Regulatory Support Document

Revised Gaseous Emission Regulations for 1985 and Later Model Year Heavy-Duty Engines

July 1983

Prepared By

Office of Mobile Sources
Emission Control Technology Division

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Introduction

EPA promulgated gaseous emission regulations for 1984 and later model year heavy-duty engines (HDEs) in December 1979, and similar regulations affecting 1984 and later model year light-duty trucks (LDTs) in September 1980. Major provisions common to both actions included statutory HC and CO emission standards, revised useful-life definitions, revised durability testing and allowable maintenance certification requirements, an idle test and idle emission standard for gasoline-powered LDTs and gasoline-fueled HDEs, and implementation of a 10 percent Acceptable Quality Level for Selective Enforcement Audit (SEA) testing. The HDE rulemaking also implemented new emission test procedures and the basic SEA program for HDEs.

In the economic analysis supporting the original 1984 HDE rulemaking, EPA found that "[m]ost engine manufacturers should have little difficulty financing the required investments, barring a post-1980 recession" (emphasis added). However, a general economic downturn occurred in late 1979, and in general, 1980 was a year of record losses for the industry. The aftereffects of this recession persisted through 1981 and 1982 for most manufacturers.

In response to this economic crisis in the industry and the need for short-term cash flow improvements, the Administration undertook a number of regulatory reform initiatives. Preliminary analyses indicated that several portions of the 1984 LDT/HDE final rulemakings requiring substantial investment could be relaxed without significant losses of emission reductions and air quality improvements expected from those rules. Some of these actions were finalized in a January 1983 rulemaking. The present rulemaking finalizes revisions to the original regulations which were not addressed in the January 1983 final rulemaking.

The three chapters of this document contain several analyses in support of the rulemaking. The first, "Economic Impact," is subdivided into sections dealing with the financial ability of the manufacturers to comply with the original HDE final rules, the costs of both the original rules and the interim standards and split-class approach contained in these rules, and the savings associated with this rulemaking relative to the original rulemaking. The second, "Environmental Impact," analyzes the impact of this rulemaking on per-vehicle lifetime emissions, decreases in emission inventories and resulting air quality benefits, and lead emissions. The last chapter, "Useful Life Cost-Effectiveness and Air Quality Impacts," analyzes the emission reductions and air quality improvements attributable to full-life useful-life, and the cost-effectiveness of these environmental benefits.

CHAPTER 1

ECONOMIC IMPACT

I. Introduction

This rulemaking implements new interim HC and CO emission standards for 1985-86 heavy-duty gasoline engines (HDGEs) and longer term HC and CO standards under a "split-class" approach for 1987 and later model year HDGEs. The interim standards are established at non-catalyst levels for HDGEs. The 1987 and later split-class approach will require the statutory HC and CO standards for Classes IIB and III HDGEs (HDGEs used in vehicles under 14,000 lbs. GVW), while all other HDGEs will be required to meet the same standards as applied in the 1985-86 period. Without this action, the catalyst-forcing HC and CO statutory standards would become effective for all HDGEs beginning in 1985. This chapter will examine the costs of the interim standards and the 1987 and later split-class approach. These costs will be compared to the costs of compliance of the original 1984 heavy-duty engine (HDE) Final Rulemaking (FRM) promulgated in December 1979.

Nearly all of the compliance cost assumptions used in the December 1979 cost analysis[1] have been updated with the latest information. The hardware cost estimates used in this analysis were developed in an EPA staff paper,[2] which was distributed for public comment on March 16, 1983. The updated capital cost estimates were also presented earlier in the draft support document to the proposal of this regulation.[3] This analysis will also update capital costs from the 1979 regulatory analysis. Thus, whenever this chapter refers to the costs which would have been incurred had the original FRM been retained, it is referring to these updated costs.

All cost figures used in this analysis are expressed in 1983 dollars unless otherwise noted. Note that the original cost estimates used in the regulatory analysis were expressed in December 1979 dollars, while the draft support document and the staff paper were expressed in 1981 and 1982 dollars, respectively. For this analysis, these costs (except fuel) have been updated to 1983 dollars by using average annual inflation rates of 10.6, 13.4 and 6.5 percent for 1980, 1981 and 1982, respectively.* Fuel costs in this analysis will be based upon current 1983 prices.

Sales projections are also updated from those developed in the 1979 regulatory analysis.** Separate sales projections for Classes IIB and III vehicles and Classes IV through VIII vehicles are presented in Table 1-1 for model years 1985-89 inclusive, the first five years of this rulemaking. These updated sales are based upon total HDV sales estimates and diesel HDV sales penetration rates obtained from a compilation of manufacturers' estimates. Total HDV sales were obtained from a study performed by Data Resources, Incorporated.[6] (These latest projections are consistent with those used in the March 16, 1983 EPA staff paper.[2])

This chapter is divided into five main sections. In the first section, the financial ability of the regulated industry to comply with the original FRM requirements is examined. In the second section, the cost implications of retention of the original FRM are reviewed. In the third section, the costs of the 1985 interim standards are analyzed to identify and quantify the savings associated with that action over the costs of the original FRM. In the fourth section, the costs and savings of the split-class approach to the 1987 and later

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* The inflation rates were determined from the producer price index (PPI) for trucks. The PPI is given by the Bureau of Labor Statistics for trucks 10,000 lbs. gross vehicle weight (GVW) and under (inflation rates are 9.1, 14.0, and 5.3 percent for 1980, 1981, and 1982 dollars, respectively), and 10,001 lbs. GVW and over (inflation rates are 12.1, 12.8, and 7.6 percent for 1980, 1981, and 1982, respectively).[4] Heavy-duty trucks that weigh less than 10,000 lbs. GVW are typically Class IIB vehicles, while trucks greater than 10,000 lbs. GVW are Classes III through VIII vehicles. Recent sales data shows that there were approximately the same number of Class IIB vehicles as Classes III-VIII vehicles sold each year between 1980-82.[5] Therefore, the average fleetwide inflation rates were estimated by assuming a 50-50 split between the two groupings for the years 1980-82.

** The sales projections of heavy-duty gasoline vehicles (HDGVs) affect the determination of many costs. These costs include fixed costs allocated on a per vehicle basis, and costs affected by factors such as the learning curve and economies of scale for production of emission control hardware. Sales projections also affect the estimates for aggregate costs.

Table 1-1

Projected Sales of Heavy-Duty Gasoline Engines

	Classes IIB-III	Classes IV-VIII
1985	234,390	96,160
1986	247,296	97,888
1987	256,662	97,777
1988	266,724	97,512
1989	267,791	93,696

model year HDGE standards are presented. In the last section, the per engine and aggregate costs of both the 1985 interim standards and 1987 split-class approach are compared to those of the original FRM to determine the net impact of this entire rulemaking.

II. The Financial Ability of the Regulated Industry to Comply with the Original HDE Final Rulemaking

A. General Economic Conditions, 1979-82

At the time the 1984 heavy-duty engine (HDE) regulations were being developed (1978-79), the HDE industry was experiencing record sales (see Table 1-2). Based on that performance, it was generally believed that the industry would have little trouble underwriting the capital investments necessary for implementation of the new regulations. The bulk of this investment was expected in the 3-year period from January 1980 through December 1982. However, a sharp economic reversal took place in late 1979 and carried through 1980, 1981 and into late 1982. Worldwide recession, along with high interest rates and "sticker shock," led to greatly reduced sales for the domestic automotive industry (see Table 1-2). Total light and heavy truck sales dropped about 54 percent between 1978 and 1981. More significantly, passenger car sales fell 30-32 percent below 1978 levels in 1980-81. Although light-duty truck (LDT) sales rebounded slightly (4 percent) in 1981, three of the four heavy-duty gasoline-powered vehicle (HDGV) manufacturers (GM, Ford and Chrysler) are primarily producers of light-duty passenger vehicles (LDVs) and, therefore, the increases in LDT sales were far outweighed by the continued slump in LDV sales. As a result of the sales decline, the automotive industry as a whole lost more than $4 billion in 1980 and $1.7 billion in 1981, including some of the biggest individual losses ever recorded for U.S. corporations (see Figure 1-1).[7,8,9]

To improve their product mix, counter foreign competition, and increase fuel economy the industry also made over $20 billion in plant and equipment expenditures during 1980 and 1981, despite the large decrease in sales. The resulting negative cash flow necessitated increased long-term and short-term borrowing. The high interest rates involved further exacerbated the situation. To stimulate sales, the industry resorted to rebates and other sales incentives, which again tended to diminish profits. Faced with unsold inventories, car and truck manufacturers cut production and instituted employee layoffs. Economic concessions were also granted to the manufacturers by organized labor. These actions resulted in

