in 1990 compared to a 1.0 gpm standard (13% compared to a 2.0 gpm standard). Moreover, it would improve air quality by 13% in 2000 compared to a 1.0 gpm standard (18% compared to a 2 gpm standard).

Health Effects

The adverse effects on public health associated with present and projected photochemical oxidant concentrations are serious and well documented. Since there is agreement that 0.41 HC is needed to reduce oxidant formation, no comparison of the health benefits of different standards is needed. The reader is referred to Chapter V for a discussion of oxidant health impacts.

Individuals afflicted with heart disease are most susceptible to risk of disability due to exposure to high CO levels. The excess disability due to increased angina attacks is projected to more than double during the period 1980 to 2000 if the CO standard is set at 9 gpm instead of 3.4 gpm. The number of excess cardiac deaths would also increase slightly.

The major issue with regard to NOx is the degree to which health effects are observed at different ambient levels. The current ambient standard is expressed as an annual average. There is increasing evidence that short term peak values may have more impact on observed health effects. Therefore, EPA will be providing a more definitive position on the need for, and nature of, a short term NO2 standard as part of the Agency's formal NO2 standard review scheduled for 1979.

A short term air quality standard is likely to result in a substantial increase in the number and severity of air quality violations. Furthermore, because auto NOx emissions would probably contribute disproportionately to high, short term NO2 concentrations, a new short term NO2 standard would probably increase the need for motor vehicle emission control.

Costs of Alternative Emission Schedules

The costs of the several alternative emission schedules are influenced primarily by the final emission levels. Estimates of the cost-per-vehicle, the impact on the Consumer Price Index (CPI), and the aggregate first cost are summarized in Tables 2 and 3 by the final emission levels of each alternative. Both tables are for 1985 and are in 1977 dollars.

TABLE 2

UNIT COSTS OF ALTERNATIVES 1/
(In 1985 Model Year, 1977 Dollars)

Change Relative to Current Standards (1.5/15/2)	Alternatives A .41/3.4/.4	B .41/3.4/1.0	C .41/9/2.0	D .41/9/1.0	E .41/3.4/1.0
Initial Cost ($) 2/	240 - 330	190 - 250	35 - 100	140 - 185	190 - 250
Lifetime Maintenance($)	90 - 100	35 - 70	0 - 17	35 - 70	35 - 70
Fuel Economy (percent)	-8 to 2	-3.5 to +2	-3 to +2	-3.5 to +2	-3.5 to +2

1/ Ranges reflect assumptions about use of optimal cost or optimal fuel economy technologies (see Appendix A).

2/ Includes an 80% markup from manufacturer to dealer.

TABLE 3

CPI and Aggregate Cost Impacts

Alternative Standards	A	B	C	D	E
Percentage point change in CPI in 1985 1/	.035	.026	.012	.019	.026
Aggregate Sticker Price Increase ($ Billions in 1965 for 1985 cars) 2/	3.0 - 4.1	2.3 - 3.1	0.4 - 1.4	1.7 - 2.3	2.3 - 3.1

1/ Based on the higher optimal fuel economy sticker prices which econometric models indicate will be those selected by the automobile industry to maximize sales.

2/ Sticker price cost is not annualized but assumed to be incurred in the year of sale. Sales in 1985 assumed to be 12.3 million cars. Range reflects assumptions of optimal cost or optimal fuel economy technologies.

The data in Tables 2 and 3 indicate that emissions standards can be met with little or no fuel economy penalty if the industry employs the optimal fuel economy technology. This will add to the sticker price of the car. However, even at the most stringent standards this incremental cost, which is less than that of the automobile air conditioning ordered with most new cars, has an insignificant impact on the CPI, less than four one-hundreths of one percentage point in all cases.

The impact of the alternatives on gasoline consumption in 1985 is shown in Table 4.

TABLE 4

IMPACT OF THE ALTERNATIVES ON THE GASOLINE CONSUMPTION IN CALENDAR YEAR 1985 OF 1978-1985 MODEL YEAR AUTOS

	A		B		C		D		E	
	Low	High	Low	High	Low	High	Low	High	Low	High
Change in Gasoline Consumption (1000 Barrels/Day)	-40.1	+101.6	-40.1	+67.7	-33.3	+54.2	-33.3	+56.7	-40.1	+67.7
Percent Change in Total Gasoline Consumption	-.57%	+1.4%	-.57%	+.97%	-.47%	+.77%	-.47%	+.81%	-.57%	+.97%

1/ See Table 17 for the assumptions used in calculating the estimates provided herein.
2/ "Low" refers to optimal fuel economy assumptions as discussed in Appendix A; a "minus" sign refers to fuel savings relative to baseline.
3/ "High" refers to optimal cost assumptions as discussed in Appendix A; a "plus" sign refers to a fuel penalty relative to baseline.
4/ The change is measured relative to current standards with optimal cost technology.
5/ These figures can be converted to approximate % changes in total petroleum product consumption by dividing by 3.

The data indicate that the alternative schedules do not result in significant differences in gasoline consumption. In all cases the range of estimates overlap, with possible reductions in total gasoline consumption shown for every schedule if the industry utilizes the optimal fuel economy technology. If the industry attempts to minimize initial cost (at the cost of fuel economy) total gasoline consumption will increase, but in no case by more than 1.4% of total gasoline consumption in 1985.

REVISED 5/24/77

The Administration Recommendation

Achievement of 0.41 gpm HC, 3.4 gpm CO and 1.0 gpm NOx is possible at no fuel penalty given sufficient lead-time and with a sticker price increase of about $250 (less than the typical cost of an auto air conditioner). Even 0.4 NOx can probably be achieved without fuel penalty but at a further sticker price increase of about $80 although fewer data at that level are available than at 1.0 NOx. Considering the public health needs along with the cost, fuel economy impacts and technological feasibility of the emission reduction technology, the Administration recommends the following emission schedule:

Model Year	HC	CO	NOx
1978	1.5	15	2.0
1979-80	0.41	9	2.0
1981-82	0.41	3.4	1.0

EPA believes it is likely that the review of NOx health research findings and other relevent data, to be completed in 1980, will show the need to reduce the NOx emission standard to 0.4 gpm for the 1983 model year.

Other Considerations

Major improvements in fuel economy are projected during 1978-85 as a result of the requirements of the Energy Policy and Conservation Act. The advance in fleet fuel economy will come about through reductions in the weight and size of automobiles, the introduction of more efficient engines and other measures. To the extent that emissions standards force the introduction of the advanced engine technologies which are also necessary to attain optimal fuel economy, the early stabilization and implementation of the technology forcing standards (particularly 1.0 NOx) could facilitate the earlier achievement of the national fuel economy goals, as well as improving air quality.

If the 0.4 gpm NOx standard is required for 1983 models, a few individual engine families may have difficulty meeting it without fuel penalties; diesels may have difficulty meeting it at all. In order to provide maximum flexibility, vehicles should be allowed to meet a 1.0 NOx level upon payment of a nonconformance penalty in an amount slightly greater than or equal to the difference between the costs of compliance at 0.4 gpm and 1.0 gpm. Diesel vehicles should be allowed to meet a 1.0 gpm standard if it can be demonstrated that they can do so for 100,000 miles.

There is some concern that large diesel vehicles* may not be able to achieve the 1.0 gpm NOx standard by 1981. To ensure that there is time for fuel-efficient diesel technology to evolve and develop, a waiver is proposed up to a 1.5 gpm level provided that:

1. A good faith effort is made to achieve 1.0 gpm.

2. the 1.5 gpm standard is demonstrated to be met for 100,000 miles.

3. The average fuel economy standard applicable for the model year is achieved by the vehicle granted such waiver.

Another concern is that small volume manufacturers who must rely on outside suppliers to provide many of the advanced emission control components may need additional lead-time in order to meet the more stringent emission standards. To alleviate this concern, low volume manufacturers should be allowed to meet a 2.0 gpm NOx standard in 1981 before moving to the 1.0 gpm standard in 1982.

The remainder of this paper is devoted to a review of the health effects from automotive air pollutants (Section II) and projected air quality and emission impacts of various emission schedules (Section III and IV). The relative differences of certain quantifiable health indicators for various emission standards schedules will be reviewed (Section V). The technological feasibility (Section VI) and the cost and fuel impacts will be summarized (Section VII) as will the economic impacts (Section VIII).

*3,000 lbs and above

II. Health Effects Summary of Carbon Monoxide, Nitrogen Dioxide, and Photochemical Oxidants

The health effects data base for CO, NO2 and oxidants were summarized in the "Air Quality Criteria" documents published from 1968 through 1970. Since that time, further research has been conducted to expand health effects data bases for these pollutants. These criteria documents are scheduled for revision over the next several years. The oxidant document will be published in 1978, an NO2 document in 1979 and the CO document in 1980. Each revision will be extensively reviewed by the scientific community. However, at this time we do not anticipate any significant changes in the ambient air standards apart from the probable promulgation of a short term NO2 standard. Summarized below are discussions of the health effects of these pollutants.

Photochemical Oxidants

Nitrogen oxides and hydrocarbons once emitted into the atmosphere undergo a series of chemical reactions to form other air pollutants, most notably oxidants. The most abundant photochemical oxidant found in the atmosphere is ozone.

High oxidant levels are associated with aggravation of asthma and chronic lung disease, irritation of the respiratory tract in healthy adults, decreased visual accuity, eye irritation and changes in heart and lung function in healthy subjects. Human exposure studies also suggest adverse health response to ozone in combination with other pollutants such as SO2.

Toxicological work with experimental animals confirms that exposures to relatively low levels of ozone produce numerous changes in cell and organ structure and function including changes indicative of chronic lung disease and increased suspectibility to infection. Other pulmonary effects have also been noted including reduced voluntary activity, chromasonal aberrations and increased neonatal mortality. Available evidence is inadequate to permit the quantification of toxicological effects observed in animals and of the synergistic potential of various air pollutants. Nor is there sufficient data to quantify the effects of ozone on natural ecosystems or on agriculture although evidence exists of major adverse effects of ozone pollution in these areas.

Nitrogen Dioxide, NO2

In addition to playing a major role in the formation of photochemical oxidant, nitrogen oxide emissions also produce nitrogen dioxide, (NO2). Epidemiologic studies published to date indicate that levels commonly found in the ambient air may cause the following effects:

(1) An excess of acute respiratory illness in exposed families,

(2) Decreased lung function in elementary school females, and

(3) Increased bronchitis morbidity in elementary school children exposed for two or more years.

Somewhat higher concentrations of NO2 have been associated with other effects including:

(1) Changes in the structure of lung tissue in rabbits,

(2) Increased occurance of respiratory infections in mice,

(3) Structural changes in the lung tissue of mice, and

(4) A loss of cellular elements in the lung tissue of rats

(5) Reduced lung function in adults exposed.

Recently, there has been considerable interest in the possible effects of shorter-term exposure to NO2. The World Health Organization (WHO) is currently considering a report on a number of effects from short-term exposure including:

(1) Increased airway resistance,

(2) Enhanced bronchial constriction in sensitive populations, and

(3) Increased sensitivity to respiratory infection.

Although some of these effects appear to be reversible - that is, when NO2 levels subside, the effects vanish and no permanent damage or prolonged effect results - it may be prudent to prevent the effect. As a result of their work, WHO may state that a short-term threshold level for healthy humans of 0.5 ppm is warranted because, at this concentration, multiple experimental studies on animals and humans are in agreement that effects can be demonstrated. The National Academy of Science has also voiced concern on two occasions for the need to develop a short term NO2 standard. The NAS argues that this "need is demonstrated in the body of evidence showing acute effects of single or repeated nitrogen dioxide exposures of six or less hours". EPA will be providing a more definitive position on the need for, and nature of, a short-term NO2 standard as part of the Agency's formal NO2 standard review, scheduled for 1979.

Nitrates and Sulfates

In addition to photochemical oxidants and NO2, NOx emissions also can lead to the formation of nitrates and it is believed that they play a role in the formation of sulfates. The best available information on health effects associated with exposure to atmospheric nitrate compounds comes from toxicological and epidemiological studies, among them the CHESS study. French, et. al., found suggestions that asthmatic attacks and other acute respiratory symptoms were more frequently associated with nitrates and sulfates than other measured pollutants including TSP, SO2, and respirable particulates. In a more recent analysis of CHESS data obtained in the southeast United States and in New York City, the statistical correlation between asthmatic attacks and pollutant concentrations were clearly higher for suspended nitrates. These results should be viewed in the following context:

(1) The CHESS studies have been criticized in a recent Congressional report for their definition of asthmatic effects, for their air monitoring, and for a number of other methodological problems.

(2) The toxicological evidence supporting a correlation between particulate nitrate species and effects in animals or in humans is considerably more limited than the data base for sulfur oxides, and

(3) The analytical problems associated with measuring particulate nitrates or atmospheric nitrates are much greater and less well-defined than that for sulfur oxides.

Carbon Monoxide

Carbon monoxide (CO) is emitted directly by automobile exhaust. CO is a very stable gas and is usually found in highest concentrations very close to the emission source. It is believed that highway vehicles account for over 90 per cent of the atmospheric CO to which the general public is exposed.

Carbon monoxide interferes with the delivery of oxygen to all tissues of the body by binding to the hemoglobin inside red blood cells to form carbon-oxyhemoglobin (COHb). Myocardium and nerve tissues are especially susceptible. Persons with heart disease are particularly susceptible because they are unable to increase blood flow to the heart to counteract the reduction of oxygen delivery. There is much data showing decrement in human performance (visual function, cognitive function, manual dexterity, auditory vigilance, etc.) at low levels of COHb (3 to 7 percent) resulting from low level exposure to CO. Individuals with anemia or emphysema or other lung disease, or who live at high altitudes are likely to be more susceptible to the effects of CO.

III. Mobile Source Contributions To Current Ambient Air Quality

Motor vehicles are the major source of carbon monoxide and a substantial contributor of nitrogen oxides and hydrocarbons. Accordingly, they play a major role in the severe oxidant, nitrogen dioxide and carbon monoxide air quality problems which exist across the country. Table 1, displays the 1974 national CO, HC and NOx emission estimates.