Table 1-2

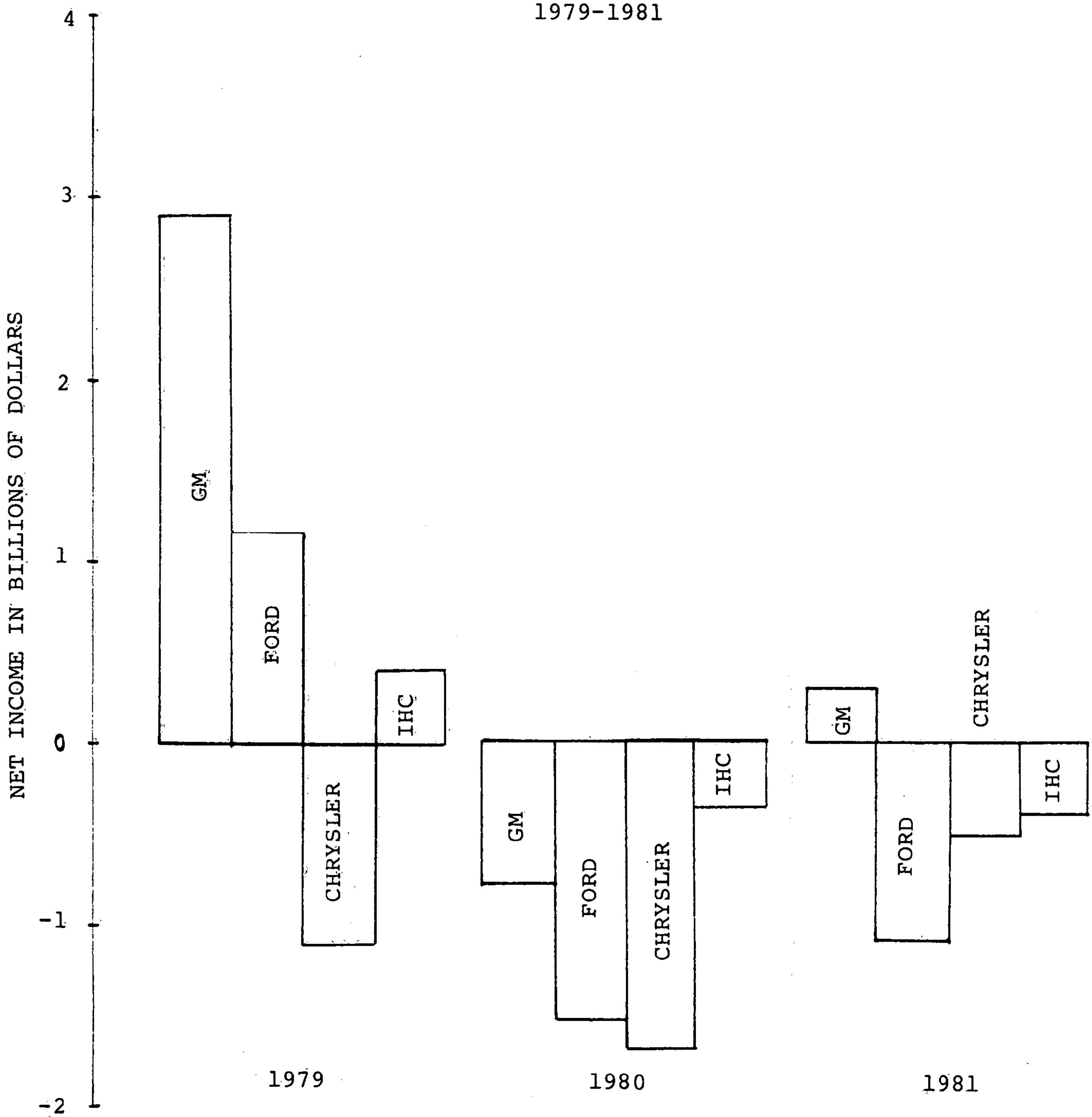
Factory Automotive and Truck Sales (1978-82)[1]

Year	LDV Sales	LDT Sales	HDV Sales
1978 % Change From 1977 Sales	9,165,190 -0.4%	3,044,890 +6%	661,349 +18%
1979 % Change From 1978 Sales	8,419,226 -8%	2,464,632 -19%	572,074 -13%
1980 % Change From 1979/78 Sales	6,400,026 -24%/-30%	1,310,264 -47%/-57%	357,019 -38%/-46%
1981 % Change From 1980/78 Sales	6,255,340 -2%/-32%	1,365,906 +4%/-55%	335,002 -6%/-49%
1982 % Change From 1981/78 Sales	5,461,074[2] -12%/-40%	1,625,902[3] +19%/-47%	279,537[3] -17%/-58%

[1] MVMA Motor Vehicle Facts and Figures 1982, pp. 9 and 12.
[2] Ward's Automotive News, February 28, 1983, p. 4.
[3] MVMA Factory Sales and Figure Fact Sheets, 1982.

Figure 1-1

Net Income for HDG Manufacturers [1]
1979-1981



[1] "Financial Analysis of HDGE Manufacturers", J. Faucett Assoc., 1982, pp. 12, 20, 27, 35.

decreased costs but also helped deepen the recession and added to the uneasiness on the part of the buying public, further decreasing the demand for their products.

As a result of the cost-cutting measures, the record losses for 1980 decreased in 1981 and GM even showed a modest net profit. However, net profit does not necessarily represent income from current operations (current sales revenues less current expenses). As will be explained in detail later, GM's net profit resulted from tax credits rather than current operations. Indeed, 1981 sales were still 55 percent lower than 1978 levels. As seen in Table 1-2, HDV and passenger car sales continued to decline throughout 1981, although not as precipitously as in 1979 and 1980. Thus, the 1981 "recovery" resulted from a reduction in costs and from tax credits due to prior-year losses, rather than from increased sales.

Thus, the HDGE manufacturers, after experiencing record sales in the period of 1978-79, suddenly faced declining sales and operating income losses due to the worldwide recession. In addition, the industry expended $20 billion in 1980-81 in capital expenditure for plant and equipment necessary to improve their competitive position. The result was a negative cash flow which increased their debt financing at a rate much higher than expected. Clearly, the financial status of the HDGE industry had weakened substantially.

For 1982, market conditions and sales continued to be depressed.[10,11,12] As shown in Table 1-2, LDVs sales were down 12 percent and HDVs were down 17 percent from the previous year. LDT sales increased 19 percent, but annual sales since 1978 were still down almost 50 percent. With the continuation of depressed sales, the financial picture did not improve in 1982 for GM, Chrysler, Ford, or IH, as explained in greater detail below.

B. Discussion of Individual Manufacturers

1. International Harvester Company (IHC)

IHC produces medium-duty and heavy-duty trucks and, except for the 1980 model year, has been the sales leader in those classes. The company stopped production of LDTs late in 1980, and so did not share in the recent sales increase in that class experienced by the other three producers. Medium-duty and heavy-duty sales have decreased by 53 percent and 30 percent, respectively, from 1978 levels, and combined with a disastrous labor strike in early 1980, have subjected the company to severe financial distress. In fact, IHC has been on the verge of bankruptcy for the past two years and has undergone a recent debt restructuring in an effort to forestall this possibility.

Figure 1-1 shows the decline in IHC profits. IHC lost $397 million in 1980 and experienced a similar loss in 1981. The 1981 loss from continuing operations was actually $636 million, but this loss was partially offset by a $243 million credit from the sale of discontinued operations.[13] IHC also made substantial capital investments in product development, which constituted another drain on working capital. Indeed, net working capital decreased by almost 40 percent from 1979-81 (see Figure 1-2), but the decrease would have been even more dramatic without the sale of assets and a massive increase in long-term borrowing. Long-term debt increased from $948 million in 1979 to almost $2 billion in 1981, an increase of over 100 percent (see Figure 1-3). IHC is a highly leveraged corporation, as is indicated by a debt/equity ratio of 2.56. Consequently, the company is highly vulnerable to cyclical swings in the economy than would those of a less highly leveraged firm such as Ford or GM.[14] IHC's weak financial position necessitated its recent debt restructuring.

Shortly after the revised non-catalyst standards were proposed in January 1982, IHc publicly announced its intention to withdraw from the HDGE market whenever the new standards and test procedure became effective. HDGEs represent only about 2.5 percent of IHc's total revenue, and this market was shrinking due to increasing dieselization of medium-duty and heavy-duty fleets.[15,16] IHc therefore decided to withdraw from the HDGE market because of their belief that very small payoffs would be achieved from further investments in HDGEs. IH requested only that EPA provide 1-year delay of the new standards and test procedures to allow them to make a more orderly withdrawal from the market.

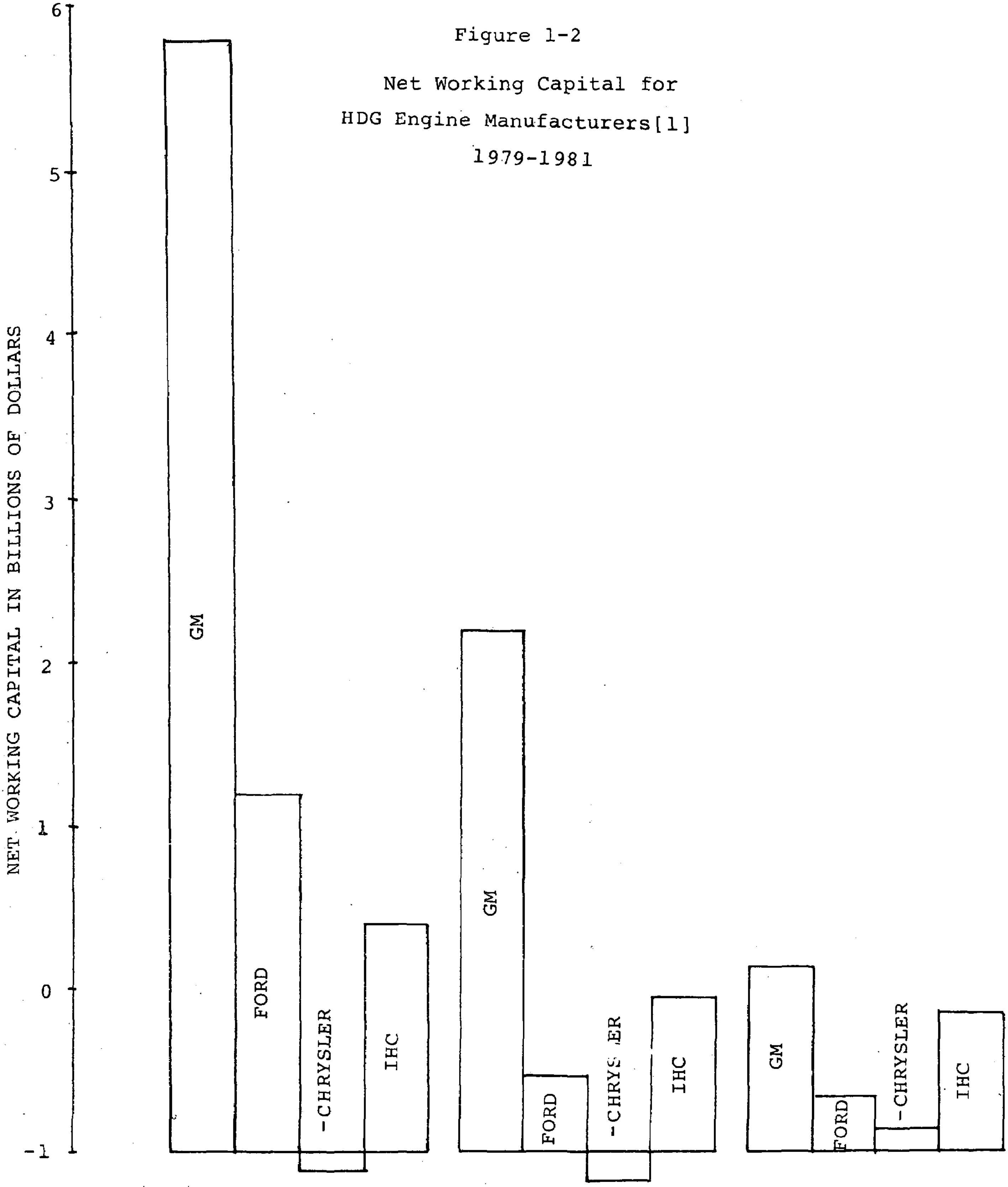
In 1982, IHC lost more money than in previous years, a total of $1.6 billion, due in large measure to a $394 million loss from discontinued operations and $440 million in debt restructuring costs.[12] IHC's 1982 dollar sales were 30 percent less than those of 1981. Thus, their financial position has deteriorated even further.

2. Chrysler Corporation

Chrysler has also faced a struggle for economic survival. In addition to seeking Federal loan guarantees, the company has been forced to sell off assets and undergo a $1.3 billion debt restructuring.[18] In 1980, Chrysler sustained the largest loss ever recorded by a U.S. corporation, $1.7 billion, which

Figure 1-2

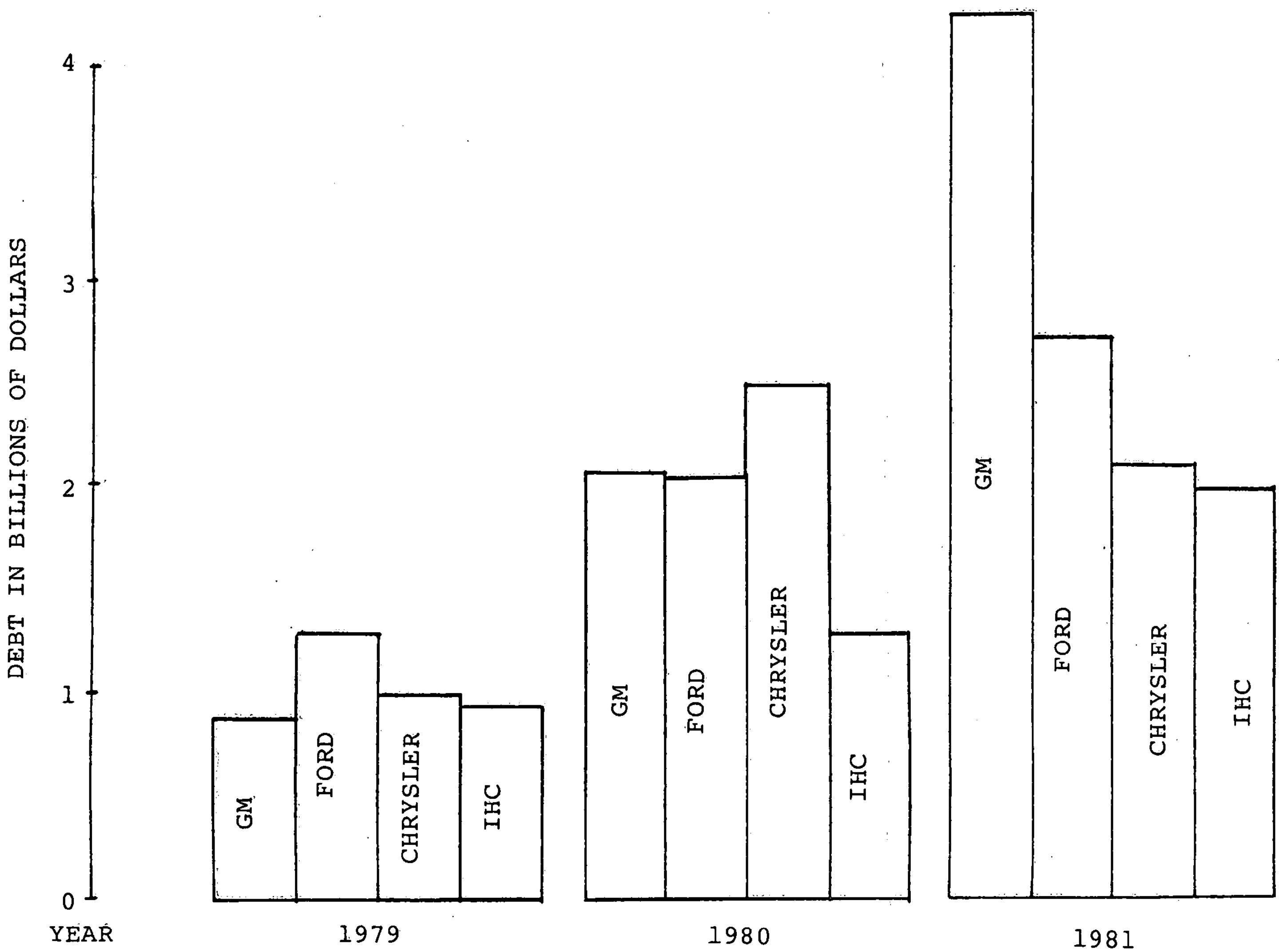
Net Working Capital for
HDG Engine Manufacturers[1]
1979-1981



[1] "Financial Analysis of the HDGE Manufacturers", J. Faucett Assoc., 1982, pp. 12, 20, 27, 35.

Figure 1-3

Long-Term Debt for HDG Engine Manufacturers[1]



[1] "Financial Analysis of the HDGE Manufacturers", J. Faucett Assoc., 1982, pp. 12, 20, 27, 35.

followed a loss of $1.1 billion in 1979 and preceded a loss of $476 million in 1981 (see Figure 1-1). Chrysler has experienced severe cash flow problems; in fact, its net working capital was negative in 1979 and 1980 (see Figure 1-2), and only recovered in 1981 after debt restructuring. In 1981, Chrysler had to depend on the liquidity of its inventories to cover 66 percent of its current liabilities (see Table 1-3).

At the time revised non-catalyst standards were proposed, Chrysler also publicly announced intention to withdraw from the HDGE market, since the minimal percentage of total sales represented by HDGEs did not justify the investment. With the recent slowing in the rate of dieselization, however, it appears that the demand for gasoline-powered HDVs may be greater than Chrysler anticipated, at least in the foreseeable future. Chrysler has, in fact, already made public that it is reconsidering its decision to leave the HDGE market.

In 1982, Chrysler's unit sales declined 7.9 percent, from 1.28 million in 1981 to 1.18 million in 1982.[11] However, Chrysler posted a profit of $170 million, attributable primarily to the divestiture of Chrysler Defense, which was sold to General Dynamics for $239 million, and cost reduction measures which reduced Chrysler's breakeven point (i.e., number of sales units needed to recover annual fixed expenses) to 1.1 million units in 1982 compared with 2.4 million units three years earlier.[11] Therefore, Chrysler's profit resulted from decreasing its production costs and selling its defense unit rather than from improved market conditions.

3. Ford Motor Company

Ford's losses were $1.5 billion and $1.1 billion, respectively, in 1980 and 1981. These were the second and fourth highest losses ever recorded for a U.S. corporation, after it had shown a profit of $1.2 billion in 1979 (see Figure 1-1). As shown below, the North American operation was largely responsible for the lack of profitability, showing net losses in all three years while the overseas portion of the corporation showed a net profit during the same period.[19]

	1979	1980	1981
U.S. & Canada	(208)	(2,119)	(1,447)
European & Other Overseas	1,377	576	387
Total Net Profit (Loss)	1,169	(1,543)	(1,060)

Table 1-3

HDGE Manufacturers Liquidity Ratios (1979-81)[1]

(1) Current Ratios: Current Assets/Current Liabilities

Manufacturer	1979	1980	1981
General Motors	1.68	1.29	1.09
Ford	1.25	1.04	1.02
Chrysler	0.97	0.94	1.08
IHC	1.74	1.41	1.48

(2) Quick (acid test) Ratios: Most Current Assets[2]/Current Liablities

Manufacturer	1979	1980	1981
General Motors	0.81	0.61	0.40
Ford	0.53	0.50	0.47
Chrysler	0.34	0.26	0.34
IHC	0.28	0.31	0.52

[1] "Financial Analysis of the HDGE Manufacturers," Jack Faucett Associates, pp. 13, 21, 28, 36, 1982.

[2] Cash, receivables, and marketable securities.

Profits from the overseas operations helped fund a $4.8 billion capital expenditure program designed to bring Ford's domestic product mix more in line with consumer demand. Nevertheless, Ford was forced to undertake considerable long- and short-term debts to finance these capital expenditures. The effect was to reduce working capital, which had been over $2 billion in 1979, to only $347 million in 1981, or a reduction of almost 85 percent (see Figure 1-2). As a result, Ford's ability to meet current obligations declined, as reflected in the current ratio shown in Table 1-3, which fell from 1.25 in 1979 to 1.02 in 1981. Ford's quick ratio, another measure of the ability to service current obligations, was .47 in 1981, meaning that less than 50 percent of current liabilities could be covered by current assets.

For 1982, Ford continued to show a loss, posting a $658 million deficit. This loss was $402 million less than the previous year, but the decrease in cost is partially attributed to reductions in operating costs and adoption of a new accounting method which reflected the absence of foreign-currency transaction losses. Ford's 1982 dollar sales declined 3 percent from 1981 and unit sales were down 2 percent from 1981.[12]

4. <u>General Motors Corporation</u>

General Motors, the largest auto manufacturer in the world, did not escape the effects of the recession. GM's net income (after taxes) declined from a $2.9 billion profit in 1979 to a $763 million <u>loss</u> in 1980, and recovered to a $333 million profit in 1981.[16] The $763 million loss in 1980 (see Figure 1-1) was the fifth largest ever recorded for a U.S. corporation; the profit in 1981, however, was largely attributable to carryforward of tax credits from the previous year's loss and to the success of its financing and insurance operations, rather than from sales. GM also made large capital expenditures to improve its product mix: a total of $3.5 billion in 1980 and 1981. Although GM traditionally avoids debt by financing capital expenditures from current operations, it was forced to borrow almost $3 billion in those years (see Figure 1-3). Even this amount did not cover the cash flow deficit, however, resulting in a decrease in working capital from $6.8 billion in 1979 to $1.2 billion in 1981 (see Figure 1-2). GM's current assets (i.e., cash, receivables and marketable securities), which were sufficient to cover 81 percent of its current obligations in 1979, would only cover 40 percent in 1981.

For 1982, GM showed a profit of $963 million.[10] Their earnings increased compared with 1981, but the automobile and truck manufacturing operations either lost money or showed only a small profit for the year. GM's overall operating income did show a profit, but much of this was due to accounting credits given for currency exchange, tax credits, and cost reductions. On the other hand, sales declined from the previous year. Worldwide factory sales were 6.24 million cars and trucks, down 7.7 percent from 1981 and the lowest unit sales since 1976.

C. Summary and Conclusions

Financial analysis of the four corporations involved in the HDGE industry clearly indicates that the financial condition of the industry was depressed in 1980 through 1982, the years in which the initial capital outlay would have been required for the 1984 statutory standards. GM and Ford both showed large drops in sales and significant losses in income from operations, and increased their debt financing well beyond normal. Chrysler and IHC posted large losses in operating income and net income, and both were on the verge of bankruptcy.