Table I

Nationwide Emissions by Source for 1974

Source	Emission in 1,000 of tons/year NO_x	HC	CO
1. Light Gasoline Autos 0-8,500 lbs GVW	4,800 (19.2)	7,600 (23.0)	52,000 (49.9)
2. Light Gasoline Trucks 0-8,500 lbs GVW	900 (3.6)	1,800 (5.5	9,500 (9.1)
3. Heavy Gasoline Vehicles 8,501 lbs GVW	800 (3.2)	1,400 (4.2)	11,400 (10.9)
4. Heavy Diesel Vehicles 8,501	1,600 (6.4)	200 (0.6)	800 (0.8)
Total Highway Vehicles	8,100 (32.4)	11,000 (33.3)	73,700 (70.7)
5. Non-Highway Mobile Sources	2,500 (10)	1,600 (4.8)	9,300 (8.9)
Total Mobile Sources	10,600 (42.4)	12,600 (38.2)	83,000 (79.6)
1. Oil and Gasoline Production and Marketing	0	4,100 (12.4)	0
2. Organic Solvent Use	0	8,900 (27.0)	0
3. Stationary Fuel Combustion	13,300 (53.2)	1,700 (5.2)	1,400 (1.3)
4. Industrial Processed	700 (2.8)	3,700 (11.2)	11,000 (10.6)
5. Solid Waste	200 (0.8)	1,000 (3.0)	3,500 (3.4)
6. Other Stationary Sources	200 (0.8)	1,000 (3.0)	5,300 (5.1)
Total Stationary Sources	14,400 (57.6)	20,400 (61.8)	21,200 (20.4)
Total U.S.	25,000	33,000	104,200

( ) Percent of Total U.S.

Carbon Monoxide

During 1974, over 104 million tons of CO were emitted in the United States by man-made sources. Seventy percent of these emissions are attributed to highway vehicles, with the automobile alone accounting for about fifty percent. Furthermore, autos and other highway vehicles contribute disproportionately more CO to those areas where high CO is experienced because of dense traffic, ground level emissions and the canyon street effect. Because of these emissions, at least 65 air quality control regions (AQCR's) experienced violations of the 8-hour average carbon monoxide ambient standard during 1973. However, no monitoring data are available for many areas of the country where it is suspected that many smaller cities are experiencing CO problems, particularly during high volume traffic conditions such as rush hour traffic in downtown areas or around relatively large and busy shopping centers.

Oxidants

A review of 1973 and available 1974 air quality monitoring data reveals that there are at least 79 AQCR's in which violations of one-hour ambient standard for photochemical oxidants (160 micrograms per cubic meter - ug/m3) were experienced in one or both years. These AQCR's include most of the large urban areas of the country.

Unlike CO, oxidant concentrations tend to be uniformly spread throughout the urban area. While most monitoring sites are physically located in or around urban areas, it is generally believed that due to the formation time required for an atmospheric movement of oxidants large portions of the rural areas also are experiencing oxidant concentrations above the national standards at sometime during the year.

In 1974, nationwide emissions of hydrocarbons (HC), a precursor to oxidants, were divided approximately 60%/40% between stationary and mobile sources. The two major sources of HC emissions are automobiles and evaporation from stationary sources, such as solvent manufacturing, cleaning, and coating operations. The remaining HC emissions are distributed among a variety of mobile and stationary sources.

There are large variations among the AQCR's in the contribution of these categories of sources to overall HC emissions. For example, among the 79 AQCR's discussed above, HC emissions from stationary sources vary from a low of less than 12% of the total to a high of over 70% of the total.

Nitrogen Dioxide

Air quality monitoring data for the period 1972-74 indicate that 3 or 4 AQCR's are currently experiencing annual concentrations above the national ambient standard (100 ug/m3) for nitrogen dioxide (NO2). In addition, there are 12 more cities where the annual NO2 concentration during 1972-74 was greater than 80% of the standard. It is estimated that NO2 concentrations in at least 4 of these 12 cities will be above the national standards in the near future.

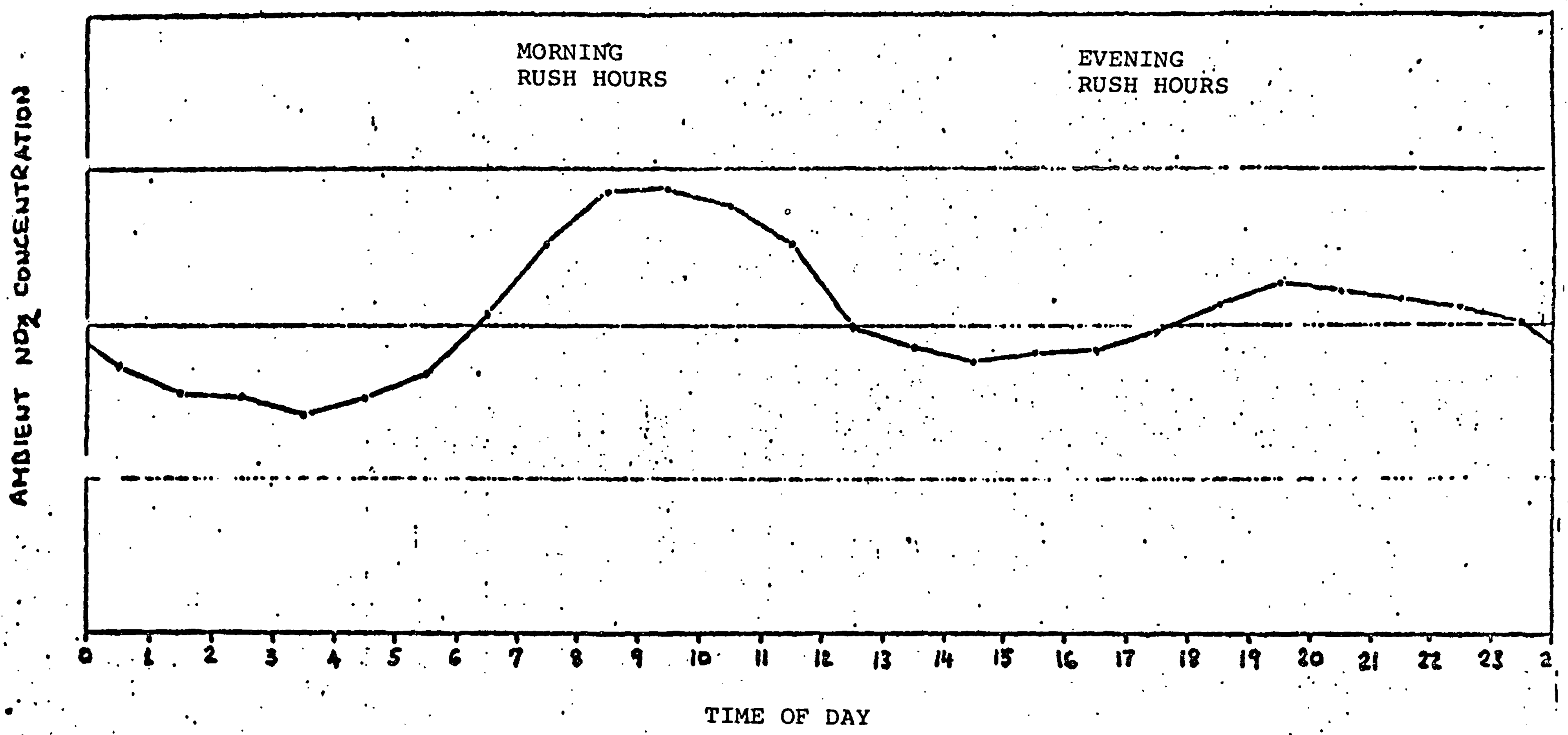


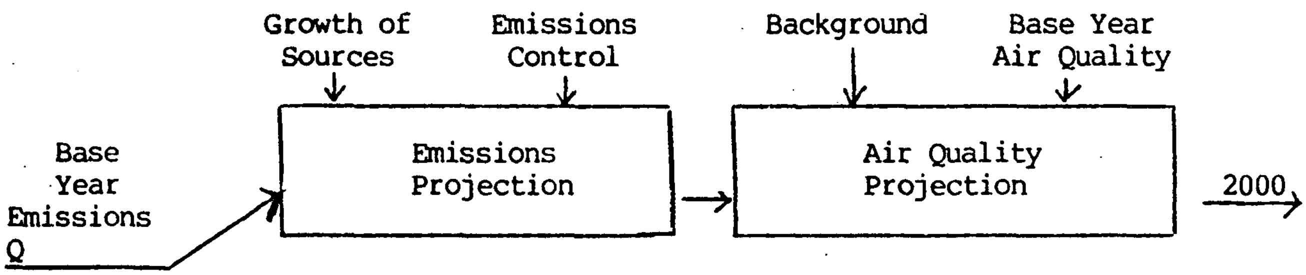
FIG. 1: NO_2 AIR QUALITY IN SOUTH COAST AIR BASIN AVERAGED OVER THE AUGUST 1974 (AUG 12-18) EPISODE AND OVER TEN MONITORING SITES

Nationwide NOx emissions during 1974 are estimated to have exceeded 25 million tons, with stationary sources accounting for 57% of the total. Automobiles accounted for 19%. Mobile sources contribute greater than proportionately to short term peak ground level NOx concentrations. Therefore, the control of NOx emissions from mobile sources will provide greater reduction in these situations than would be indicated by their proportion of annual NOx emissions (see Figure 1). This will be particularly significant should a short term NO2 health standard be promulgated.

In summary, a number of AQCR's are currently experiencing air quality above the ambient standards for the automobile related pollutants. Most of the problems with CO are believed to be primarily due to exhaust emissions from the internal combustion engines. For CO, it is believed that high concentrations are encountered only in the near vicinity of large volumes of mobile source traffic, and are, therefore, mainly confined to the urban areas. Oxidant concentrations above the ambient standard are being monitored in most areas where monitoring equipment is located. It is believed that the oxidant problem is pervasive and not confined solely to the urban areas. While the two largest sources of HC emissions are automobiles and evaporation (solvent manufacturing, cleaning, coating operation, etc.) more than 50% of the total emissions come from many relatively small and diversely located sources, which individually have relatively low HC emission rates. Most man-make NOx emissions come from fuel combustion processes, with utility boilers (electric power generators) and the automobile being the largest individual source categories.

IV. Projecting Air Quality for Future Years

Projecting air quality into the future is a two-step process as shown below. Changes in emissions from a base year are estimated from growth, changes in control technology, and changes in emission sources. The change in air quality is then calculated from the projected change in emissions.



Emissions Projection

As indicated above, emissions in any future year depend upon the growth in the numbers of each source relative to the base year and the ratio of emissions from each source in the projection year to its emissions in the base year, per unit. This latter factor is dependent upon the degree of control of both new and existing sources as well as the rate of turnover of older to newer, usually lower emitting sources.

Three major source categories are presented in this report. They are light duty vehicles, other mobile sources, and stationary sources. The growth rates and degrees of control for each of these source categories were determined by accounting for specific sources within each category.

Base year emissions are derived from inventories collected by states and submitted in State Implementation Plans. In some cases, more recent inventories have been made and placed in the National Emission Data System (NEDS) and are used for this study. These emission estimates are for annual averages and therefore may not accurately represent the emissions at the time of the observed air quality.

Each Air Quality Control Region has a different ratio of mobile to stationary sources. Therefore projected emissions will be different for each area because of the different growth rates for different sources.

The largest unknown in the projection model occurs in the estimates of growth and in future technology and control regulations. Optimistic estimates for future national growth and stationary source emission reduction technology were assumed. It is expected that some areas of the country will experience greater growth than other areas. Some areas may also require more stringent control than will other areas.

Projection of Air Quality

The air quality projections for each of the three pollutants are somewhat different. These will be discussed separately.

Carbon Monoxide

Since the "hot spots" for CO are always located in areas of high traffic density the impact on future air quality of mobile source emissions and their control appears to dominate the CO situation; stationary sources have very little impact. Therefore, it is necessary to apply an adjustment factor to the stationary source categories to realistically estimate future air quality. Factors of .20 for area sources, .10 for industry and 0 for power plants were used. This means that a pound of CO from a new industrial source was assumed to have only 1/10 the air quality impact on the roadside CO "hot spot" as a pound of CO emitted on the street in front of the sampler. These adjustment factors were selected after considering the results from dispersion models for power plants and industry and a review of the relationship between traffic density and CO levels in several situations.

Because CO does not react rapidly in the atmosphere, the assumption of linearity between the changes in CO concentration and the changes in emissions near the monitor is reasonable. Measurements of ambient CO concentration, however, are not good indicators of regional air quality, because CO concentrations are very localized. Moving a monitor a few feet from curb to sidewalk will cause a large change. High CO concentrations are found at busy intersections, street-side, and at other locations of high traffic density. The most direct measurement of the effect on humans of ambient carbon monoxide would be the percent of blood carboxyhemoglobin in a representative sample of the population.

° An eight-hour average background concentration of 1 ppm is assumed for carbon monoxide.

Hydrocarbons and Oxidants

Photochemical oxidants are not emitted directly into the atmosphere but result primarily from a series of chemical reactions between oxidant precursors (nitrogen oxides and organic compounds) in the presence of sunlight. The principal sources of organic compounds are the hydrocarbon emissions from automobile and truck exhausts, gasoline vapors, paint solvent evaporation, open burning, dry cleaning fluids, and industrial operations. There are also natural sources such as seepage from the ground and emissions from vegetation. Nitrogen oxides are emitted primarily from combustion sources such as electric power generation units, gas and oil-fired space heaters, and automobile, diesel and jet engines. Nitric oxide (NO) is the major form of nitrogen oxide emitted in combustion processes. Nitrogen dioxide (NO2) is formed from NO and is the compound which decomposes in sunlight to initiate the formation of ozone.