Depressed sales in the motor vehicle industry forced massive borrowing and eroded the domestic manufacturers' ability to underwrite the necessary capital investment for the 1984 statutory standards. In the regulatory analysis to the original final rulemaking, it was stated that the 1984 statutory standards were economically feasible for the manufacturers, barring any post-1980 recession. Considering that the financial status of the heavy-duty industry had been weakened severely in the 1980-82 timeframe, compliance with the statutory heavy-duty HC and CO emission standards in 1984 represented much more of a burden than it would have had economic conditions remained constant.

Section 202(a)(3)(k) of the Clean Air Act of 1977 provides that the Administrator may revise an emission standard for a specific period of time if he finds "...that compliance... cannot be achieved...without increasing cost or decreasing fuel economy to an excessive or unreasonable degree..." Given that compliance with the 1984 statutory standards would involve large capital expenditures at a time when the industry was under severe economic strain, EPA believes that revisions to the 1984 standards and their timing are appropriate. With the apparent improvement in market conditions for 1983, the promulgation of the standards as provided by this rulemaking should be economically feasible for the HDGE manufacturers.

III. Cost of Implementing the Original Final Rulemaking

The costs which would have been incurred had the original FRM been retained will be analyzed in this section. The costs to be determined are per engine costs, aggregate costs, and capital costs. These costs will be compared later in this chapter to the costs of the interim standards and the split-class approach.

A. Per-Engine and Aggregate Cost Estimates for the Original FRM

In support of the 1979 final rule, EPA performed an economic analysis to determine the aggregate cost and first price impact of the regulations.[1] As stated in the Introduction, most of these costs have since been updated in the EPA staff paper, and these updated costs will be used here.[2,3] (Detailed derivations of the costs are presented in the staff paper and supporting analyses.)

The staff paper presented vehicle/engine costs in two categories: those related to non-catalyst technology and those related to catalyst technology. The non-catalyst related development and hardware costs include the automatic choke, early fuel evaporation, heated air intake, increased air injection, EGR, air modulation, and carburetor/engine modifications. In 1983 dollars, these costs total $113. The catalyst-related costs were separated in the staff paper for Classes IIB-III vehicles and Classes IV-VIII vehicles, because application and cost of catalyst technology differ between the two groups of vehicles. For Classes IIB-III vehicles, components to the catalyst control system include the oxidation catalyst, stainless steel exhaust pipe, chassis heat shields, and fuel restrictors. Also, the engines in these vehicles will require minor modifications to use unleaded fuel. The total costs of these components and modifications, plus the amortized certification costs for these vehicles, amounted to $155.[2] For Classes IV-VII vehicles, the first price cost increase is estimated to be about $550.[2] This cost is greater than that for Classes IIB and III vehicles because of the need for a more durable oxidation catalyst, a catalyst protection system, and additional research and development (R&D) to develop such systems. A weighted average first price increase for catalyst-related control technology would be $270 for all HDGEs, assuming that 70 percent of all HDGEs sold between 1985-89 will be Classes IIB and III (based upon the 1985-89 sales figures shown in Table 1-1). The total first price increase of both catalyst and non-catalyst control would be the sum of $270 and $113, or $383.

Operating costs will increase for catalyst control systems because of the use of unleaded gasoline instead of leaded gasoline. Assuming a $0.03 per gallon fuel differential, the staff paper estimated this cost to be $218 for Classes IIB-III vehicles and $469 for Classes IV-VIII vehicles (discounted at 10 percent to the year of vehicle purchase).* The difference in costs between the two groups of vehicles is due to the average fuel economies of each group (12.4 mpg for Classes IIB and III vehicles and 5.8 mpg for Classes IV-VIII vehicles). Since the publication of the staff paper, EPA has reduced the average useful-life estimate from 120,000 miles to 110,000 miles. Therefore, the Classes IIB-III and Classes IV-VIII costs for unleaded fuel are $202 and $431, respectively when discounted to the year of vehicle purchase. The weighted average fuel differential cost is $270. This fuel differential cost is partially offset by an estimated maintenance savings of $252 due to fewer exhaust system and spark plug replacements. Thus, at a $0.03 per gallon fuel differential, the weighted average total of these operating and maintenance costs would be the fuel differential cost at $270 less $252 due to fewer spark plug and exhaust system replacements, or $18 assuming all HDGVs will switch from leaded to unleaded fuel. However, it will be assumed here, as was for the staff paper, that some Chrysler vehicles are already using unleaded fuel.[2] This was estimated at 8 percent of all HDGVs, so the weighted average operating and maintenance costs would decrease from $18 to $17.

Fuel economy will likely improve as a result of new emission control hardware and engine modifications. In the staff paper, this improvement was estimated to be about 10 percent. The latest available test data indicate that fuel economy improvements of 7 to 10 percent are still expected. For every 1 percent improvement in fuel economy that might occur, the savings would be about $117 during the lifetime of a vehicle. This savings is based on an average HDGV fuel economy of 9.24 miles per gallon, an unleaded gasoline price of $1.30 per gallon, an average HDGV lifetime of 110,000 miles for 8 years, and a 10 percent discount rate. As will be discussed later, the fuel impact, if any, will be the same under the original FRM or this rulemaking.

The 5-year aggregate cost was not determined in the staff paper, but can be calculated by multiplying lifetime vehicle

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* At a $0.05 per gallon fuel differential, the operating costs were estimated at $336 and $718 for Classes IIB and III and Classes IV-VIII vehicles, respectively. A $0.03 fuel differential cost is assumed in this chapter, even though a $0.05 fuel differential cost currently exists. It is expected that in the long run, as increased quantities of unleaded fuel are produced and as production of leaded fuel decreases, the differential will decrease to be $0.03.[1]

costs by the HDGV sales between 1985-89. The average lifetime vehicle costs without the fuel consumption savings is $400. The estimated sales is 1.76 million between 1985 and 1989. Discounting costs at 10 percent per year to the year of present value (1985), results in an aggregate cost of $583 million. If the fuel consumption savings is included, the average lifetime costs are reduced by $117 for every 1 percent improvement in fuel economy. This would also reduce or eliminate the aggregate costs. The net aggregate cost would drop to less than zero at only a 4 percent fuel economy improvement. Both the aggregate cost and the per vehicle cost for the original FRM are shown in Table 1-4.

B. Capital Cost Estimate for the Original FRM

Compliance with the requirements of the original FRM include captial costs to acquire new certification testing facilities, R&D expenditures, certification testing, and tooling costs for emission control hardware (e.g., catalytic converters, larger air pumps, air modulation systems, parameter adjustment and deceleration fuel shut-off). The capital cost estimates used in this analysis are taken from two sources: the regulatory analysis from the December 1979 FRM and the January 1982 draft support document. A summary of these costs are shown in Table 1-5.

In the December 1979 FRM, the capital costs for certification facilities, R&D, and certification testing were determined in 1980 dollars. In 1983 dollars, these costs (undiscounted) are:*

Certification facilities	$12M
R&D	$25M
Certification testing	$2.0M

While the R&D and certification testing costs shown above may change as a result of this regulation, the certification facilities cost will not. The original FRM specified a new emissions test procedure (the transient test), requiring new certification test equipment and associated facility modifications. Test facility and modification costs are capital costs that are still necessary under this rulemaking. Because this rulemaking will not affect these requirements, and because virtually all of these costs have already been

* Selective Enforcement Audit (SEA) costs were included in the original FRM. However, SEA was delayed to 1986 the first portion of this rulemaking. Consequently, SEA costs are not considered here.

Table 1-4

Cost of Control for the Original FRM

Development and Hardware	
Non-catalyst related control	$113
Catalyst-related control	$270[1]
Total First Price Increase	$383
Operating and Maintenance (O&M)	
Savings due to fewer exhaust system and spark plug relacements	-$232[2]
Unleaded fuel at $0.03/gallon	$249[3]
Total O&M[4]	$17
Total	$400
Aggregate Costs of First Price Increase Plus O&M	
Sales, 1985-89	1,755,896
Aggregate Cost (discounted @ 10% per year to 1985)	$583M

[1] This is a weighted average cost of $155 for Classes IIB and III HDGVs and $550 for Classes IV through VIII HDGVs. It is estimated that Classes IIB and III and Classes IV through VIII HDGVs will comprise 70 and 30 percent of the total HDGV fleet, respectively.

[2] This savings is reduced by 8 percent to account for those HDGVs already using unleaded fuel.

[3] This cost is reduced by 8 percent to account for those HDGVs already using unleaded fuel. This is also a weighted average cost of $130 for Classes IIB and III HDGVs and $119 for Classes IV through VIII HDGVs. At a $0.05/gallon unleaded to leaded fuel differential, the weighted average cost would be $415.

[4] Fuel economy savings are estimated to be 7-10 percent, or $819-1,170 during the lifetime of a HDGE. These savings will not change under the interim standards or the original FRM.

Table 1-5

Capital Costs for the Original FRM
(1983 dollars undiscounted)[1,2]

Undiscounted Tooling Costs	
Catalytic Converters	$ 8.6M
Larger Air Pumps	47.1M
Air Modulation System	2.0M
Chassis Heat Shields/ Stainless Steel Exhaust	1.8M
Parameter Adjustment	2.7M
Deceleration Fuel Shut-off	8.0M
Engine Modifications	29.4M[3]
Total	$ 99.6M
R&D (heavy-duty catalyst only)	24.9M
Pre-Production R&D	8.8M[4]
Certification	2.0M[5]
Grand Total	$135.3M

[1] See Reference 3 for more detail.
[2] All costs were initially expected to be invested in 1981 and 1982.
[3] This number is based on six engine families requiring modifications. It is predicted that nine total gasoline-fueled engine families will be certified in 1985, when these modifications would be required. However, one GM and two Chrysler families are not expected to require further tooling or equipment for engine modifications, so six families are used to compute the engine modification tooling cost. Using EPA's estimate of about $4.9 million per engine family, the total modification cost would be $29.4 million. (Note that this estimate differs from that calculated in the draft support document.)
[4] Based on nine engine families, at a cost of $980,000 per engine family.
[5] Testing cost only, based on nine engine families, at a cost of $218,000 per engine family. Certification facilities costs are estimated at $12 million, but are not included in this table because they will not change under the original FRM or this rulemaking.

realized,* the costs presented in the original FRM have not been updated for this analysis. The undiscounted capital costs for R&D and certification testing of the original FRM requirements are included in Table 1-5. Also included in that table are pre-production R&D costs.[3] (The certification facilities costs is not included in Table 1-5 because it is unaffected by this rulemaking.)

While the certification facilities, certification testing, and R&D costs were explicitly determined in the regulatory analysis to the original FRM, the tooling costs associated with the manufacturing of the emission control hardware were not given separately as capital costs. However, these costs were stated in a cost per unit manner as part of the manufacturing cost. Separate identification of these costs now is important, as they represent a significant portion of the required investment, as well as a source of the potential savings associated with the revised 1985 HDGE emission standards. The derivation of these tooling costs is explained in an EPA memorandum, "Tooling Cost Calculation for HDG Engine Emission Control Components."[21] The initial estimates of the tooling capital costs associated with the original FRM are shown in Table 1-5.

The total capital cost necessary for compliance with the original FRM is therefore $135.3 million, as shown in Table 1-5. (Again, this excludes the certification facility costs.)

IV. Costs of the 1985 Interim Standards

The rationale behind this rulemaking has been the provision of short-term economic relief to the HDGE industry. Toward that end, preliminary analyses indicated that a significant portion of the capital investment and R&D costs related to the original FRM were tied directly to the implementation of catalytic converter technology on HDGEs. As a result, the decision was made to provide revised emission standards beginning in the 1984 model year which could be achieved without the use of catalysts. Since the 1-year continuation of the 1983 and earlier standards has already been promulgated, these interim standards will now be effective beginning with the 1985 model year. These standards will be referred to as the 1985-86 interim standards.

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* See Chapter 3 of the Transient Test Study, attached as Appendix B to the Summary and Analysis of Comments document of this rulemaking.

A. Non-Catalyst Technology Compliance Costs

This section will discuss the costs associated with the interim standards. The technological feasibility discussion in the Summary and Analysis of Comments outlined the emission control techniques and strategies which are most likely for HDGEs.[18]

This analysis will assume that, when possible, the manufacturers design and build their emission control systems to comply with the requirements of the 40 percent acceptable quality level (AQL) beginning in 1985, even though under current policy HDE SEA would not begin until 1986. This would allow the manufacturers to avoid repeated R&D, retooling, and recertification costs that might be necessary to comply with a 40 percent AQL in 1986. This is the most efficient use of resources, and is how EPA anticipates the manufacturers to conduct their development and certification programs.

Costs for achieving compliance with the emission standards would lie in three main areas: pre-production R&D, engine and component modifications, and new emission control hardware.

1. Pre-Production R&D Costs

Pre-production R&D costs will be discussed in terms of Phase I, or emission characterization, and Phase II, development and application of emission control systems and engine/component modifications. These programs, along with costs, will differ from manufacturer to manufacturer, and consequently, costs by manufacturer are difficult to determine. The estimates given below are average costs based upon conservative assumptions and should be representative of actual costs.

Phase I of each manufacturer's pre-production R&D program would most likely be a complete characterization of the emissions of each engine family using both the transient and steady-state test procedures. This would include emissions characterizations at different calibrations, as well as initial optimization of the engine's emissions performance prior to any modifications or additions. This preliminary testing would give the manufacturers information necessary to make decisions as to which modifications and emission control components to pursue.

With this initial data, Phase II of the R&D program would begin, and would include the development and application of the emission control systems and engine/component modifications. This task would fall upon the HDGE manufacturers and their component vendors. Once the engine modifications have been made and the necessary components added, the engines would have to be recharacterized and reoptimized as was done in Phase I.

Costs for Phase I characterization and optimization can be estimated by determining the number of transient tests necessary to adequately characterize an engine's emissions performance. A liberal estimate of the level of effort required would be 40 transient tests per family. This would include two tests at each calibration and a void rate of 10 percent. Each full transient emission test is estimated to cost $580[3] which yields a total testing cost of about $23,000 per family. This estimate is conservative, and may overestimate the actual cost, because most manufacturers would use hot starts and steady-state maps and would tend to keep full transient tests to a minimum at this stage. As is shown in Table 1-6, when other fixed costs are included, this cost becomes $42,000 per family.

Costs for Phase II of the R&D process are more difficult to estimate. This is primarily because this includes costs for development of prototype emission control components, and the modification and optimization of existing components. However, virtually all of the additions and modifications which EPA anticipates to be necessary for HDGEs have already been used in the LDV/LDT fleets for several years, and some are already used on some HDGE families. This transferability of experience will reduce necessary development expenses. As an initial estimate, a figure of $17,000 per family (inflated to 1983 from the draft support document[3]) will be used to estimate these component and modification costs. Phase II will also require a recharacterization and reoptimization after the modifications have been made and the components added. This would add an additional $23,000 per engine family (inflated to 1983 from the draft support document,[3]) bringing Phase II costs to $40,000 (= $17,000 + $23,000) per family (Table 1-6).

Total Phase I and Phase II costs per family sum to $82,000 (= $42,000 + $17,000 + $23,000). Preliminary certification data and information from manufacturers indicate that the number of Federal HDGE families will likely decrease from 16 at present (five for GM, three for Ford, three for Chrysler, and five for IHC) to 7-9 by 1985 (four for GM, three for Ford, and zero to two for Chrysler) due to declining market demand for HDGEs and the announced withdrawal from the market by IHC. Assuming nine HDGE families, the total pre-production R&D cost would be $738,000 industry-wide.

Table 1-6

Pre-Production R&D Testing Costs

(1) Phase I

Manufacturer	(a) Number of Engine Families[1]	(b) Fixed Costs Per Family[2]	(c) Testing Costs Per Family[3]	(d) Phase I R&D Total[4]
Chrysler	2	$19K	$23K	$ 84K
Ford	3	$19K	$23K	$126K
GM	4	$19K	$23K	$168K

(2) Phase II

Manufacturer	(a) Number of Engine Families[1]	(b) Fixed Costs Per Family[5]	(c) Testing Costs Per Family[3]	(d) Phase II R&D Total[4]
Chrysler	2	$17K	$23K	$ 80K
Ford	3	$17K	$23K	$120K
GM	4	$17K	$23K	$164K

[1] Based on projected Federal certification families for 1985, and assuming IHC will leave the market.
[2] Engine: $2,300, Break-in: $10,500, Engineering Overhead: $5,800.
[3] 40 transient tests at $580 per test.
[4] (a) (b + c).
[5] Prototype emission control hardware and modifications.

2. Emission Control System Costs

Emission control system costs can be broken down into two categories: the costs due to engine and component modifications, and the costs of emission control hardware. Both categories will be examined below.

a. Modifications and Improvements

EPA expects that substantial emission reductions will be gained in engine and component modifications. Additional reductions will be achieved through calibration changes. The emission-related modifications and improvements which will be necessary to meet the 1985-86 interim emission standards will vary by engine family. The costs of control for each family will vary according to its emission characteristics and the currently used emission control hardware. The cost of the necessary modifications and recalibrations is therefore difficult to estimate on a per engine basis. Recalibrations are not too difficult to perform and are generally inexpensive, while engine modifications may require more extensive redesign and retooling. A summary of the expected modifications and costs are shown in Table 1-7.

Carburetion modifications will also incur costs. In the long term, the price of the carburetor will probably remain relatively unaffected, but manufacturers and vendors will have to recover their costs for redesign and retooling.[21] An initial cost of $10 per engine was estimated originally by EPA in 1982 dollars. In 1983 dollars, the cost is approximately $11. Using a 10 percent discount and assuming these costs are amortized over a 2-year production period (1985-86), this requires an investment of about $5.9 million if the investment is made in 1984. This results in an investment of $650,000 per engine family to cover costs for carburetor redesign, optimization, and retooling if necessary. (This investment estimate should be conservative, due to the fact that some carburetor configurations are now used for more than one engine family.) Finally, an additional $5 should be added to the initial $11 figure to cover parameter adjustment and other carburetor-related modifications.

Manifold design changes and combustion chamber modifications are also another significant source for improvement. Changes to the design of the intake manifold could improve air/fuel distribution to the cylinders, resulting in lower HC and CO emissions. (Decreases in the combustion chamber surface-to-volume ratio and dead volume would also aid in reducing HC emissions, but such design modifications are leadtime intensive. At the 2.5 HC standard, these approaches

Table 1-7

1985 Non-Catalyst Standards Emission Control
Related Modifications/Improvements (1983 dollars)

Carburetion:	
Power Enrichment	$11
Accelerator Pump	
General Fuel Metering	
Parameter Adjustment and Other Modifications	$5
Manifold and/or Combustion Chamber Redesign	$16
Miscellaneous:	
Air Injection System (diverter and pressure relief valves)	[1]
Spark Timing, A/F Ratio, EGR	[1]
Calibrations	[1]
Total	$32

[1] Some modifications likely, but costs are negligible.

are not considered likely or necessary.) Some modifications are also expected for the exhaust manifold, due to the increased number and location change of air injection points, increased air injection rate, and need to improve the thermal reaction dynamics. Also, better materials are needed to ensure higher exhaust temperatures brought on by leaner A/F calibrations and increased thermal reaction in the exhaust. The total cost is estimated to be $16. Capital costs, based upon a 2-year recovery period and assuming investment takes place in 1984, are estimated to be $8.58 million industry-wide.

The costs to implement new calibrations of spark timing, EGR, and air/fuel ratio should be negligible, as should the costs be for optimization of the air injection system. (The cost for additional air injection is included in the hardware costs discussed below.)

In summary, as an initial estimate EPA will use a per engine modification/improvement cost of $32 (= $11 + $5 + $16), assuming all modifications are implemented. This would cover the recalibrations, carburetion improvements, modifications of the exhaust manifold, and other improvements which EPA believes will be necessary to comply with the interim standards.

b. Emission Control Hardware

The emission control hardware anticipated for compliance with the interim standards is similar to that which has been used in the LDV/LDT fleets. Much of the technology and performance experience will be readily transferable to HDGEs, and has been in some cases.[22] Table 1-8 lists the hardware which will likely be used beginning in 1985.[17]

The costs shown in Table 1-8 have been taken from two sources: manufacturers' comments,[23] and two reports prepared by an EPA contractor.[24,25] In both cases, the costs reflect the economies of scale expected in HDGE production and have been inflated to reflect the purchasing power of 1983 dollars. The hardware costs represent what EPA expects to be applied to the average engine.

3. Total Emission Control System and Other First Price Costs

The first price increase can be calculated by adding together the engine and emission control system modification costs, emission control hardware costs, amortized pre-production R&D cost, and amortized certification cost. Engine and emission control system modification costs and emission control hardware costs are shown in Tables 1-7 and 1-8

Table 1-8

1985 Non-Catalyst Standards
Emission Control System Hardware Costs[1,2]

Automatic Choke (electric)	$ 4
Early Fuel Evaporation	$19
Heated Air Intake	$ 9
Increased Air Injection	$42
EGR	$18[3]
Air Modulation	$ 9
Total	$101

[1] See Reference 2.
[2] These costs were originally estimated in 1982 dollars, and were subsequently inflated to 1983 dollars.
[3] Expected to be used by one manufacturer (GM) only. Ford and Chrysler engines already have an EGR system.

sum to $133. Per engine pre-production R&D cost is estimated at about $1 at the consumer level, bringing the total emission control system cost to $134 per engine if all modifications and components are incorporated.