The factors which determine the concentrations of oxidants formed in the atmosphere include: (1) the amount and kinds of organic compounds initially present and the rate at which additional organics are emitted to the atmosphere; (2) the amount of nitrogen oxides initially present and their emission rates; and (3) sunlight ultra-violet intensity, temperature, and other meteorological factors. The interactions of these factors and the chemical reactions involved are very complex and have been the subject of continuing scientific investigation during the last 20 years, including atmospheric studies, laboratory smog chamber studies, and computer simulation of the oxidant forming process. For the purposes of this analyses it was conservatively assumed that a proportional model adequately describes the HC-oxidant relationship. Background levels were assumed to be 0.02 ppm.

Nitrogen Oxides and Nitrogen Dioxide

Almost all NOx is emitted as NO. The rate at which NO is converted to NO2 is a function of many factors including ozone concentrations, hydrocarbon concentrations, hydrocarbon reactivities, ultraviolet radiation intensity and ambient total NO . A portion of the total NO plus NO2 (NOx) from power plants is brought to the ground while a portion of that emitted from motor vehicles is being dispersed upward. The NOx is being mixed throughout the urban atmospheric environment and it becomes reasonably ubiquitous. Over the long-term NO2 levels do not tend to vary strongly across the urban setting. Since, for the projections only an annual average NO2 is projected, it is not critical that the spatial or temporal variations in concentration be identified and a linear model is a good first approximation.

The background for NO2 is assumed to be an annual average of 8 ug/m3.

Assumptions Used in the Projection of Air Quality

The projections of air quality are based on the scenarios summarized in Table 2. These scenarios include a number of emission standards for light duty vehicles and other mobile sources and single estimates for growth rates and control for stationary sources.

For light duty vehicles the new emissions standards are assumed to take effect according to the schedules listed in Table 3. The replacement rate for light duty vehicles is assumed to provide for a turnover in vehicles every thirteen years. The assumed distribution of ages of vehicles is presented in Table 4. The emission factor ratios for mobile sources are summarized in Table 2. The emission reduction assumed for trucks is less than the emission reduction from light duty vehicles.

For carbon monoxide a growth of one percent compounded annually was selected for all mobile sources. This is a lower growth rate than has been historically observed for metropolitan areas. It was chosen to reflect the fact that carbon monoxide is a localized problem where traffic density is already high and that growth in these areas will not be as great as for the broader metropolitan areas. No increased congestion due to this growth was assumed, clearly a conservative assumption.

For nitrogen oxides and hydrocarbons, growth rates of two percent compounded annually were selected for all mobile sources. These are lower than most areas are presently experiencing and are based based on the assumption that automobile and truck use in metropolitan areas will not continue to grow at the present rate. They were

Table 2

Assumptions For Air Quality Projections

Pollutant	Emission Standards	LIGHT DUTY VEHICLES: Emission Factor Ratio to Base Year (1970 HC & CO 1972 NO_x) — Without I/M 1980	1990	1999	With I/M 1980	1990	1999	Growth Rate Percent Compounded	OTHER MOBILE SOURCES	Emission Factor Ratio to Base Year (1970) 1980	1990	1999	Growth Rate Percent Compounded	STATIONARY SOURCES: Emission Factor Ratio to Base Year (1970) 1980	1990	1999	Growth Rate Percent Compounded
Carbon Monoxide	A	.59	.17	.15	.43	.08	.07		LDT	.66	.51	.49		.85	.60	.45	
	B	.59	.17	.15	.43	.08	.07		HDG	.81	.74	.72					
	C	.61	.32	.31	.45	.16	.16	1%	HDD	.84	.57	.57	1%				3.2%
	D	.61	.31	.30	.45	.16	.16										
	E	.56	.17	.15	.41	.08	.07										
Hydrocarbons	A	.48	.17	.16	.43	.12	.11		LDT	.66	.39	.34		.85	.50	.25	
	B	.48	.17	.16	.43	.12	.11		HDG	.81	.46	.38					
	C	.50	.19	.18	.44	.14	.13	2%	HDD	.97	.89	.88	2%				3.2%
	D	.50	.17	.16	.44	.12	.11										
	E	.48	.17	.16	.43	.12	.11										
Nitrogen Oxides	A	.73	.29	.20	.73	.29	.20		LDT	.77	.51	.48		.90	.70	.50	
	B	.73	.53	.52	.73	.53	.52		HDG	1.04	.93	.91					
	C	.73	.66	.66	.73	.66	.66	2%	HDD	.95	.93	.93	2%				3.0%
	D	.73	.53	.52	.73	.53	.52										
	E	.70	.53	.52	.70	.53	.52										

TABLE 3

LIGHT DUTY VEHICLE EXHAUST EMISSION STANDARDS SCHEDULES

Model Year	Hydrocarbons					Carbon Monoxide					Nitrogen Oxides				
Emission Schedule	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
1978	1.5	1.5	1.5	1.5	1.5	15	15	15	15	15	2.0	2.0	2.0	2.0	2.0
1979	.41	.41	1.5	1.5	.41	9	9	15	15	3.4	2.0	2.0	2.0	2.0	2.0
1980	.41	.41	.41	.41	.41	9	9	9	9	3.4	2.0	2.0	2.0	2.0	1.0
1981	.41	.41	.41	.41	.41	3.4	3.4	9	9	3.4	1.0	1.0	2.0	2.0	1.0
1982	.41	.41	.41	.41	.41	3.4	3.4	9	9	3.4	1.0	1.0	2.0	1.0	1.0
1983	.41	.41	.41	.41	.41	3.4	3.4	9	9	3.4	.4	1.0	2.0	1.0	1.0
1984	.41	.41	.41	.41	.41	3.4	3.4	9	9	3.4	.4	1.0	2.0	1.0	1.0
1985	.41	.41	.41	.41	.41	3.4	3.4	9	9	3.4	.4	1.0	2.0	1.0	1.0

TABLE 4

DISTRIBUTION OF VEHICLE MILES TRAVELED BY AGE OF AUTOMOBILE

0 to 1 yr.	11.2%
1 to 2 yr.	14.3%
2 to 3 yr.	13.0%
3 to 4 yr.	12.1%
4 to 5 yr.	10.8%
5 to 6 yr.	9.4%
6 to 7 yr.	7.9%
7 to 8 yr.	6.3%
8 to 9 yr.	4.7%
9 to 10 yr.	3.2%
10 to 11 yr.	1.9%
11 to 12 yr.	1.3%
12 to 13 yr.	1.3%
13 yr and over	2.6%

selected because the hydrocarbons and nitrogen oxides are the precursors for oxidant and nitrogen dioxide formation, pollutants which are a problem over wide areas and are not restricted to localized areas of high traffic density.

Stationary source growth rates were estimated from economic indicators for four groupings of sources: electric generation, industrial activites, area sources and other point sources. The sources of carbon monoxide and hydrocarbons are expected to grow at 3.2 percent compounded. A growth of 3.0 percent was assumed for nitrogen oxide sources.

A single scenario was modeled for stationary sources based on new control technology with successively more stringent controls being applied from 1980 to 1990 and 2000. The assumption about possible control technology was based on a review of existing technologies and technologies which are still under development. In some cases it is unclear how the degree of control estimated will actually be achieved but the estimates were based on technological optimism. For the degree of control assumed, regulations in addition to the present regulations would be necessary to achieve the emission reductions.

While national growth rates were assumed for this study, the contribution of each source category in the base year was estimated for each specific area of the country.

The contributions for each source category were taken from State Implementation Plans or, if these were not considered adequate, estimated from data within the National Emissions Data System (NEDS). The source contributions by region are presented in Tables 5, 6, and 7.

Carbon Monoxide Air Quality Projections

Table 8 summarizes the impact on carbon monoxide air quality of the different emission standards schedules based on the conservative assumptions summarized above. By 1990 average air quality levels are projected to improve by 60% (68% with I/M) under either schedules A, B or E but only by 47% and 48% under schedules C and D (61% with I/M). A total of 12 AQCR's are projected to exceed the standard in 1990 under schedules A, B and E (only 5 with I/M) whereas 15 will exceed under schedules C and D (11 with I/M). Over the decade 1980 to 1990 Schedule E will result in the minimum number of violations, 4,521, of all scenarios run (1,535 with I/M). Schedules A and B will result in 5,533 violations, a 22% increase over Schedule E. (1910 or a 24% increase with I/M). Under schedules C and D the number of violations would virtually double to over 9100 (a 64% increase to

TABLE 5

SOURCE CONTRIBUTION OF CARBON MONOXIDE EMISSIONS IN PERCENT FOR BASE YEAR

No.	Urban Area	Light Duty Vehicles	Other Mobile Sources	Stationary* Sources
004	Birmingham	71	23	6
009	North Alaska	69	21	10
013	Clark-Mohave	73	27	0
015	Phoenix-Tucson	73	26	1
024	Los Angeles	74	25	1
028	Sacramento Valley	72	25	3
029	San Diego	74	26	0
030	San Francisco	73	26	1
031	San Joaquin Valley	72	27	1
036	Denver	73	26	1
042	Hartford-N.Haven	74	26	0
043	NY-NJ-Conn.	74	25	1
045	Philadelphia	72	26	2
047	National Capitol	73	26	1
062	E. Wash.-N. Idaho	73	26	1
067	Chicago	70	26	4
080	Indianapolis	72	26	2
094	Kansas City	72	27	1
115	Baltimore	72	26	2
119	Boston	74	26	0
131	Minn.-St. Paul	73	26	1
158	Central New York	74	25	1
193	Portland	71	25	4
197	S.W. Penna.	72	26	2
220	Wasatch Front	72	26	2
229	Puget Sound	73	26	1
	Other Urban Areas**	60	36	3

*Stationary sources have been adjusted to account for receptor location

**Emissions inventory for other urban areas based on U.S. average emissions

TABLE 6

SOURCE CONTRIBUTION OF HYDROCARBON EMISSIONS IN PERCENT FOR BASE YEAR

No.	Urban Area	Light Duty Vehicles	Other Mobile Sources	Stationary Sources
004	Birmingham	46	21	33
005	Mobile-Pensacola	47	19	34
013	Clark-Mohave	54	15	31
015	Phoenix-Tucson	51	20	29
024	Los Angeles	47	22	31
028	Sacramento Valley	39	18	43
029	San Diego	54	25	21
030	San Francisco	39	18	64
031	San Joaquin	37	17	46
033	S. E. Desert	40	18	42
036	Denver	55	26	19
043	NY-NJ-Conn.	50	23	27
045	Philadelphia	54	25	21
047	National Capitol	55	25	20
079	Cincinnati	48	22	30
067	Chicago	27	13	60
070	St. Louis	30	22	48
106	S. Lou.-S.E. Texas	43	20	37
115	Baltimore	25	13	62
119	Boston	49	23	28
131	Minneapolis-St.Paul	44	26	30
153	El Paso-Las Cruces	59	28	13
160	Genesse-Finger Lakes	57	26	17
173	Dayton	47	22	31
193	Portland	42	19	39
197	S.W. Pennsylvania	48	23	29
214	Corpus-Christi	18	9	73
215	Dallas-Ft.Worth	47	20	33
216	Houston-Galveston	28	13	59
229	Puget Sound	59	27	14
	Geographic Areas			
	Northeast	42	22	36
	East Central	38	25	37
	Mid Central	16	11	73
	Southeast	32	23	44
	West Central	37	37	25
	Southwest	18	18	64
	West	34	25	42

TABLE 7

SOURCE CONTRIBUTION OF NITROGEN OXIDE EMISSIONS IN PERCENT FOR BASE YEAR

No.	Urban Area	Light Duty Vehicles	Other Mobile Sources	Stationary Sources
015	Phoenix-Tucson	40	22	38
024	Los Angeles	46	18	36
030	San Francisco	45	20	35
036	Denver	32	15	53
043	NY-NJ-Conn.	26	10	64
045	Philadelphia	21	11	68
047	National Capitol	31	12	57
067	Chicago	21	12	67
070	St. Louis	12	13	75
115	Baltimore	20	11	69
131	Minneapolis-St. Paul	24	19	57
215	Dallas-Fort Worth	30	24	46
216	Houston	15	15	70
220	Wasatch Front	37	18	45
	Geographic Divisions			
	Northeast	28	17	55
	East Central	18	18	64
	Mid Central	20	17	63
	Southeast	19	19	62
	West Central	26	30	44
	Southwest	19	23	58
	West	29	28	43

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TABLE 8

COMPARISON OF CO AIR QUALITY IMPACTS FOR VARIOUS AUTOMOBILE

EMISSION STANDARDS

Emission Standard For Automobiles	I & M Status	Mobile Source Growth Rate	Average Percent Change in CO Air Quality as Compared to 1970 Level				Number of AQCR's Projected to be above CO Standard Out of 30 AQCR's Examined				Total Number of Times 8-hour CO Standards is Projected to be Violated in 30 AQCR's Examined.					
			1980	1985	1990	2000	1980	1985	1990	2000	1980	1985	1990	2000	1980-1990	1980-2000
Schedule C	Without	1%	27	43	47	45	25	21	15	16	2,241	709	443	581	9,200	14,320
	With	1%	39	58	61	58	23	12	11	12	1,003	112	63	95	2,523	3,313
Schedule D	Without	1%	27	43	48	46	25	21	15	16	2,241	709	405	534	9,137	13,831
	With	1%	39	58	61	58	23	12	11	12	1,003	112	63	95	2,523	3,313
Schedule A and B	Without	1%	28	51	60	59	24	14	12	12	2,074	290	86	86	5,533	6,393
	With	1%	40	62	68	67	23	8	5	5	941	47	17	17	1,910	2,080
Schedule E	Without	1%	30	54	60	59	24	14	12	12	1,823	201	86	86	4,521	5,381
	With	1%	42	64	68	67	22	8	5	5	764	35	19	17	1,535	1,705

2523 with I/M). It should be noted that the numbers of violations are only for the 26AQCR's modelled; additional violations would occur in.other areas which were not modelled.

Hydrocarbons/Oxidants

Table 9 summarixes the oxidant air quality impact of the various hydrocarbon standards. For schedules A, B and E it is estimated that 37AQCR's out of 48 modelled will still exceed standards in 1990 (36 with I/M) compared to 40AQCR's with schedules C and D (36 withI/M). The average percent change in air quality falls from a 37% improvement with schedules A, B and E (40% withI/M) to a 36% improvement with schedules C and D (39% with I/M). In terms of violations of the oxidant standard, schedules A, B and E result in 51,992 over the period 1980 to 1990 (44,327 with I/M or 15% less) whereas schedules C and D result in 54,582 and 53,381 violations,respectively (46,522 and 45,511 with I/M), an increase of 5% and 3%, respectively.

Nitrogen Dioxide

Table 10 summarizes the annual average NO2 air quality impact of the alternative emission standards considered. Only under schedule A will the air quality improve between now and 1990 and even then by only 3%; schedules B, D and E are projected to result in a 6% worsening of air quality while schedule C is projected to degrade the air quality by 10%. While 4ACQR's will exceed the standard under schedule A, 6AQCR's are projected over the standard under schedules B, D and E and 7 over with schedule C.

Table 10A summarizes the short term NO2 air quality impact of the alternative emission standards considered, assuming standards of 0.11 or 0.19 are adopted.1/ This should in no way be construed as an endorsement of these standards but only as a useful indicator of the potential impact of the alternative emissions standards schedules on short term air quality levels. By 1990, schedule A is projected to result in 1302 excursions over the 0.11 level (347 excursions above 0.19) while schedules B, D and E will result in 1569 violations (486 at 0.19) and schedule C will result in 1701 violations (554 at 0.19). Schedules B, D and E result in about 21% more excursions above than schedule A (40% more at 0.19) while schedule C results in 31% more (60% more at 0.19).

1/ This range is similar to a range of standards being examined by the World Health Organization (WHO).

TABLE 9

COMPARISON OF OXIDANT AIR QUALITY IMPACTS FOR VARIOUS AUTOMOBILE EMISSION STANDARDS

Emission Standard For Automobiles	I & M Status	Mobile Source Growth Rate	Average Percent Change in Oxidant Air Quality As Compared to 1970 Level				Number of AQCR's Projected To be Above Oxidant Standard Out of 48 AQCR's Examined				Total Number of Times 8-hour Oxidant Standard is Projected To Be Violated in 48 AQCR's Examined					
			1980	1985	1990	2000	1980	1985	1990	2000	1980	1985	1990	2000	1980-1990	1980-2000
Schedule C	Without	2%	12	29	36	45	47	41	40	31	10,308	4,797	3,253	1,612	54,582	78,90
	With	2%	15	33	39	49	47	41	36	27	9,270	3,976	2,739	1,195	46,522	66,1[illegible]
Schedule D	Without	2%	12	30	37	46	47	41	37	30	10,308	4,671	3,037	1,433	53,381	75,7[illegible]
	With	2%	15	34	40	50	47	41	36	26	9,270	3,872	2,549	1,056	45,511	63,5[illegible]
Schedule A and B	Without	2%	13	30	37	46	47	41	37	30	9,954	4,551	3,037	1,433	51,992	74,34
	With	2%	15	34	40	50	47	41	36	26	9,101	3,759	2,549	1,056	44,327	61,90
Schedule E	Without	2%	13	30	37	46	47	41	37	30	9,954	4,551	3,033	1,433	51,992	74,34
	With	2%	15	34	40	50	47	41	36	26	9,101	3,759	2,549	1,056	44,327	61,90

TABLE 10

COMPARISON OF LONG-TERM NO_2 AIR QUALITY FOR VARIOUS AUTO EMISSION STANDARDS

Emission Standard Schedule	Average % Change In Air Quality				No. of AQCR's Above Annual NO_2 Standard			
	1980	1985	1990	2000	1980	1985	1990	2000
Schedule C	-4	-6	-10	-13	5	7	7	7
Schedule D	-4	-4	-6	-8	5	5	6	7
Schedule B	-4	-3	-6	-8	5	4	6	7
Schedule A	-4	-1	3	5	5	4	4	4
Schedule E	-4	-3	-6	-8	4	4	6	7

TABLE 10A

Comparison of Short-Term NO_2 Air Quality For Various Auto Emission Standards

Emission Standards Schedule	No. of Times WHO Draft Level of .11 ppm Exceeded in worst month				No. of Times WHO Draft Level of .19 ppm Exceeded in worst month			
	1980	1985	1990	2000	1980	1985	1990	2000
Schedule C	1,544	1,596	1,701	1,700	473	499	554	613
Schedule D	1,544	1,524	1,569	1,626	473	464	486	517
Schedule B	1,544	1,499	1,569	1,626	473	452	486	517
Schedule A	1,544	1,429	1,302	1,224	473	418	347	318
Schedule E	1,528	1,499	1,569	1,626	466	452	486	517

V. Health Consequences Projections For Alternative Control Strategies

This section describes certain of the health consequences projections estimated to result from the implementation of varying levels of mobile source emission control assuming fixed levels of light duty vehicle growth. Health consequences projections are estimated for the periods 1980 to 2000.

The projections are for those effects for which dose response relations have been estimated and do not represent the great bulk of other health consequences or synergistic effects which have not been quantified (see section II) and these impacts therefore, should not be construed as meaningful in absolute terms. In the following paragraphs these health consequences projections are discussed on a per pollutant basis.

Carbon Monoxide

Estimates of excess cardiac deaths and excess hours of person disability due to angina attacks resulting from elevated carbon monoxide levels for each of the automotive emission standards schedules are displayed in Table 11. These projections assume that only ten percent of the urban population is exposed to harmful levels of carbon monoxide. They are based on an average year. For high and low years the effects may vary fifty or more percent from these projected consequences.

The estimates for the period 1980 to 2000 vary from 45 excess deaths for schedule C (7 with I/M) to 43 deaths with schedule D (also 7 with I/M) to 18 deaths with schedules A and B (5 with I/M) to a low of 15 deaths with schedule E (4 with I/M). On a per year basis the 1990 estimates are lower than those for 1980 or 2000 which indicates that expected growth will overtake control between 1990 and 2000.

During the period 1980 to 1990 adverse health effects as indicated by excess person hours of disability due to angina attacks are projected to be 3% less under schedule D than schedule C (no difference with I/M). Introducing the statutory standard (3.4 gpm) according to schedules A and B reduces angina disability by 45% during this period compared to schedule C (31% less with I/M) and by 54% with schedule E (41% with I/M). Most of the health benefit for all scenarios occurs in the near future, as vehicles now on the road are replaced with vehicles having lower emissions.

Photochemical Oxidants

Six health consequences are projected in Table 12 for photochemical oxidant exposure: excess aggravation of heart and lung disease in elderly patients; excess aggravation of asthma; excess eye discomfort; excess cough; excess chest discomfort; and excess headache.

Nitrogen Dioxide

Estimates of excess days of restricted activity due to excess attacks of lower respiratory disease in children from projected elevated nitrogen dioxide levels for each of the alternative emissions schedules are displayed in Table 13.

Significant differences exist over the period 1980 to 2000 for respiratory attacks projected by continuing with the current 2.0 g/mi nitrogen oxides emission standard versus implementing either a 1.0 g/mi standard or the statutory 0.4 g/mi standard. For the total health impact between 1980 and 2000, a 3 to 4 percent improvement is projected for schedules B, D, and E over schedule C. The statutory standard schedule A is projected to provide a 26 percent improvement. The benefits of implementing the statutory standard are most apparent in the per year estimates for the year 2000, as a 35% reduction is projected for that year when the statutory standard is compared with the present nitrogen oxides emission standard.

While the quantification of health effects and the development of dose response characteristics is controversial and while different scientists might raise or lower the impacts, the preceding quantification reflects the best judgments of EPA's medical staff. (These subjects are discussed further on pages 10 through 12 above (Chapter II)).

VI. Technological Considerations - Timing Of the Standards

(a) 1978 Model Year

Virtually all automobile manufacturers are planning to meet emission standards of 1.5 HC, 15 CO, 2.0 NOx for model year 1978. Most of the automobile manufacturers indicated that their plans for model year 1978 are based on the 1976 Committee Report on Amendments to the Clean Air Act. Even though the changes to the Clean Air Act contained in that Report were subsequently not adopted by Congress, the manufacturers' position appears to be that the intent of Congress was to adopt emission standards of 1.5 HC, 15 CO, 2.0 NOx for model year 1978.

Because the manufacturers have targeted their development toward meeting 1.5 HC, 15 CO, 2.0 NOx for model year 1978, there is little possibility that emission standards much different from these levels could be successfully implemented for that year. Even for a relatively similar standard like 0.9 HC, 9 CO, 2.0 NOx, for example, some durability vehicles would have to be rerun, calibration and system modifications for each data vehicle would have to be reexamined and possibly redeveloped, new or additional supplies of certain components might be required which are not now planned for. This leads to the conclusion that at this point there is not enough lead time to do anything significantly different from what the manufacturers are already planning to do for the model year 1978.

Summary of Two Types of Health Impacts From Carbon Monoxide Exposure

Emission Standard For Automobiles	I & M Status	Excess Cardiac Deaths						Excess Person-Hours of Disability From Angina Pectoris					
		1980	1985	1990	2000	1980-1990	1980-2000	1980	1985	1990	2000	1980-1990	1980-2000
Schedule C	Without	9	2	1	2	30	45	116,253	39,945	29,881	41,147	509,857	864,997
	With	3	0	0	0	6	7	56,343	5,680	3,157	5,701	137,033	181,323
Schedule D	Without	9	2	1	2	30	43	116,253	39,945	20,557	38,018	494,317	787,192
	With	3	0	0	0	6	7	56,343	5,680	3,156	5,701	137,032	181,317
Schedules A and B	Without	8	1	0	0	18	18	107,597	14,071	3,592	4,250	279,072	318,282
	With	3	0	0	0	5	5	50,613	1,571	131	166	95,047	96,532
Schedule E	Without	7	0	0	0	14	15	95,085	10,280	3,582	4,250	232,995	272,205
	With	2	0	0	0	4	4	45,294	718	131	166	80,495	81,980

Table 12

PROJECTED HEALTH IMPLICATIONS

(2% LDV Growth) FOR ALTERNATIVE OX SCENARIOS

I/M Status	Emissions Standards Schedule	Projected Health Consequence: Aggravation of Elderly Heart and Lung Disease	Aggravation of Asthma	Eye Disease	Cough	Chest Discomfort	Headache
1990							
W/O	C	7,840	784	623,665	122,829	11,533	1,862,584
W	C	6,257	626	512,078	98,024	9,195	1,669,712
W/O	D	7,163	716	576,577	112,223	10,555	1,790,145
W	D	5,730	573	470,640	89,767	8,354	1,592,208
W/O	A,B	7,163	716	576,577	112,233	10,555	1,790,145
W	A,B	5,730	573	470,640	89,767	8,354	1,592,208
W/O	E	7,163	716	576,577	112,233	10,555	1,790,145
W	E	5,730	573	470,640	89,767	8,354	1,592,208
2000							
W/O	C	3,474	347	316,215	54,429	4,928	1,352,913
W	C	2,335	234	231,882	36,584	3,270	1,157,510
W/O	D	3,128	313	283,893	49,006	4,358	1,267,838
W	D	1,939	194	199,222	30,370	2,594	1,057,296
W/O	A,B	3,128	313	283,893	49,006	4,358	1,267,838
W	A,B	1,939	194	199,222	30,370	2,594	1,057,296
W/O	E	3,128	313	283,893	49,006	4,358	1,267,838
W	E	1,939	194	199,222	30,370	2,594	1,057,296
1980 to 2000							
W/O	C	246,298	24,631	16,325,167	3,814,263	365,608	40,676,921
W	C	201,580	20,165	13,805,164	3,158,117	300,692	36,706,496
W/O	D	236,121	23,609	15,626,915	3,699,219	350,665	39,427,490
W	D	193,236	19,320	13,143,797	3,027,308	287,194	35,339,066
W/O	A,B	228,877	22,889	15,325,601	3,585,941	340,166	39,138,708
W	A,B	199,291	19,198	13,086,313	3,007,155	285,171	35,266,795
W/O	E	228,877	22,889	15,325,601	3,585,941	340,166	39,138,708
W	E	199,291	19,198	13,086,313	3,007,155	285,171	35,266,795

Table 13

COMPARISON OF LONG-TERM NO_2 HEALTH EFFECTS FOR VARIOUS

AUTO EMISSIONS STANDARDS

Emission Standards Schedule	Mobile Source Growth Rate	In 1000's	Excess Days of Restricted Activity Due to Lower Respiratory Disease in Children		
		1980	1990	2000	1990 - 2000
Schedule C	2%	2398	2826	3066	55,893
Schedule D	2%	2398	2693	3053	54,076
Schedule B	2%	2398	2693	3053	54,076
Schedule A	2%	2398	1989	2002	41,186
Schedule E	2%	2344	2693	3053	53,896

(b) Post 1978

Estimates of the earliest dates that more stringent emission standards could be achieved from an emission control technology standpoint are provided in the table below. A discussion of each of the standards considered follows:

Emission Standard			Earliest Model Year
Hydrocarbons	Carbon Monoxide	Nitrogen Oxides	
0.41	9.0	2.0	1979
0.41	3.4	2.0	1980
0.41	3.4	1.0	1981
0.41	3.4	0.4	1982

(i) .41 HC, 9 CO, 2.0 NOx

Achievement of this standard can be accomplished in 1979 if the industry knows by July 1, 1977 it will be required. This is when final decision must be made regarding control systems for the 1979 model year design. Any additional delay in establishing the 1979 standard will seriously jeopardize its achievement. Those companies that may have been working toward another set of standards as a 1979 goal could delay the introduction of their 1979 models until January 1, 1979 to gain additional time for development.

At this level of emissions control the greatest challenge is the 0.41 HC. This will have to be achieved with well designed air injection, bigger catalysts, and exhaust heat conservation techniques such as port liners. At the 2.0 NOx level there would be no increase in HC from tighter NOx control, as there could be at 1.5 or less NOx. The 9.0 CO would come along with the .41 HC.

(ii) 0.41 HC, 9 CO, 1.5 NOx

These standards are numerically the same as the standards for California for model year 1977. While extension of technology developed for California to Federal application might seem at first to be relatively straightforward, there are differences between California and Federal certification protocols that complicate the issue somewhat. Therefore, the California experience is not directly translatable into projections of compliance with Federal emission standards that are numerically the same.