Not all engine families, however, will need to incorporate all of these components and modifications. Some families already use items such as automatic chokes and heated air intake; these costs need not be incurred again. In the staff paper it was estimated that on the average about 80-85 percent of all heavy-duty engines would incorporate all the modifications and components. Applying this 80-85 percent to the $134 maximum per-engine cost, the average cost per engine is in the $107-114 range. This analysis will use the middle ($110) of this range as the average per-engine cost. This cost includes all profit and overhead and is presented in 1983 dollars. An additional $3 per engine[2] is added to cover certification costs, bringing the total cost to about $113.

4. Operating and Maintenance Costs

With the control technologies and approaches discussed above, there is quite likely to be some improvement in fuel economy relative to current engines. Based upon the most recent test data, the increase in fuel economy would be in the 7-10 percent range. Assuming an average fuel economy of 9.24 miles per gallon (mpg), a leaded gasoline price of $1.27 per gallon, and an average lifetime of 110,000 over 8 years, an average HDGV owner could expect to save approximately $114 for each 1 percent improvement in fuel economy. Based upon the most recent test data, this yields a lifetime fuel savings of $798 to $1,140 per vehicle.

The fleetwide use of heated air intake and automatic chokes may cause a small increase in lifetime maintenance costs. These components usually require minor servicing (operational checks and lubrication) in intervals of 12,000-24,000 miles. A cost of $20 will be included to cover this maintenance over the vehicle lifetime.[26]

5. Capital Costs of the Revised HDGE Emission Standards

The 1985 interim HDGE emission standards will require capital costs related to engine and component modifications, pre-production R&D, and tooling costs associated with emission control hardware. As shown in Table 1-9, these costs sum to $68.6 million. These include $0.7 million for pre-production R&D, $2.0 million for certification, and $65.9 million to cover costs to "tool up" for the new emission control hardware. EPA expects that many of the new emission control components can be

Table 1-9

Capital Costs of the 1985 HDGE Interim Emission Standards (1983 undiscounted dollars)[1]

Pre-Production R&D	$ 0.7M
Tooling:	
Engine/Component Modifications	$ 5.9M
Manifold Modifications	$ 8.6M
Automatic Choke	$ 4.3M
Early Fuel Evaporation	$ 2.6M
Heated Air Intake	$ 0.5M [2]
Increase Air Injection	$38.3M
Air Modulation System	$ 2.0M
EGR	$ 1.0M
Parameter Adjustment	$ 2.7M
Subtotal	$65.9M
Certification	$ 2.0M
TOTAL	$68.6M

[1] See Reference 3 for more detail.
[2] No estimate available, but should be small; 150K has been included for each of the three manufacturers.

obtained from currently existing production capacity, thus eliminating the need for new tooling and equipment. Since the level of this occurrence could not be precisely quantified, the tooling costs estimated for HDGEs have not been downwardly adjusted, and should be considered to be worst case costs.

6. Summary of Costs of Interim Standards Over Current Engines

In summary, the costs for the 1985-86 interim standards are divided into capital costs, development and hardware costs (on a per-engine basis), and operating and maintenance costs (also on a per-engine basis). The capital costs include $0.7 million for pre-production R&D, $2.0 million for certification, and $65.9 million for "tooling" costs, yielding a total cost of $68.6 million. For development and hardware costs, carburetor and engine modifications amount to $32 per engine, emission control hardware amounts to $101 per engine, R&D costs amount to $1 per engine, yielding a total development and hardware cost of $134 if used on all engines; however, assuming that all engines will not incur all of these costs, a weighted average cost of about $110 is assumed. Certification costs of $3 per engine brings the total cost to $113. Maintenance costs would be about $20 over the vehicle lifetime, whereas fuel savings attributable to improved fuel economy are expected to exceed $700. These costs are summarized in Table 1-10.

The aggregate costs to the nation can be calculated by totaling the first price increases and the increase (or savings) in operating costs and multiplying the result by the 1985-86 projected sales figures. The resultant costs are also shown in Table 1-10.

B. Cost Comparison: Interim Standards Vs. Original FRM

Having now reviewed and updated the costs associated with the original FRM (see Tables 1-4 and 1-5 and refer to Section II.A.) and having identified and developed the costs associated with the interim emission standards (see Section IV.A.), the remaining task is to compare the costs in the appropriate categories to determine the savings. This will be done for capital costs, first price increase, and operating/maintenance costs.

Table 1-11 (1) compares the capital costs of the 1985-86 interim standards over the original FRM catalyst standards. The total savings in tooling, R&D, and certification costs is shown in Table 1-12 and amounts to $66.7 million. The major portion of this savings is due to the delay of the development and use of catalysts and the associated engine modifications necessary to use these systems.

Table 1-10

Vehicle Lifetime and Aggregate
Cost of Control of Interim Standards

First Price Increase:	
Emission Control System Costs, Amortized R&D, and Certification	$113
Operating and Maintenance (O&M):[1]	
Increased Emission Related Maintenance	$20
Total	133[1]
Sales, 1985-86	675,734
Aggregate Cost of First Price Increase and O&M (discounted @ 10%/year, to 1985)	$86M[1]

[1] Fuel economy savings are estimated to be 7-10 percent over current consumption, or $798-1,140 during the lifetime of a HDGE. These savings are essentially the same as those that would have been realized under the original FRM, except these are based on the use of leaded gasoline, and the original FRM used unleaded gasoline.

Table 1-11

Cost Comparison of Interim Standards to the Original FRM

	Original 1984 FRM	1985-86 Interim Revision
1. Capital Costs		
Tooling/Hardware and Engine Modifications	$99.6M	$65.9M
R&D	33.7M	0.7M
Certification	2.0M	2.0M
Total	$135.3M	$68.6M
2. First Price Increase (per engine)		
Emission Control System Costs, Amortized R&D, and Certification	$383	$113
3. Operating and Maintenance (O&M) Costs		
Unleaded Fuel Differential	$249	--
Exhaust System and Spark Plug Savings	-$232	--
Increased Emission-Related Maintenance	--	$ 20
Total Operating Costs	$17	$20
4. Aggregate Costs		
Total First Price Increase Plus O&M	$400	$133
Sales, 1985-86	675,734	675,734
Aggregate Costs (discounted at 10% per year to 1985)	$258M	$86M

Table 1-12

Savings of Interim Standards Over the Original FRM

Capital Cost Savings	$66.7M
Savings per engine	
First price increase	$270
Operating/Maintenance	-$3
Fuel Economy	$0
Total per engine	$267
Aggregate Savings (discounted @ 10%/year to 1985)	$172M

As a result of the delay, the hardware portion of the first price increase will decrease. The expected hardware/R&D/certification portion of the first price increase will drop from $383 (1983 dollars) for the original FRM to $113 for the 1985-86 interim standards, for a savings of $270 per engine. These cost comparisons are shown in Table 1-11 (2), and the savings are summarized in Table 1-12.

Operating and maintenance costs will not be affected as dramatically. Although the original FRM has a cost of $268 due to the fuel price differential, it also shows a savings of $232 due to decreased exhaust system and spark plug maintenance.

Both the original FRM and the analysis of the interim standards predicted a fuel economy improvement. The original FRM predicted a 4-9 percent increase (and based cost estimates upon the 4 percent value), while the more recent data suggest that 7-10 percent improvements are likely. On the other hand, EPA's fuel economy analysis[21] predicts that 1985-86 and 1987 catalyst-based fuel economy will be comparable. In other words, the fuel economy benefit attributed to catalysts in the original FRM is actually achieved by the engine calibrations required to meet the interim standards. In short, EPA expects similar improvements in fuel economy for the current rulemaking as were predicted under the requirements promulgated with the original FRM, hence no cost differential is noted.

The only cost incurred by the interim standards that is not incurred by the original FRM is a $20 maintenance cost for operational checks and lubrication of the heated air inlet and automatic choke. These costs are shown in Table 1-11.[3] When all these costs are added together, the operating and maintenance costs of the original FRM is $3 more than that of the interim standards, as shown in Table 1-12.

The total per engine savings of the interim standards amounts to $267 when the first price increase and operating costs are added and compared to that of the original FRM.

The aggregate costs to the nation of the interim standard period (1985-86) are compared for the interim standards and the original FRM in Table 1-11 (4). The aggregate costs were calculated by totaling the first price increase and the increase (or savings) in operating costs, and multiplying the result by the 1985-86 projected sales figures. The resultant savings are summarized in Table 1-12.

V. Costs and Savings Associated with the 1987 Split-Class Approach

For 1987 and later model years, EPA is retaining the statutory standards for HDGEs used in Classes IIB and III vehicles (i.e., those HDGEs used in HDVs with a GVW of up to 14,000 lbs.). These vehicle classes are expected to represent 70-75 percent of all HDGV sales by 1990, and are very similar in terms of powerplant selection and operating characteristics to heavier LDTs.[27] They should, therefore, be able to utilize extensions of conventional LDT catalyst technology. HDGEs used in Class IV and larger vehicles (GVW in excess of 14,000 lbs.) would continue to comply with the interim standards. Manufacturers would therefore be spared the relatively expensive task of developing catalytic converters and catalyst protection systems for the larger engines used in the more severe service applications. The problem of catalyst durability in the heavier HDGVs would thus be minimized.* EPA projects that this approach will yield savings over the original FRM provisions in emission control system costs and operating and maintenance costs. The discussion below quantifies thse costs and the resultant savings.

A. Costs Associated with the 1987 and Later Model Year Split-Class Approach

1. Capital Costs

Much of the capital investment necessary for implementing the split-class approach has already been committed under the interim standards. The additional capital costs are primarily tooling expenses related to the application of catalysts to Classes IIB and III HDGEs. However, much of the tooling costs normally associated with catalytic converter technology will not be necessary under the split-class approach, since similarity in vehicle/engine specifications between conventional LDTs and Classes IIB-III HDGVs, and excess capacity for LDT catalytic converter production will permit some component transferability.