Time and effort are required to develop emission control systems to meet 0.41 HC while retaining good fuel economy calibrations. This is borne out by the experience in California where fuel economy of the California fleet has lagged the Federal fleet (on a equal model mix basis) by 1-2 years largely as a result of the less than optimum systems and calibrations used to meet the more stringent California standards. However, it should be noted that even though there was a difference in fuel economy between California and Federal fleets when computed on an identical or equal sales mix, the fact that California buyers elected to purchase lighter and more fuel efficient vehicles resulted in no significant difference in fuel economy between the California and Federal fleets on an actual sales mix in 1976.

The 0.41 HC, 9 CO, 1.5 NOx standards would tend to encourage the development and introduction of 3-way catalyst systems if these levels are followed in succeeding model years by lower NOx standards.

(iii) <u>0.41 HC, 3.4 CO, 2.0 NOx</u>

In the 1979-1980 time period, the 3.4 CO level will be difficult to meet while retaining good fuel economy even with the use of advanced oxidation catalyst systems. These systems would be similiar to current Federal systems but to optimize fuel economy would utilize larger more efficient oxidation catalysts, air injection, heat conservation techniques (port liners, insulated manifolds) and start catalysts or lean thermal reactors (on the heavy cars). If NOx standards more stringent than 2.0 gpm are eventually going to be required, 3-way catalysts may also be used to meet these more stringent standards. However, the 3.4 CO would be a tough target for 3-way catalysts in the 1979-80 time frame and therefore this standard may not permit or encourage the early phase-in of the 3-way catalyst technology that will be needed to meet tighter NOx standards with little or no fuel economy penalty.

(iv) <u>0.41 HC, 3.4 CO, 1.0 NOx</u>

These standards can be met in 1981. The most difficult pollutant to control at the 0.41 HC, 3.4 CO, 1.0 NOx level will be CO, if 3-way catalyst systems are used. The addition of a downstream oxidation catalyst and air injection might be required on some vehicles. Without the use of 3-way catalysts, control of both HC and NOx to these levels will be difficult.

(v) <u>0.41 HC, 3.4 CO, 0.4 NOx</u>

The timetable for introduction of the 0.41 HC, 3.4 CO, 0.4 NOx standards could be as early as 1983 and would allow time to incorporate good fuel economy calibrations. One of the more important pacing items for this standard is the lead time necessary to develop and adopt the sophisticated fuel metering systems that may be required. Feedback carburetion may not be good enough, and fuel injection systems of some type may be needed.

VII. Cost and Fuel Economy and Fuel Consumption Impacts of Various Levels of Emissions Standards

Estimates of the changes in vehicle first cost, lifetime maintenance cost, and fuel economy associated with meeting various levels of emission standards are summarized in Table 14. The Base Case from which all of the changes are estimated is achievement of 1.5/15/2.0 standards using Optimal Cost technology. 1977 model year vehicles using optimal cost technology (high energy ignition proportional exhaust gas recirculation and oxidation catalysts) but adjusted for optimal fuel economy served as the Base Case. These same vehicles with the addition of electronics are assumed to improve by about 2% in fuel economy.

Separate estimates are given in Table 15 for the 1980, 1983, and 1985 model years. These estimates for different model years, which differ from one another to only a small degree, were made by computing weighted average cost increments and fuel economy penalties for each of the model years using the separate estimates derived for light and heavy cars and estimated fractions of light and heavy cars in the new vehicle fleet of each model year. Light cars (defined in this study as having emission test weights of 3000 lbs. or less) were assumed to make up 35% of the new vehicle fleet in the 1980 model year, 45% in 1983, and 50% in 1985; heavy cars (greater than 3000 lbs. test weight) make up the remainder of the new vehicle fleet in each model year. The cost in Table 15 generally decline with time because of this assumed reduction in heavy car sales.

(a) Cost/Fuel Economy Impact

Table 14 indicates that achievement of emission standards as stringent as 0.41/3.4/1.0 is judged to be achieveable in the early 1980's with no sacrifice in fuel economy from the levels which could be obtained under current (1.5/15/2.0) standards. However, this will require the application of technology significantly more sophisticated than that typically used on today's cars. In particular, the use of sophisticated electronic control of engine parameters such as spark timing and exhaust gas recirculation rate and the use of three-way catalysts at the more stringent NOx emission levels have been assumed. These technologies are currently under intensive development and evaluation by major automobile manufacturers and are either already being used on a trial basis on some production models or are planned for such limited use on some 1978 models. It is proposed, however, that if these more sophisticated technologies are not used, there would probably be some fuel economy penalty.

The use of this more sophisticated emission control technology is estimated to increase the average sticker price of new cars by approximately $250 at the 0.41/3.4/1.0 standards level and by lesser amounts at less stringent standards. Lifetime maintenance costs (excluding maintenance that would be done solely to keep emission levels low, such as in response to an inspection/maintenance program) are estimated to increase by about $80 at the 0.41/3.4/1.0 standards (see Table 16).

Table 14

Cost & Fuel Economy Estimates*
(1977 $)

Emissions Level HC/CO/NOx (gm/mi)	Cost Optimal 1/ Light Cars Cost 4/	FE 5/	Maint 6/	Cost Optimal 1/ Heavy Cars 3/ Cost 4/	FE 5/	Maint 6/	Fuel Optimal 2/ Light Cars Cost 4/	FE 5/	Maint 6/	Fuel Optimal 2/ Heavy Cars 3/ Cost 4/	FE 5/	Maint 6/
1.5/15/2.0		Base			Base							
0.41/9/2.0	$35	-2%	$0	$35	-4%	$0	$90	+2%	$15	$125	+2%	$15
0.41/3.4/2.0	$35	-2%	$0	$35	-4%	$0	$90	+2%	$15	$140	+2%	$15
0.41/9/1.5	$85	-3%	$15	$95	-2%	$55	$110	+2%	$15	$145	+2%	$70
0.41/3.4/1.5	$105	-3%	$15	$95	-2%	$55	$150	+2%	$15	$220	+2%	$70
0.41/9/1.0	$105	-4%	$15	$170	-3%	$55	$145	+2%	$70	$220	+2%	$70
0.41/3.4/1.0	$175	-4%	$15	$220	-3%	$55	$220	+2%	$70	$285	+2%	$70
0.41/9/0.4	$185	0 to -8%	$70	$210	0 to -8%	$90	$220	0 to +2%	$70	$330	0 to +2%	$90
0.41/3.4/0.4	$195	0 to -8%	$90	$285	0 to -8%	$90	$300	0 to +2%	$90	$360	0 to +2%	$110

1/Minimum cost design to meet emission levels.

2/Maximum fuel economy design to meet emission levels.

3/More than 3,000 lbs.

4/Additional sticker price above base case.

5/Change in fuel economy relative to base case.

6/Maintenance costs over 100,000 miles.

*Note that emission control technology changes for the different emission levels as detailed in Appendix A

Table 15

WEIGHTED INITIAL COST
(1977 $)

Emission Levels (gm/mi)	1980 Optimum Cost 1/	1980 Optimum Fuel 2/	1983 Optimum Cost 1/	1983 Optimum Fuel 2/	1985 Optimum Cost 1/	1985 Optimum Fuel 2/
0.41/9/2.0	$35	$110	$35	$110	$35	$110
0.41/3.4/2.0	$35	$125	$35	$115	$35	$115
0.41/9/1.5	$90	$135	$90	$130	$90	$130
0.41/3.4/1.5	$100	$200	$100	$190	$100	$185
0.41/9/1.0	$145	$190	$140	$185	$140	$185
0.41/3.4/1.0	$200	$260	$200	$255	$190	$250
0.41/9/0.4	$200	$290	$200	$280	$200	$275
0.41/3.4/0.4	$250	$340	$245	$335	$240	$330

1/Minimum cost design to meet emission levels.

2/Maximum fuel economy design to meet emission levels.

Table 16

WEIGHTED MAINTENANCE COST 1/
(1977 $)

Emission Level (gm/mi)	1980 Optimum Cost 2/	1980 Optimum Fuel 3/	1983 Optimum Cost 2/	1983 Optimum Fuel 3/	1985 Optimum Cost 2/	1985 Optimum Fuel 3/
0.4./9/2.0	$ 0	$17	$ 0	$17	$ 0	$17
0.41/3.4/2.0	$ 0	$17	$ 0	$17	$ 0	$17
0.41/9/1.5	$40	$50	$35	$45	$35	$45
0.41/3.4/1.5	$40	$50	$35	$45	$35	$45
0.41/9/1.0	$40	$70	$35	$70	$35	$70
0.41/3.4/1.0	$40	$70	$35	$70	$35	$70
0.41/9/0.4	$85	$85	$80	$80	$80	$80
0.41/3.4/0.4	$90	$100	$90	$100	$90	$100

1/Over 100,000 miles without Inspection and Maintenance

2/Minimum cost design to meet emission levels.

3/Maximum fuel economy design to meet emission levels.

In addition, other techniques are being developed to obtain fuel economy increases by making the engine work harder on the average. These techniques include dual displacement engines, improved transmissions, and higher compression ratio engines with knock-sensitive spark advance. The relation between fuel economy and emissions for complete engine systems based on these new techniques is not known.

Alternatively, these standards could be met by manufacturers using less sophisticated, and less costly, emission control technology, but at the cost of some loss in fuel economy. With a sacrifice of 3% to 4% in fuel economy, systems costing $40 to $65 less (depending on the level of the emission standards) could be used. Still greater cost reductions (with larger fuel economy losses) are possible, but this analysis assumed that manufacturers would not be willing to accept substantially larger fuel economy penalties because of the need to comply with manufacturer fleet-average fuel economy standards.

The estimates for the most stringent emission standards considered in this analysis (0.41/9.0/0.4 and 0.41/3.4/0.4) are substantially more uncertain because of the general lack of empirical test data for the types of systems judged likely to be required to meet such standards. With this caveat EPA estimates that achievement of the current statutory emission standards (0.41/3.4/0.4) is possible with little or no fuel economy penalty, and with an average increase in vehicle sticker price of about $330 relative to today's cars.

At present, the distinction between Optimal Cost and Optimal Fuel Economy systems at the 0.41/3.4/0.4 standards is probably somewhat artificial. The technolgy for meeting those standards is uncertain enough to make an accurate definition of the technology likely to allow a full range of models to comply with those standards rather difficult. Nevertheless, there appears to be significant potential for meeting those standards with little or no fuel economy penalty through the further improvement and application of emission control technologies. (Detailed in Appendix A.)

Additional detailed discussion of the cost/fuel/economy/system design relationships is provided in Appendix A. Tables A-1 through A-8 provide a detailed description of the control systems under consideration for the various levels of emission standards.

(b) Fuel Consumption Impacts

The potential impact on total fuel consumption of the various emission standards is shown in Table 17. The figures given represent the change (in barrels per day) in lifetime new car fleet fuel consumption estimates. These changes for each model year vehicle are also expressed as a percent of total gasoline consumption over the same period (10 years).

TABLE 17

Comparison of New Car Fleet Consumption Estimates 3/5/

Model Year	Base Fuel Consumption 1/ (1000 B/D)	Increase Consumption Relative to Base Gasoline Consumption 4/ (1000 B/D) (Cost Optimal/Fuel Optimal) Emission Control Schedule A	B	C	D	E	Percent Change in Consumption Relative to Total Gasoline Consumption 2/4/ & (Cost Optimal/Fuel Optimal) Emission Control Schedule A	B	C	D	E
1978	362	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
1979	343	+11/-6.8	+11/-6.8	0/0	0/0	+11/-6.8	+.16/-.10	+.16/-.10	0/0	0/0	+.16/-.10
1980	326	+11/-6.5	+11/-6.5	+11/-6.5	+11/-6.5	+11/-6.5	+.15/-.09	+.15/-.09	+.15/-.09	+.15/-.09	+.15/-.09
1981	303	+10/-6.1	+10/-6.1	+10/-6.1	+10/-6.1	+10/-6.1	+.14/-.09	+.14/-.09	+.14/-.09	+.14/-.09	+.14/-.09
1982	283	+9.6/-5.7	+9.6/-5.7	+9.6/-5.7	+9.6/-5.7	+9.6/-5.7	+.14/-.08	+.14/-.08	+.14/-.08	+.14/-.08	+.14/-.08
1983	266	+21/-5.3	+9.0/-5.3	+9.0/-5.3	+9.0/-5.3	+9.0/-5.3	+.30/-.07	+.13/-.07	+.13/-.07	+.13/-.07	+.13/-.07
1984	251	+20/-5.0	+8.8/-5.0	+7.5/-5.0	+8.8/-5.0	+8.8/-5.0	+.29/-.07	+.13/-.07	+.11/-.07	+.13/-.07	+.13/-.07
1985	237	+19/-4.7	+8.3/-4.7	+7.1/-4.7	+8.3/-4.7	+8.3/-4.7	+.27/-.07	+.12/-.07	+.10/-.07	+.12/-.07	+.12/-.07
MY Totals 1978-1985	2371	+101.6/ -40.1	+67.7/ -40.1	+54.2/ -33.3	+56.7/ -33.3	+67.7/ -40.1	+1.4/-.57	+.97/-.57	+.77/-.47	+.81/-.47	+.97/-.57

1/ Fuel Consumption for given model year with base emission standards (1.5 HC, 15 CO, 2.0 NOx) and cost optimal technology and fleet average fuel economy equal to the fuel economy standards for that model year.

2/ Based on average annual gasoline consumption of 7.0 MMB/D between now and 1985.

3/ Based on sales weighted average penalty (savings) for light and heavy cars. Where a range in fuel economy estimates is given in Table 1, the maximum penalty was assumed for cost optimal technology, and the maximum savings for fuel optimal technology.

4/ Negative numbers indicate fuel savings relative to base.

5/ Based on 10 million new vehicles per model year and 10,000 miles per year.

Other Technological Considerations

(a) Rhodium

The three way catalyst system developed to date by Volvo uses a Platinum (Pt)-Rhodium (Rh) mixture that is different from the Platinum-Palladium (Pd) mixture used in oxidation catalysts. Because of its use of a high percentage of RH (relative to Pt), the 3-way catalyst has raised questions about the availability of Rh.

An EPA analysis of this issue shows that the short-term (2-3 years) supply of Rhodium is probably adequate to meet demand if all cars were to use a 3-way catalyst with the Volvo mixture (high proportion of Rhodium relative to Platinum). However, other industrial users might have to find substitutes for Rhodium. In the long-term, whether the additional demand for Rhodium could be met, at least from South African mines, if all cars use the Volvo mixture, depends to a large extent on finding additional markets for Platinum that is mined along with Rhodium. On the other hand, if all cars were to use 3-way catalysts with a "natural" ratio of Rhodium to Platinum and Palladium (about 5% of the total loading), the South African mines would have no trouble meeting the demand for Rhodium.

(b) Fuel Economy/NOx Relationship for Low Power to Weight Ratio Vehicles

Questions have been raised about whether underpowered vehicles which tend to be high fuel economy cars have to work harder during the Federal Test Procedure and thus make higher emissions than cars with traditional weight to horse-power ratios. How much harder they have to work is an important issue. If they use maximum power the use of current carburetor designs generally involves crude means of power enrichment. This would tend to lower NOx emissions. CO, however, could then be higher and difficult to control. However, if the purpose for going to underpowered vehicles is to improve fuel economy they would not likely be designed to operate with crude means of power enrichment during the test. Power enrichment would degrade fuel economy not improve it, compared to a vehicle operating without power enrichment. Electronic feedback carburetors currently under development should help solve this problem.

Even with proper control of the fuel enrichment, higher power conditions might cause NOx to increase, if nothing was done to attempt to control the NOx. Under these conditions, the system would obviously have to be recalibrated or redesigned to attempt to improve NOx control. If the engine is operating at a higher load factor, its EGR tolerance could be actually improved, and the EGR calibration could be retailored to account for the higher load condition. Alternatively, other design approaches could be used to control NOx by increasing EGR tolerance of the basic engine, as has been demonstrated by Nissan. (The Nissan 2 spark plug car with oxidation catalyst).

An additional consideration that works in favor of a lighter-weight vehicle is the fact that they produce less exhaust volume during the test, so mass emission (proportional to exhaust volume times concentration) can be less at a given exhaust concentration. For vehicles that "work harder" during the cycle, catalyst light-off characteristics may also be improved, thus leading to lower HC and CO emissions.

(c) Diesel Vehicle Emissions

It has been argued by industry that Diesel powered vehicles will not be able to meet a NOx standard of 1.0 gpm. These arguments must be considered in light of the weight of vehicles being discussed and the control technology (e.g., EGR) being used. The lightest-weight Diesel-powered automobiles would likely be able to meet a 1.0 gpm NOx emission standard without the use of Exhaust Gas Recirculation (EGR). Volkswagen (VW), results show that current Diesels of this type are about 0.34 HC, 1.0 CO, 0.96 NOx (average of 4K and 50K cert results - VW durability car). A modified VW "fuel economy" version of the above vehicle tested at EPA had 0.78 HC, 1.0 CO, 0.80 NOx (including DF) with fuel economy of 50 MPG city and 65 MPG highway.

Heavier Diesel-powered vehicles may require EGR. A GM 4500 IW vehicle being certified for 1978 (average of 5 to 30 K durability results) was 0.93 HC, 1.8 CO, 1.35 NOx without EGR. The NOx and the HC were above the 1.0 and 0.41 levels. EGR for Diesels has been indicated as one part of an emission control system to get to low NOx (below 1.0 NOx) levels (SAE 760211, SAE 770430), and the above-mentioned technical papers predict that control to below 1.0 NOx is possible (SAE 770430 predicts NOx control below 0.4 NOx). Chrysler Corp. has also indicated that some Diesel concepts have potential for NOx levels below 1.0 NOx.

When NOx is controlled to low levels with EGR, particulate emissions and HC and CO tend to increase. Fuel economy is affected only slightly, if at all, by some calibrations and control technique that yield low NOx emissions.

Preliminary evidence indicates that some diesel EGR systems may plug with extended use. This problem is considered to be solvable given sufficient lead time. Since HC and CO emissions (especially HC emissions) can tend to be degraded with the use of EGR, more work will be needed to provide acceptable performance at low HC, CO, and NOx levels. Combustion chamber and injection system design are two areas in which work is expected to be done. Technological improvements in these two areas are likely, with HC improvements possible.

The particulate emissions from Diesels are also of concern to EPA because of the potential significant contribution to air quality control regions particulate problems. EPA is studying the total mass and other aspects of Diesel particulate, but as yet no firm guidelines on allowable Diesel particulate emissions have been set. Control of Diesel particulates if needed, is expected to be a formidable technical task.

VIII. Economic Impacts of Standards

New car sales are projected to rise to approximately 12.3 million cars per year by 1985. This increase in sales will also substantially increase the size of the labor force employed directly in automobile manufacturing and original equipment parts supply industries.

Although changes in the sales volume of new cars is determined primarily by the overall health of the economy, 1/ changes in the sticker prices of new cars will also have a quantifiable, if considerably less significant, impact on new car sales. The 1985 sales and employment impacts related to two alternative sets of emissions standards are shown in the table below.

TABLE 18

	1985 Emissions Standards	
	.41/3.4/1.0	.41/9.0/1.0
New Car Sales (000)	-73	-50
Auto Manufacturer and OEM Jobs (000)	-15	-10

This estimate does not take into account the partially offsetting increases in employment in (1) the service and replacement parts industries that would occur as a result of owners driving their older cars longer and (2) the emissions control equipment industry. The data indicate that standards of .41/9.0/1.0 will reduce "potential" sales in 1985 by about 50,000 cars (four-tenths of one percent of total sales) resulting in reductions in the "potential" labor force 2/ of approximately 10,000 jobs. Moving to a standard of .41/3.4/1.0 would reduce potential sales by another 23,000 cars (total reductions of six-tenth of one percent) with potential employment dropping another 5,000 jobs. 3/4/

1/ The econometric model used in this projection shows a decrease in new car sales of .5 million cars from 1984 to 1985 because of changes in basic economic conditions.

2/ Actual employment will still increase substantially over today's levels.

3/ These additional sales and labor force reduction estimates for 1985 would be 56,000 to 82,000 cars and 12,000 to 17,000 jobs respectively if the .4 NOx standard is ultimately adopted.

4/ The employment and sales impacts are based on long-term elasticities. The first year impact will be greater.

Changes in the Consumer Index Impact (CPI)

The Report by the Federal Task Force on Motor Vehicle Goals Beyond 1980 considered the CPI changes of emissions control, safety and fuel economy programs using standards for HC/CO/NOx of .41/3.4/2.0. That study concluded that these aggregate costs have an "insignificant" impact on the CPI. Based on the incremental sticker price increases for 1985 cited in Table 15 above, the approximated average annual price effects of alternative emissions standards alone are shown in Table 19 below.

TABLE 19
Change in Consumer Price
Index (CPI) 1/ 2/

STANDARDS ALTERNATIVES	A	B	C	D	E
	.035	.026	.012	.019	.026

1/ Using the highest sticker price (Optional Fuel Economy technology).

2/ These estimates overstate the CPI impact of emissions controls because emissions control costs are considered quality adjustments and therefore do not directly affect the CPI.

Here again the impact of the emissions standards alone on the CPI must be viewed as insigificant with no set of standards changing the CPI by more than four one-hundreths of one percentage point.

APPENDIX A

Fuel Economy/Cost/System Design Relationship

A vehicle can be designed with emission control technology that will have poor fuel economy at a given emission standard if the control technology relies on non-optimal engine calibrations or is short of emission control capability. To compensate for the shortcoming in emission control capability, engine calibrations may have to be set so as to reduce emissions in a manner that compromises fuel economy, and fuel economy penalties can result.

However, if the emission control system has excess capability to control emissions, the use of engine calibrations that provide good fuel economy performance is feasible and emission standards can be met with no fuel economy penalty. In model year 1975, for example, the use of new emission control technology (i.e. catalysts) allowed better fuel economy calibrations to be used on the engine. This permitted fuel economy gains over model year 1974, even though the emission standards for model 1975 were substantially more stringent than those for model year 1974.

However, the use of even the best emission control technology does not guarantee good fuel economy, since fuel economy is determined principally by certain basic engine calibrations. If these basic engine calibrations deviate from the good fuel economy calibrations, fuel economy losses can result, regardless of the emission control technology used. The calibrations that result in good fuel economy for a given engine are a complicated combination of, for example, spark timing, air-fuel ratio, and EGR rate as a function of engine speed and load. Much experimental work is now underway to determine these calibrations for the engines planned for use in future model years. Considering the three calibration variables of spark timing, air-fuel ratio, and EGR rate, it appears that a good fuel economy calibration can be obtained over a range of air-fuel ratios. However, if EGR is not used, the air-fuel ratio calibration for good fuel economy is known to be slightly lean of stoichiometry.

This means that if an engine is operated at the stoichiometric air-fuel ratio, without EGR, as could be the case for a 3-way catalyst emission control system, a fuel economy loss would result when compared to slightly lean operation without EGR. Even though the emission control might be satisfactory without EGR, the desire to obtain good fuel economy calibrations might require the use of EGR and concomitant spark timing recalibration. This could tend to improve the NOx control while making HC control more difficult.

This sensitivity of fuel economy to engine calibrations and the still-evolving understanding of the interrelationships among the calibration variables often lead to a wide divergence of technical opinion about the fuel economy potential of a new emission control technology. This is particularly true during the early stages of development when emphasis is placed on determining the emission performance.

Historically, new emission control systems have improved in fuel economy over the years as more experience has been gained in system optimization. The improvement in fuel economy of the 1976 models over the 1975 models was to some degree due to the continued optimization of engine calibrations. Further, the fuel economy penalties apparent at the more stringent California emission standards is an illustration of compromises in engine calibration when an emission control system (e.g. the oxidation catalyst) approaches its limit of control capability.

In order to meet future, more stringent emission standards while retaining good fuel economy calibrations, emission control systems will have to be used that have improved emission control capability over systems currently in production. These improved systems will need emission control capability beyond that just required to meet the emission standards. Such improved systems are now being developed by the automobile industry.

The development of technology to control emissions and permit good fuel economy calibrations to be maintained is expected to take longer than just the development of technology solely for the purpose of controlling emissions. For example, the use of electronic controls which have the potential to be an important part of future low emission, fuel efficient systems will require the generation and analysis of significant quantities of new engine data in order to determine more optimal calibrations.

Certain automobile manufacturers have indicated that, given time, future emission standards as stringent as 0.41 HC, 3.4 CO, 1.0 NOx can be met with little or no loss in fuel economy. Other manufacturers, however, maintain that fuel economy penalties will exist at these emission levels. Although the capability to meet the statutory emission standards (0.41 HC, 3.4 CO, 0.4 NOx) while retaining good fuel economy calibrations is also possible, little data have been reported by the automobile manufacturers on complete, improved emission control systems targeted toward these standards. The reason for this lack of data may be that the automobile industry has not considered 0.4 NOx to be a real target. This lack of data will probably continue to exist until 0.4 NOx is made a firm standard.

The impact of future emission standards on fuel economy should also be considered in relationship to other technological approaches for improving fuel economy. Taken in combination, reduced vehicle weight, improved rolling resistance, lower friction, drivetrain improvements, improved accessory drives, improved aerodynamics, and vehicle power-to-weight ration changes can have a much larger impact on fuel economy than the fuel economy penalties reported by some as being due to emission control.

Revised 4/13/77

Table A-1

Impacts of Various Standards Levels on Automotive Technology, Costs, and Fuel Economy
(1977 $)

HC/CO/NOx Emission Standards (g/mi)	Optimal Cost Assumptions: Control Technologies Used	Sticker Price Increase 1/	Maintenance Cost Increase 2/	Fuel Economy 3/ Penalty	Optimal Fuel Economy Assumptions: Control Technologies Used	Sticker Price Increase 1/	Maintenance Cost Increase 2/	Fuel Economy 3/ Penalty
0.41/9.0/2.0	Lighter Weight Cars Use:				Lighter Weight Cars Use:			
	High Energy Ignition (HEI)	(Base)	(Base)		High Energy Ignition (HEI)	(Base)	(Base)	
	Proportional EGR (PEGR)	(Base)	(Base)		Electronic Spark Control (ESC)	($ 7)	($ 0)	
	Air Injection (AIR)	($35)	($ 0)		Electronic EGR Control (EEGR)	($13)	($17)	
	Oxidation Catalyst (OC)	(Base)	(Base)		Air Injection (AIR)	($35)	($ 0)	
					Oxidation Catalyst (OC)	(Base)	(Base)	+2%
		$ 35	$ 0	-2%	Simple Elec. Control Unit (SECU)	($35)	($ 0)	
						$ 90	$ 17	
	Heavier Weight Cars Use:				Heavier Weight Cars Use:			
	High Energy Ignition (HEI)	(Base)	(Base)		High Energy Ignition (HEI)	(Base)	(Base)	
	Proportional EGR (PEGR)	(Base)	(Base)		Electronic Spark Control (ESC)	($ 7)	($ 0)	
	Air Injection (AIR)	($35)	($ 0)		Electronic EGR Control (EEGR)	($13)	($17)	
	Cold Spark Retard	($ 0)	($ 0)		Air Injection (AIR)	($35)	($ 0)	
	Oxidation Catalyst (OC)	(Base)	(Base)		Start Catalyst (SC)	($35)	($ 0)	
					Oxidation Catalyst (OC)	(Base)	(Base)	+2%
		$ 35	$ 0	-4%	Simple Elec. Control Unit (SECU)	($35)	($ 0)	
						$125	$ 17	

Table A-2

Revised 4/13/77

Impacts of Various Standards Levels on Automotive Technology, Costs, and Fuel Economy
(1977 $)