A recent EPA staff analysis of engine applications indicates that all of the HDGEs which are also used in LDTs fall in the Classes IIB-III application group.[27] Therefore, it appears likely that catalyst technology and other engine modifications necessary to use unleaded gasoline could be applied with minor modifications (and costs) to Classes IIB-III

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* In addition, EPA will also allow up to 5 percent of each manufacturer Classes IIB and III HDGV sales to be reclassified as Classes IV-VIII vehicles for the purposes of gaseous emissions standards allowing these limited reclassifications will further minimize any catalyst development problems for the more severe applications that might occur in Classes IIB and III HDGEs.

vehicles. On the other hand, the development of new catalyst and catalyst-production technology (e.g., higher temperature substrate materials) for engines used in Classes IV-VIII would likely be required, primarily for overcoming temperature-related durability problems which accompany the application of catalysts to the larger and heavier HDGEs in Classes IV and VIII. This task would be more expensive and difficult than the application of catalysts to lighter weight vehicles in Classes IIB and III.

Capital costs associated with catalytic converter production should, therefore, be saved under the split-class approach. A substantial number of catalysts are presently purchased from suppliers, so the catalysts production requirement for Classes IIB and III trucks can likely be satisfied with existing surplus LDT production capacity, either on the part of the engine manufacturers or their suppliers.* Little, if any, additional tooling costs would be incurred.

Similarly, a number of HDGEs share tooling with LDT engines, and many of the modifications necessary to burn unleaded gasoline, estimated in the original FRM as costing $29.4 million, either have already been made or can easily be incorporated from LDT components. However, assuming the worst case in which all Classes IIB and III engine families would require tooling for engine modifications, not all of the $29.4 million would be incurred. It is estimated that in 1987, seven engine families will fall into the Classes IIB-III category, and four engine families will fall into the Classes IV-VIII category.[27] This estimate assumes that two new families will be created due to catalyst versus non-catalyst applications of certain engine configurations. Of the seven engine families in the Classes IIB and III category, one GM and two Chrysler families would likely require no further tooling or equipment for engine modification to burn unleaded fuel, so four families are used to compute the engine modification tooling cost. Using EPA's estimate of about $4.09 million per engine family,[7] the total engine modification tooling cost would be $16.4 million.

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* LDT sales declined some 45 percent between 1979 and 1981, for a decrease in absolute numbers of trucks sold of about 1.1 million units annually. Since LDT sales are down significantly, excess capacity (about 1 million units) for production of oxidation catalysts exists for Classes IIB and III HDGVs. A study by an EPA contractor has also indicated the existence of considerable excess catalyst production capacity in the industry.[28]

Some tooling costs will be incurred for stainless steel exhaust systems and chassis heat shield production. EPA estimates these costs at $1.8 million (see Table 1-5), although here, too, some LDT components may be adaptable. Adding all these costs results in a total of $18.2 million for tooling costs as shown in Table 1-13.

2. Research and Development Costs

Because of the use of catalyst technology in the LDT area and the basic similarity of the applications, transfer of this technology to the two lightest HDGV GVW classes should be relatively straightforward. Some of these heavy-duty trucks (manufactured by Chrysler), in fact, already use catalysts. The bulk of the $33.7 million expense originally projected for the original FRM was expected to be incurred for developing catalysts suitable for the heavier vehicle/engine applications and for addressing any worst case catalyst durability problems that might arise. The 1987 split-class approach should make that expenditure unnecessary.

With respect to durability testing expenses, some manufacturers may run test fleets to 110,000 miles to ensure catalyst durability in these applications. In most cases, however, EPA projects that shorter distances of mileage accumulation will be needed, and will be used only to verify dynamometer testing of catalyst durability and the worst case durability of vehicle-related components. The cost per vehicle (1983 dollars) of such a test fleet would likely include:[29,30]

Prototype vehicle	$ 16.4K
Engineering Supervision	$ 24.6K
Mileage accumulation to 110,000 mi (incl. maintenance and overhead)	$424K
32 test at $580 each	$ 25.3K
Total	$490K per vehicle

Assuming two vehicles per engine family and seven Classes IIB and III engine families, the total cost is estimated to be $6.9 million. Discounted at 10 percent per year to January 1987 (the beginning of the first model year the catalyst standards are effective), and assuming that such testing would occur about a year prior to the 1987 model year, the cost becomes $7.5 million. This cost represents an upper limit as it is likely that some engine families will not have to be tested for catalyst durability, and that most, if not all, of the durability assessments will be performed on engine dynamometers.

Table 1-13

Capital Costs of the 1987 and Later
1. HDGE Emission Standards (1983 dollars)

Pre Production R&D	$6.9M
Tooling:	
Engine/Component Modifications	$16.4M
Stainless Steel Exhaust	$1.8M
Certification	$1.5M
Total	26.6M

3. Certification Costs

The original FRM divided certification costs into two categories: deterioration factor (DF) determination and testing of a representative selection of emission-data engines at the 125-hour service accumulation point. Although the manufacturers are not constrained to determine DFs through durability testing, it is anticipated that the costs for whatever method they use will not be significantly different from costs of the current method. The regulatory analysis to the original FRM provided estimates of these costs at $122K and $39K,[1] respectively, assuming that three emission data engines from each family would be tested at the 125-hour point. Adjusting these costs to 1983 dollar levels results in costs of $164K and $52K for DF determination and emission-data testing. Assuming that all seven Classes IIB and III engine families from three manufacturers are likely to be involved, the total cost should run about $1.5 million (undiscounted). The discounted cost would be $1.7 million if discounted to January 1987 using a 10 percent discount rate, and assuming that emission durability testing begins one year prior to 1987 model year production. The cost would be less if fewer engine families are certified or if manufacturers extrapolate their DFs from the results of the test fleets.

4. Emission Control System Costs

Table 1-14 presents the estimated emission control hardware costs for Classes IIB and III vehicles. Catalyst cost is based on the estimated average cost of the best Ford and GM LDT oxidation catalysts and current Chrysler HDGE catalysts.* A stainless steel exhaust system and chassis heat shielding will be required. Some modifications will be necessary to run the engines on unleaded fuel (i.e., valve seat inserts and hardened valve stems/guides). A fuel restrictor for the fuel tank will also be required. The total hardware costs are estimated to be $151 per engine.

Compliance with the idle emission standard is achieveable at little or no cost increase when catalytic converter technology is used.

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* In some worst case situations, or perhaps for convenience sake, some manufacturers may choose to use dual conventional LDT catalysts rather than developing a system for their HDGEs. In this case, the use of two conventional catalysts would increase hardware costs by not more than $93.

Table 1-14

Per Vehicle Cost of Control for 1987 and Later Classes IIB-III HDGVs over 1985-86 Costs[1]

Development and Hardware:	
Oxidation Catalyst	$ 93
Stainless Steel Exhaust System	26
Engine Modifications - Unleaded Fuel	18
Chassis Heat Shields	11
Fuel Restrictor	3
	$151
Proveout and Certification	$ 4
Subtotal	$155
Operating and Maintenance:	
Savings due to fewer exhaust system and spark plug replacements	$-232[2]
Unleaded fuel at $0.03/gal.	$186[2,3]
Total[4]	$-46
Total Cost per Vehicle	$109

[1] Including manufacturer profit and overhead applied at a rate of 29 percent of cost.

[2] Includes 8 percent adjustment for those Chrysler HDGVs already using unleaded fuel. Spark plug and exhaust system savings would be $252 and the fuel differential cost would be $218 if Chrysler has no product offerings in Classes IIB and III which use unleaded fuel in 1985-86.

[3] At $0.05/gallon fuel differential, the cost would be $309 with the 8 percent adjustment for HDGVs already using unleaded fuel.

[4] Fuel economy savings are estimated to be 7-10 percent over current fuel consumption, or a savings of $819-1,170 during the lifetime of a HDGE. These savings will not change under the split-class approach or the original FRM.

5. Operating and Maintenance Costs

Costs to the operator will rise when an HDGV is equipped with a catalyst because of the use of unleaded gasoline. The additional costs are largely dependent on the price differential between leaded and unleaded fuel. (EPA has normally calculated these costs at a price differential of $.03 per gallon, which has been projected as likely for the mid-1980's.) The average fuel economy for Classes IIB and III trucks is about 12.4 miles per gallon.* Therefore, the increase in operating costs due to use of unleaded gasoline will be $202 (discounted to year of vehicle purchase using a 110,000 mile average lifetime over eight years).[2] This increase is offset by a decrease in maintenance costs due to improved spark plug and exhaust system longevity as a result of using unleaded gasoline. EPA estimates a savings of $252 per engine in this area. The net difference in operating costs should then represent a savings of $50 per engine over the costs that would be incurred under non-catalyst standards. Since some Classes IIB and III HDGVs (some of the Chrysler vehicles) currently use catalyst technology, these savings/costs should be reduced by 8 percent proportionally from a savings of $50 to a savings of $46, assuming those HDGVs presently using unleaded fuel continue to do so in 1985 and 1986. These costs are summarized in Table 1-14.

6. Aggregate Costs of 1987 and Later Split-Class Approach

The aggregate cost period of mobile source regulations is typically taken as the first five years following the effective date of the regulation. Thus, the period of interest for this entire regulation (i.e., the combined interim standards and split-class approach) is 1985-89. Since the aggregate costs of the first two years, or the interim period, have already been calculated (see Table 1-10), aggregate costs for remaining three years, 1987-89, need to be determined here for the split-class approach.

The aggregate cost of incorporating catalysts on Classes IIB and III vehicles can be calculated by multiplying the

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* The move to catalyst standards should not change the fuel economy experienced by Classes IIB and III HDGVs relative to the levels seen under the interim standards. However, the actual lifetime dollar savings will be slightly greater because the fuel saved will be unleaded fuel, which is $.03 more expensive than leaded fuel in this analysis.

expected lifetime cost per vehicle ($109) by the expected sales of Classes IIB and III HDGVs for 1987-89. The expected Classes IIB-III sales should not include those vehicles which are likely to be reclassified as Classes IV-VIII vehicles as mentioned earlier in this section.

Table 1-15 summarizes the aggregate cost calculations for the split-class approach. Discounted at 10 percent to 1985, the first year of the entire regulation, the aggregate cost is $61 million. The total discounted 5-year aggregate cost of this regulation is the interim standard cost of $86 million (Table 1-11) plus the $61 million just determined for 1987-89, or $147 million.

B. Savings Due to Implementation of the Split-Class Approach

The savings due to the split-class approach will result from deferral of the catalyst technology requirements in Classes IV through VII gasoline-fueled vehicles.