Optimal Cost Assumptions

HC/CO/NOx Emission Standards (g/mi)	Control Technologies Used	Sticker Price 1/ Increase	Maintenance Cost 2/ Increase	Fuel Economy 3/ Penalty
0.41/3.4/2.0	Lighter Weight Cars Use:			
	High Energy Ignition (HEI)	(Base)	(Base)	
	Proportional EGR (PEGR)	(Base)	(Base)	
	Air Injection (AIR)	($35)	($ 0)	
	Oxidation Catalyst (OC)	(Base)	(Base)	
		$ 35	$ 0	-2%
	Heavier Weight Cars Use:			
	High Energy Ignition (HEI)	(Base)	(Base)	
	Proportional EGR (PEGR)	(Base)	(Base)	
	Air Injection (AIR)	($35)	($ 0)	
	Cold Spark Retard	($ 0)	($ 0)	
	Oxidation Catalyst (OC)	(Base)	(Base)	
		$ 35	$ 0	-4%

Optimal Fuel Economy Assumptions

HC/CO/NOx Emission Standards (g/mi)	Control Technologies Used	Sticker Price 1/ Increase	Maintenance Cost 2/ Increase	Fuel Economy 3/ Penalty
0.41/3.4/2.0	Lighter Weight Cars Use:			
	High Energy Ignition (HEI)	(Base)	(Base)	
	Electronic Spark Control (ESC)	($ 7)	($ 0)	
	Electronic EGR Control (EEGR)	($13)	($17)	
	Air Injection (AIR)	($35)	($ 0)	
	Oxidation Catalyst (OC)	(Base)	(Base)	
	Simple Elec. Control Unit (SECU)	($35)	($ 0)	+2%
		$ 90	$ 17	
	Heavier Weight Cars Use:			
	High Energy Ignition (HEI)	(Base)	(Base)	
	Electronic Spark Control (ESC)	($ 7)	($ 0)	
	Electronic EGR Control (EEGR)	($13)	($17)	
	Improved Fuel Metering (IFM)	($17)	($ 0)	
	Air Injection (AIR)	($35)	($ 0)	
	Start Catalyst, Unswitched (SC)	($35)	($ 0)	
	Oxidation Catalyst (OC)	(Base)	(Base)	
	Simple Elec. Control Unit (SECU)	($35)	($ 0)	
		$142	$ 17	+2%

Table A-3

Impacts of Various Standards Levels on Automotive Technology, Costs, and Fuel Economy

(1977 $)

HC/CO/NOx Emission Standards (g/mi)	Optimal Cost Assumptions: Control Technologies Used	Sticker Price Increase 1/	Maintenance Cost Increase 2/	Fuel Economy Penalty 3/
0.41/9.0/1.5	Lighter Weight Cars Use:			
	High Energy Ignition (HEI)	(Base)	(Base)	
	Electronic EGR Control (EEGR)	($ 13)	($ 17)	
	Air Injection (AIR)	($ 35)	($ 0)	
	Oxidation Catalyst (OC)	(Base)	(Base)	
	Simple Elec. Control Unit (SECU)	($ 35)	($ 0)	
		$ 83	$ 17	-3%
	Heavier Weight Cars Use:			
	High Energy Ignition (HEI)	(Base)	(Base)	
	Proportional EGR (PEGR)	(Base)	(Base)	
	Improved Fuel Metering (IFM)	($ 20)	($ 0)	
	Oxygen Sensor (OS)	($ 10)	($ 30)4/	
	Electronic A/F Ratio Control (EA/F)	($ 13)	($ 23)	
	Three-Way Catalyst (TWC)	($115)	($ 0)	
	Oxidation Catalyst Removed	-($100)	-($ 0)	
	Simple Elec. Control Unit (SECU)	($ 35)	($ 0)	
		$ 93	$ 53	-2%

HC/CO/NOx Emission Standards (g/mi)	Optimal Fuel Economy Assumptions: Control Technologies Used	Sticker Price Increase 1/	Maintenance Cost Increase 2/	Fuel Economy Penalty 3/
0.41/9.0/1.5	Lighter Weight Cars Use:			
	High Energy Ignition (HEI)	(Base)	(Base)	
	Electronic Spark Control (ESC)	($ 7)	($ 0)	
	Electronic EGR Control (EEGR)	($ 13	($ 17)	
	Improved Fuel Metering (IFM)	($ 20)	($ 0)	
	Air Injection (Air)	($ 35)	($ 0)	
	Oxidation Catalyst (OC)	(Base)	(Base)	
	Simple Elec. Control Unit (SECU)	($ 35)	($ 0)	
		$110	$ 17	+2%
	Heavier Weight Cars Use:			
	High Energy Ignition (HEI)	(Base)	(Base)	
	Electronic Spark Control (ESC)	($ 7)	($ 0)	
	Electronic EGR Control (EEGR)	($ 13)	($ 17)	
	Improved Fuel Metering (IFM)	($ 20)	($ 0)	
	Oxygen Sensor (OS)	($ 10)	($ 30) 4/	
	Electronic A/F Ratio Control (EA/F)	($ 13)	($ 23)	
	Three-Way Catalyst (TWC)	($115)	($ 0)	
	Oxidation Catalyst Removed	-($100)	-($ 0)	
	Complex Elec. Control Unit (CECU)	($ 65)	($ 0)	
		$143	$ 70	+2%

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Table A-4

Impacts of Various Standards Levels on Automotive Technology, Costs, and Fuel Economy

(1977 $)

Optimal Cost Assumptions

HC/CO/NOx Emission Standards (g/mi)	Control Technologies Used	Sticker Price Increase 1/	Maintenance Cost Increase 2/	Fuel Economy Penalty 3/
0.41/3.4/1.5	Lighter Weight Cars Use:			
	High Energy Ignition (HEI)	(Base)	(Base)	
	Electronic EGR Control (EEGR)	($ 13)	($ 17)	
	Improved Fuel Metering (IFM)	($ 20)	($ 0)	
	Air Injection (AIR)	($ 35)	($ 0)	
	Oxidation Catalyst (OC)	(Base)	(Base)	
	Simple Elec. Control Unit (SECU)	($ 35)	($ 0)	
		$103	$ 17	-3%
	Heavier Weight Cars Use:			
	High Energy Ignition (HEI)	(Base)	(Base)	
	Proportional EGR (PEGR)	(Base)	(Base)	
	Improved Fuel Metering (IFM)	($ 17)	($ 0)	
	Switched Air Aspirator (SAA)	($ 7)	($ 0)	
	Oxygen Sensor (OS)	($ 10)	($ 30) 4/	
	Electronic A/F Ratio Control (EA/F)	($ 13)	($ 23)	
	Three-Way Catalyst (TWC)	($115)	($ 0)	
	Oxidation Catalyst Removed	-($100)	-($ 0)	
	Simple Elec. Control Unit (SECU)	($ 35)	($ 0)	
		$ 97	$ 53	-2%

Optimal Fuel Economy Assumptions

HC/CO/NOx Emission Standards (g/mi)	Control Technologies Used	Sticker Price Increase 1/	Maintenance Cost Increase 2/	Fuel Economy Penalty 3/
0.41/3.4/1.5	Lighter Weight Cars Use:			
	High Energy Ignition (HEI)	(Base)	(Base)	
	Electronic Spark Control (ESC)	($ 7)	($ 0)	
	Electronic EGR Control (EEGR)	($ 13)	($ 17)	
	Improved Fuel Metering (IFM)	($ 20)	($ 0)	
	Air Injection (AIR)	($ 35)	($ 0)	
	Electronic AIR Control (EAIR)	($ 7)	($ 0)	
	Oxidation Catalyst (OC)	(Base)	(Base)	
	Complex Elec. Control Unit (CECU)	($ 65)	($ 0)	
		$148	$ 17	+2%
	Heavier Weight Cars Use:			
	High Energy Ignition (HEI)	(Base)	(Base)	
	Electronic Spark Control (ESC)	($ 7)	($ 0)	
	Electronic EGR Control (EEGR)	($ 13)	($ 17)	
	Improved Fuel Metering (IFM)	($ 20)	($ 0)	
	Electronic Air Aspirator (EAA)	($ 7)	($ 0)	
	Oxygen Sensor (OS)	($ 10)	($ 30) 4/	
	Electronic A/F Ratio Control (EA/F)	($ 13)	($ 23)	
	Start Catalyst, Switched (SC)	($ 70)	($ 0)	
	Three-Way Catalyst (TWC)	($115)	($ 0)	
	Oxidation Catalyst Removed	-($100)	-($ 0)	
	Complex Elec. Control Unit (CECU)	($ 65)	($ 0)	
		$220	$ 70	+2%

Impacts of Various Standards Levels on Automotive Technology, Costs, and Fuel Economy

Optimal Cost Assumptions (1977 $)

HC/CO/NOx Emission Standards (g/mi)	Control Technologies Used	Sticker Price Increase 1/	Maintenance Cost Increase 2/	Fuel Economy Penalty 3/
0.41/9.0/1.0	*Lighter Weight Cars Use:*			
	High Energy Ignition (HEI)	(Base)	(Base)	
	Electronic EGR Control (EEGR)	($ 13)	($ 17)	
	Improved Fuel Metering (IFM)	($ 20)	($ 0)	
	Air Injection (AIR)	($ 35)	($ 0)	
	Oxidation Catalyst (OC)	(Base)	(Base)	
	Simple Elec. Control Unit (SECU)	($ 35)	($ 0)	
		$103	$17	- 4%
	Heavier Weight Cars Use:			
	High Energy Ignition (HEI)	(Base)	(Base)	
	Proportional EGR (PEGR)	(Base)	(Base)	
	Improved Fuel Metering (IFM)	($ 20)	($ 0)	
	Electronic Air Aspirator (EAA)	($ 7)	($ 0)	
	Oxygen Sensor (OS)	($ 10)	($ 30) 4/	
	Electronic A/F Ratio Control (EA/F)	$ 13)	($ 23)	
	Start Catalyst, Switched (SC)	($ 70)	($ 0)	
	Three-Way Catalyst (TWC)	($115)	($ 0)	
	Oxidation Catalyst Removed	-($100)	-($ 0)	
	Simple Elec. Control Unit (SECU)	$ 35)	($ 0)	
		$170	$ 53	-3%

Optimal Fuel Assumptions

HC/CO/NOx Emission Standards (g/mi)	Control Technologies Used	Sticker Price Increase 1/	Maintenance Cost Increase 2/	Fuel Economy Penalty 3/
0.41/9.0/1.0	*Lighter Weight Cars Use:*			
	High Energy Ignition (HEI)	(Base)	(Base)	
	Electronic Spark Control (ESC)	($ 7)	($ 0)	
	Electronic EGR Control (EEGR)	($ 13)	($ 17)	
	Improved Fuel Metering (IFM)	($ 20)	($ 0)	
	Oxygen Sensor (OS)	($ 10)	($ 30) 4/	
	Electronic A/F Ratio Control (EA/F)	$ 13)	($ 23)	
	Three-Way Catalyst (TWC)	($115)	($ 0)	
	Oxidation Catalyst Removed	-($100)	-($ 0)	
	Complex Elec. Control Unit (CECU)	$ 65	($ 0)	
		$143	$ 70	+2%
	Heavier Weight Cars Use:			
	High Energy Ignition (HEI)	(Base)	(Base)	
	Electronic Spark Control (ESC)	($ 7)	($ 0)	
	Electronic EGR Control (EEGR)	($ 13)	($ 17)	
	Improved Fuel Metering (IFM)	($ 20)	($ 0)	
	Electronic Air Aspirator (EAA)	($ 7)	($ 0)	
	Start Catalyst, Switched (SC)	($ 70)	($ 0)	
	Three-Way Catalyst (TWC)	($115)	($ 0)	
	Oxidation Catalyst Removed	-($100)	-($ 0)	
	Complex Elec. Control Unit (CECU)	($ 65)	($ 0)	
	Oxygen Sensor (OS)	($ 10)	($ 30) 4/	
	Electronic A/F Ratio Control (EA/F)	($ 10)	($ 23)	
		$217	$ 70	+2%

Impacts of Various Standards Levels on Automotive Technology, Costs, and Fuel Economy
(1977 $)

Optimal Cost Assumptions

HC/CO/NOx Emission Standards (g/mi)	Control Technologies Used	Sticker Price Increase[1]	Maintenance Cost Increase[2]	Fuel Economy Penalty[3]
0.41/3.4/1.0	Lighter Weight Cars Use:			
	High Energy Ignition (HEI)	(Base)	(Base)	
	Electronic EGR Control (EEGR)	($ 13)	($ 17)	
	Improved Fuel Metering (IFM)	($ 20)	($ 0)	
	Air Injection (AIR)	($ 35)	($ 0)	
	Start Catalyst Switched (SC)	($ 70)	($ 0)	
	Oxidation Catalyst (OC)	(Base)	(Base)	
	Simple Elec. Control Unit (SECU)	($ 35)	($ 0)	
		$173	$ 17	-4%
	Heavier Weight Cars Use:			
	High Energy Ignition (HEI)	(Base)	(Base)	
	Proportional EGR (PEGR)	(Base)	(Base)	
	Improved Fuel Metering (IFM)	($ 20)	($ 0)[4]	
	Oxygen Sensor (OS)	($ 10)	($ 30)	
	Electronic A/F Ratio Control (EA/F)	($ 13)	($ 23)	
	Three-way Catalyst (TWC+OC)	($205)	($ 0)	
	Air Injection (AIR)	($ 35)	($ 0)	
	Oxidation Catalyst Removed	-($100)	($ 0)	
	Simple Elec. Control Unit (SECU)	($ 35)	($ 0)	
		$218	$ 53	-3%

Optimal Fuel Economy Assumptions

Control Technologies Used	Sticker Price Increase[1]	Maintenance Cost Increase[2]	Fuel Economy Penalty[3]
Lighter Weight Cars Use:			
High Energy Ignition (HEI)	(Base)	(Base)	
Electronic Spark Control (ESC)	($ 7)	($ 0)	
Electronic EGR Control (EEGR)	($ 13)	($ 17)	
Improved Fuel Metering (IFM)	($ 20)	($ 0)	
Electronic Air Aspirator (EAA)	($ 7)	($ 0)[4]	
Oxygen Sensor (OS)	($ 10)	($ 30)	
Electronic A/F Ratio Control (EA/F)	($ 13)	($ 23)	
Start Catalyst, Stitched (SC)	($ 70)	($ 0)	
Three-way Catalyst (TWC)	($115)	($ 0)	
Oxidation Catalyst Removed	-($100)	($ 0)	
Complex Elec. Contorl Unit (CECU)	($ 65)	($ 0)	
	$220	$ 70	+2%
Heavier Weight Vehicles Use:			
High Energy Ignition (HEI)	(Base)	(Base)	
Electronic Spark Control (ESC)	($ 7)	($ 0)	
Electronic EGR Control (EEGR)	($ 13)	($ 17)	
Improved Fuel Metering (IFM)	($ 20)	($ 0)[4]	
Oxygen Sensor (OS)	($ 10)	($ 30)	
Electronic A/F Ratio Control (EA/F)	($ 13)	($ 23)	
Three-way Catalyst (TWC)	($115)	($ 0)	
Air Injection (AIR)	($ 35)	($ 0)	
Electronic Air Control (EAIR)	($ 7)	($ 0)	
Oxidation Catalyst (OC)	(Base)	(Base)	
Complex Elec. Control Unit (CECU)	($ 65)	($ 0)	
	$285	$ 70	+2%

Table A-7

Impacts of Various Standards Levels on Automotive Technology, Costs, and Fuel Economy

(1977 $)

Optimal Cost Assumptions

HC/CO/NOx Emission Standards (g/mi)	Control Technologies Used	Sticker Price Increase[1]	Maintenance Cost Increase[2]	Fuel Economy Penalty[3]
0.41/9.0/0.4	Lighter Weight Cars Use:			
	High Energy Ignition (HEI)	(Base)	(Base)	
	Electronic EGR Control (EEGR)	($ 13)	($ 17)	
	Improved Fuel Metering (IFM)	($ 20)	($ 0)	
	Switched Air Aspirator (SAA)	($ 7)	($ 0)	
	Oxygen Sensor (OS)	($ 10)	($ 30)[4]	
	Electronic A/F Ratio Control (EA/F)	($ 13)	($ 23)	
	Start Catalyst, Switched (SC)	($ 70)	($ 0)[6]	
	Three-Way Catalyst (TWC)	($115)	($ 0)	
	Oxidation Catalyst Removed	-($100)	-($ 0)	
	Simple Elec. Control Unit (SECU)	($ 35)	($ 0)	
		$183	$ 70	0% to -8%
	Heavier Weight Cars Use:			
	High Energy Ignition (HEI)	(Base)	(Base)	
	Electronic Spark Control (ESC)	($ 7)	($ 0)	
	Electronic EGR Control (EEGR)	($ 13)	($ 17)	
	Mechanical Fuel Injection (MFI)	($100)	($ 45)	
	Oxygen Sensor (OS)	($ 10)	($ 30)[4]	
	Three-Way Catalyst (TWC)	($115)	($ 0)	
	Oxidation Catalyst Removed	-($100)	-($ 0)	
	Complex Elec. Control Unit (CECU)	($ 65)	($ 0)	
		$210	$ 92	0% to -8%

Optimal Fuel Economy Assumptions

HC/CO/NOx Emission Standards (g/mi)	Control Technologies Used	Sticker Price Increase[1]	Maintenance Cost Increase[2]	Fuel Economy Penalty[3]
0.41/9.0/0.4	Lighter Weight Cars Use:			
	High Energy Ignition (HEI)	(Base)	(Base)	
	Electronic Spark Control (ESC)	($ 7)	($ 0)	
	Electronic EGR Control (EEGR)	($ 13)	($ 17)	
	Improved Fuel Metering (IFM)	($ 20)	($ 0)	
	Electronic Air Aspirator (EAA)	($ 7)	($ 0)	
	Oxygen Sensor (OS)	($ 10)	($ 30)[4]	
	Electronic A/F Ratio Control (EA/F)	($ 13)	($ 23)	
	Start Catalyst, Switched (SC)	($ 70)	($ 0)	
	Three-Way Catalyst (TWC)	($115)	($ 0)	
	Oxidation Catalyst Removed	- ($100)	-($ 0)	
	Complex Control Unit (CECU)	($ 65)	($ 0)	
		$220	$ 70	0% to +2%
	Heavier Weight Cars Use:			
	High Energy Ignition (HEI)	(Base)	(Base)	
	Electronic Spark Control (ESC)	($ 7)	($ 0)	
	Electronic EGR Control (EEGR)	($ 13)	($ 17)	
	Electronic Fuel Injection (EFI)	($140)	($ 45)	
	Electronic Air Aspirator (EAA)	($ 7)	($ 0)	
	Oxygen Sensor (OS)	($ 10)	($ 30)[4]	
	Start Catalyst, Switched (SC)	($ 70)	($ 0)	
	Three-way Catalyst (TWC)	($115)	($ 0)	
	Oxidation Catalyst Removed	-($100)	-($ 0)	
	(Complex Elec. Control Unit (CECU)	($ 65)	($ 0)	
		$327	$ 92	0% to +2%

Table A-8

Impacts of Various Standards Levels on Automotive Technology, Costs, and Fuel Economy

(1977 $)

HC/CO/NOx Emission Standards (g/mi)	Optimal Cost Assumptions: Control Technologies Used	Sticker Price Increase 1/	Maintenance Cost Increase 2/	Fuel Economy Penalty 3/	Optimal Fuel Economy Assumptions: Control Technologies Used	Sticker Price Increase 1/	Maintenance Cost Increase 2/	Fuel Economy Penalty 3/
0.41/3.4/0.4	Lighter Weight Cars Use:				Lighter Weight Cars Use:			
	High Energy Ignition (HEI)	(Base)	(Base)		High Energy Ignition (HEI)	(Base)	(Base)	
	Electronic EGR Control (EEGR)	($ 13)	($ 17)		Electronic Spark Control (ESC)	($ 7)	($ 0)	
	Mechanical Fuel Injection (MFI)	($ 90)	($ 45)		Electronic EGR Control (EEGR)	($ 13)	($ 17)	
	Oxygen Sensor (OS)	($ 10)	($ 30) 4/		Electronic Fuel Injection (EFI)	($110)	($ 45)	
	Three-Way Catalyst (TWC)	($115)	($ 0)		Electronic Air Aspirator (EAA)	($ 7)	($ 0)	
	Oxidation Catalyst Removed	-($100)	-($ 0)		Oxygen Sensor (OS)	($ 10)	($ 30) 4/	
	Complex Elec. Control Unit (CECU)	($ 65)	($ 0)		Start Catalyst Switched (SC)	($ 70)	($ 0)	
		$193	$ 92	0 to -8%	Three-Way Catalyst (TWC)	($115)	($ 0)	
					Oxidation Catalyst Removed	-($100)	-($ 0)	
					Complex Elec. Control Unit (CECU)	($ 65)	($ 0)	
						$297	$ 92	0 to +2%
	Heavier Weight Cars Use:				Heavier Weight Cars Use:			
	High Energy Ignition (HEI)	(Base)	(Base)		High Energy Ignition (HEI)	(Base)	(Base)	
	Electronic Spark Control (ESC)	($ 7)	($ 0)		Electronic Spark Control (ESC)	($ 7)	($ 0)	
	Electronic EGR Control (EEGR)	($ 13)	($ 17)		Electronic EGR Control (EEGR)	($ 13)	($ 17)	
	Mechanical Fuel Injection (MFI)	($100)	($ 45)		Electronic Fuel Injection (EFI)	($140)	($ 45)	
	Switched Air Aspirator (SAA)	($ 7)	($ 0)		Advanced Oxygen Sensor (AOS)	($ 13)	($ 45) 4/	
	Oxygen Sensor (OS)	($ 10)	($ 30) 4/		Three-Way Catalyst (TWC)	($110)	($ 0)	
	Start Catalyst, Switched (SC)	($ 70)	($ 0)		Air Injection (AIR)	($ 35)	($ 0)	
	Three-Way Catalyst (TWC)	($115)	($ 0)		Electronic AIR Control (EAIR)	($ 7)	($ 0)	
	Oxidation Catalyst Removed	-($100)	-($ 0)		Small Oxidation Catalyst (SOC)	($ 70)	($ 0)	
	Complex Elec. Control Unit (CECU)	($ 65)	($ 0)		Oxidation Catalyst Removed	-($100)	-($ 0)	
		$287	$ 92	0 to -8%	Complex Elec. Control Unit (CECU)	($ 65)	($ 0)	
						$360	$107	0 to +2%

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Impacts of Various Standards Levels on Automotive Technology, Costs, and Fuel Economy

NOTES:

1/ Equivalent sticker price and maintenance cost increases are in 1977 dollars and are relative to the Optimal Cost Assumptions for the 1.5/15/2.0 levels.

2/ Maintenance cost increased are for a 100,000 mile vehicle lifetime, are expressed in undiscounted 1975 dollars, and are relative to the Optimal Cost Assumptions for the 1.5/15/2.0 levels. Maintenance Cost are assumed to be those that would occur without Inspection/Maintenance programs in place.

3/ Fuel economy penalty is average estimated for near-term implementation of standards (1979 to 1983 period) and is relative to the Optimal Cost Assumptions for the 1.5/15/2.0 levels. Negative numbers are penalties, positive numbers are gains.

4/ Oxygen sensor replacement interval of 30,000 miles (three changes over 100,000 miles) assumed.

Key to Control Technology Acronyms

AIR Air injection system including air pump, check valve, and manifold for injection of air at exhaust ports. For start catalysts and other systems where switching of air injection location is required after warm up extra components would be included to accomplish this function.

AOS Advanced oxygen sensor. Exhaust oxygen sensor capable of providing an analog signal proportional to the actual excess oxygen concentration.

CECU Complex electronic control unit. Digital electronic control unit capable of handling control of three or four engine parameters. Includes basic engine condition sensors. Sensors and actuators for specific control functions are separately itemized.

EAA Electronically-controlled air aspirator. Reed valve type air induction system for providing extra air to start catalyst during warm up. Includes catalyst temperature sensor (if any) and actuator for control by central electronic control unit.

EAIR Electronically-controlled air injection. Valve and actuator for proportional control of air injection rate by electonic control unit.

EA/F Electronic control of air/fuel ratio. Position sensor and actuator for modulation of carburetor air/fuel ratio by central electronic control unit.

EEGR Electronically-controlled exhaust gas recirculation. Position sensor and actuator for modulation of egr valve postion by central electonic control unit.

EFI Electronic fuel injection. Electronically-controlled fuel injection system including electronic control unit and basic engine condition sensors. Replaces functions of CECU and EA/F.

ESC Electronic spark timing control. Firing circuits for control of ignition timing by central electronic control unit.

HEI High energy ignition. Ignition system capable of providing high energy discharge to spark plugs to minimize misfire.

IFM Improved fuel metering. Improved carburetor capable of more precise control of air/fuel ratio during transient driving conditions.

IOC Improved oxidation catalyst. Higher efficiency (75% HC conversion efficiency over FTP at 50,000 miles vs. 70% efficiency assumed for standard oxidation catalyst) oxidation catalyst assumed in "High Range" system of 3 Agency Study at 0.41/3.4/1.5 levels.

Table 3 (Continued)

Key to Control Technology Acronyms

MFI	Mechanical fuel injection. Mechanically (pressure) modulated fuel injection system. Assumed to include electronic signal processing and actuator to permit feedback control of air/fuel ratio from an exhaust oxygen sensor, but not to have the full electronic monitoring and control capabilities of a central electronic control unit.
OC	Oxidation catalyst.
OS	Oxygen sensor. Exhaust oxygen sensor used in three-way catalyst system to provide step function (rich or lean) indication of exhaust condition to fuel metering control system (EA/F, EFI, or MFI).
PEGR	Proportional exhaust gas recirculation. Exhaust gas recirculation system which provided for mechanical modulation of EGR flow rate based on intake manifold vacuum or other engine condition signal.
PL	Port liners. Insulation of exhaust ports on cylinder head to conserve exhaust heat for purposes of greater thermal oxidation of HC and CO in exhaust manifold and quicker warm up of catalysts (especially start catalyst) and oxygen sensor.
SAA	Switched air aspirator. Mechanically or electrically (solenoid) operated reed valve type air induction system for providing extra air to start catalyst during warm up.
SECU	Simple electronic control unit. Digital electronic control unit capable of handling control of one or two engine parameters. Includes basic engine condition sensors. Sensors and actuators for specific control functions are separately itemized.
SC	Start catalyst. Small oxidation catalyst located close to exhaust manifold where it will come quickly to operating temperature after engine starting, so as to provide catalytic control of high start up HC and CO emissions before main oxidation catalyst reaches operating temperature. As used in 3 Agency and 5 Agency studies, start catalyst is assumed to include any air aspirator needed to provide extra air during warm up (engine is running rich because of choke) and any switching mechanism to remove start catalyst from exhaust gas flow path after warm up so as to conserve catalyst efficiency.

Table 3 (Continued)

Key to Control Technology Acronyms

SOC Small oxidation catalyst. A smaller volume oxidation catalyst included in the EPA Study Optimal Fuel Economy system for heavier cars at the 0.41/3.4/0.4 levels. This catalyst, together with AIR and EAIR would be used downstream of the three-way catalyst to provide additional HC and CO control under certain driving conditions.

SSC Switched start catalyst. Start catalyst (see SC) provided with a means for diverting the exhaust flow around the start catalyst after main catalyst reaches operating temperature.

TWC Three-way catalyst. Catalyst formulated to provide efficient simultaneous control of HC, CO, and NO_x when operated at a stoichiometric air/fuel ratio. In the 3 Agency and 5 Agency studies the acronym TWC is used for a complete three-way catalyst system, including the oxygen sensor (OS), electronic air/fuel ratio control (EA/F) and electronic control unit (SECU).

TWC/OC Combined three-way and oxidation catalyst unit with provisions for air injection between separate catalyst elements.

USC Unswitched start catalyst. Start catalyst (see SC) which remains in the exhaust flow stream at all times. Less expensive than switched start catalyst, but has lower high mileage efficiency because of additional catalyst deterioration caused by continuous contact with exhaust gases.