The split-class approach will eliminate much of the capital costs identified in the original FRM. R&D and tooling costs for upgraded catalytic converters are the primary costs that would be reduced or eliminated. However, some investments will still be necessary under the split-class approach. These investments would include $18.2 million for catalytic converter tooling, $6.9 million for pre-production R&D, and $1.5 million for certification (see Table 1-13). However, while capital costs are necessary under the split-class approach, there is still a net savings of $40.1 million under the combined interim standards and split-class approach when compared to the original FRM. Thus, most of the savings that were already accounted for under the interim standards are maintained under the split-class approach.

The savings compared to the original FRM in vehicle price and maintenance costs of Classes IV through VIII HDGVs are shown in Table 1-16. The development, hardware, and certification savings are inflated to 1983 from those figures presented in the staff paper.[2] The operating and maintenance savings are also taken from the staff paper, with a fuel differential of 3 cents per gallon assumed. The total lifetime savings for Classes IV-VIII vehicle are $715 because catalysts are not required.

The aggregate savings compared to the original FRM are simply the lifetime costs per vehicle that were expected to have occurred multiplied by the Classes IV-VIII gasoline-fueled vehicle sales from 1987-89. (The years 1987-89 are relevant

Table 1-15

Aggregate Costs to the Nation: 1987 Split-Class Approach

Category of Costs	Costs of Split-Class Approach
Costs per Class IIB-III Engine:	
First Price Increase	$155
Operating/Maintenance Cost	-46[1]
Total per Engine	$ 109
Projected Sales 1987-89[2]	751,618
Aggregate Costs (present value in 1985)[3]	$61M

[1] Fuel consumption savings over present engines will continue, but no further improvement is expected over interim standards.

[2] The years 1987-89 are the years of interest, since they are still within the first five years of this rulemaking (the number of years typically used for determining aggregate costs), which begins in 1985 with the interim standards. The 1987-89 projections include projected reclassifications where 5 percent of Classes IIB and III vehicles will be allowed to be exempt from meeting the statutory standards.

[3] Discounted at 10 percent to 1985, the first year of the interim standards.

Table 1-16

Per Vehicle Savings Due to Implementation of Non-Catalyst Standards for Classes IV-VIII Gasoline-Fueled Heavy-Duty Vehicles

Development and Hardware:	
Oxidation Catalyst	$373
Chassis Heat Shields	$ 11
Stainless Steel Exhaust	$ 26
Converter Protective System	$ 21
Unleaded Fuel Engine Modifications	$ 18
Fuel Restrictor	$ 3
R&D	$ 94
	$546
Proveout and Certification	$ 4
Subtotal	$550
Operating and Maintenance:	
Savings due to fewer exhaust system and spark plug replacements	-$232[1]
Unleaded fuel at $0.03 per gallon	$397[1][2]
Subtotal	$165
Total Savings per Vehicle	$715

[1] Includes 8 percent adjustment for those Chrysler HDGVs already using unleaded fuel. The spark plug and exhaust pipe savings and the fuel differential cost would be -$252 and $469, respectively, if Chrysler has no product offerings in these weight classes.

[2] At a fuel differential of $0.05/gallon, the cost would be $661, including the 8 percent adjustment for those HDGVs already using unleaded fuel.

years for which to determine aggregate savings because they are the last three years within the first five years of the effective date of this regulation.) The aggregate savings compared to the original FRM, discounted at 10 percent to 1985, or the first year of this regulation (i.e., the first year of the interim standards), would be $177 million (see Table 1-17).

VI. Savings of Combined Interim Standards/Split-Class Approach Over the Original FRM

A. Capital Cost Savings

The net capital cost savings for the two sets of standards promulgated under this entire rulemaking are simply those costs that would have been expended under the original FRM less those costs expected to be spent under the combined interim standards/split-class approach. Table 1-18 summarizes the net savings, which is estimated to be $40.1 million.

B. Savings in Cost to Consumer

The savings that would be passed on to the consumer include those savings from the purchase price and operating costs. This savings is the difference in the estimated cost of the original FRM and the estimated cost of the interim standards and split-class approach. The net savings is shown in Table 1-19.

The first price increase estimated for the original FRM was $383, and that estimated for the interim standards was $113. For the split-class approach, the estimated cost should be a fleetwide weighted average cost, determined by once again assuming that about 70 percent of all HDGVs fall into the Classes IIB-III category in 1987 (based upon sales projections shown in Table 1-1). The first price increase of Classes IIB-III vehicles was estimated to be $155 (Table 1-14), and 70 percent of this is $110. Therefore, the average fleetwide savings in the first price increase is $383 less $113 and $110, or $160 as summarized in Table 1-19.

Operating costs under the original FRM are shown in Table 1-4. Briefly reviewing, these costs include $249 for using unleaded fuel instead of leaded fuel, less a savings of $232 due to fewer exhaust system and spark plug replacements. The net operating cost is $17. (Note that savings arising from the projected fuel economy benefit are not presented because they are expected to be comparable with those achieved with interim standards and the split-class approach.)

Table 1-17

Aggregate Per Vehicle Savings to the Nation Due to Implementation of Non-Catalyst Standards for Class IV-VIII Gasoline-Fueled Heavy-Duty Vehicles[1]

1.	Costs per engine	$550
	Net operating/maintenance costs	$165
	Total per engine	$715
2.	Estimated Sales 1987-89[2]	328,544
	Total Discounted savings[3]	$177 million

[1] Relative to the December 1979 FRM requirement.
[2] Includes reclassified Classes IIB and III HDGVs.
[3] Discounted at 10 percent to 1985, the first year of the interim standards.

Table 1-18

Capital Cost Savings of Combined
Interim Standards and 1987 and Later
Split-Class Approach (millions of dollars)

	Original FRM	Interim Standards	Split-Classes Approach	Undiscounted Savings
Tooling	$99.6M	$65.9M	$18.2M	$15.5M
R&D:				
Heavy-duty catalyst	$24.9M	--	--	$24.9M
Preproduction	$8.8M	$0.7M	$6.9M	$1.2M
Certification	$2.0M	$2.0M	$1.5M	-$1.5M[1]
Total	$135.3M	$68.6M	$26.6M	$40.1M

[1] A negative savings is actually an additional cost of the combined interim standards and split-classes approach. It occurs here, because of the additional round of certification asssociated with the interim/split classes approach instead of just one with the original FRM.

Table 1-19

Savings to Consumer of Combined Interim Standards and 1987 and Later Split Classes Approach Compared to the Original FRM

	Original FRM	Interim Standards	Split Classes Approach[1]	Savings
1. First Price Increase	$383	$113	$110	$160
2. Operating Costs:				
Unleaded Fuel Differential	$249	--	$130	$119
Exhaust System and Spark Plug Savings	-$232	--	-$162	-$70[2]
Emission-Related Maintenance	--	$ 20	--	-$20
Total Operating	$17	$20	-$32	$29
3. Total Cost to Consumer:				
First Price Increase	$383	$113	$110	$160
Operating Costs	$17	$20	-$32	$19
	$400	$133	$78	$189

[1] Weighted average cost for total gasoline-fueled vehicle fleet.

[2] A negative savings is actually a cost to the combined interim standards and split-class approach.

For the interim standards, the operating cost was estimated to be $20 for maintenance of emission control components. For the split-class approach, the net operating costs were determined to be a savings of $46 for Classes IIB and III HDGVs, because the savings due to fewer spark plug and exhaust system replacements was greater than the additional cost of burning unleaded as opposed to leaded fuel. Since only Classes IIB and III HDGVs will incur these savings, the fleetwide average savings would be 70 percent of $46, or $32.

When all of the operating costs of the combined interim standards and split-class approach are compared to the original FRM, the net savings is $29. This savings is also shown in Table 1-19.

Finally, the total savings to the consumer by implementing the interim standards and split-class approach instead of the original FRM, is simply the first price savings of $160 plus the net operating savings of $29. The total savings amounts to $189.

C. Savings in Aggregate Costs

The savings in aggregate costs of this regulation over the original FRM are simply the savings determined earlier for the interim standards (Table 1-12) and those savings determined for Classes IV-VIII vehicles (Table 1-17). The sum of these savings is $349 million, which covers the first five years of this regulation. All aggregate costs are discounted at 10 percent to 1985, the first year of this regulation. These costs are summarized in Table 1-20.

Table 1-20

Aggregate Cost Savings to the
Nation Due to Interim Standards and
1988 Split-Classes Approach (discounted)

Interim Standard Savings[1]	$172M
Split-Class Savings 1988-89[2]	$177M
Total Aggregate Savings	$349M

[1] See Table 1-12
[2] See Table 1-17.

References

1. "Regulatory Analysis and Environmental Impact of Final Emission Regulations for 1984 and Later Model Year Heavy-Duty Engines," U.S. EPA, OMS, ECTD, SDSB, December 1979.

2. "Detailed Information on Sales, Costs of Control, and Emission Control Benefits Used in Cost Effectiveness Analysis," addendum to "Staff Report, Issue Analysis - Final Heavy-Duty Engine HC and CO Standards," U.S. EPA, OANR, OMS, ECTD, SDSB, March 1983.

3. "Draft Regulatory Support Document, Revised Gaseous Emission Regulations for 1984 and Later Model Year Light-Duty Trucks and Heavy-Duty Engines," U.S. EPA, OANR, OMS, ECTD, SDSB, September 1981.

4. "Index of Truck Prices in the Producer Price Index," Bureau of Labor Statistics, U.S. Department of Labor.

5. MVMA Motor Vehicle Facts and Figures 1982, Motor Vehicle Manufacturers Association, 1982.

6. Data Resources U.S. Long-Term Review, Summer 1982, Data Resources, Inc., 1982.

7. Financial Analysis of the HDGE Manufacturers, Prepared For EPA by Jack Faucett Associates, pp. 38-40, August 1982.

8. "Motor Vehicles Industry Status Report," Jack Faucett Associates, p. 4, November 1982.

9. Automotive News, p. 1, October 18, 1982.

10. Ward's Automotive News, p. 2, February 14, 1983.

11. Ward's Automotive News, p. 7, February 28, 1983.

12. Ward's Automotive News, p. 10, December 27, 1982.

13. See pp. 31-32 of [7] above.

14. Ibid, p.33.

15. See Table V-DD of [1] above.

16. Ibid, p. 5.

References (cont'd)

17. "Summary and Analysis of Comments to the NPRM for Revised Gaseous Emission Regulations for 1984 and Later Model Year Light-Duty Trucks and Heavy-Duty Engines," U.S. EPA, OANR, OMS, ECTD, SDSB, May 1983.

18. Ibid, p.24, 28.

19. Ibid, p. 16.

20. Ibid, pp. 7 and 8.

21. EPA Memorandum, Tooling Cost Calculations for HDGE Emission Control Components, From G. Passavant, U.S. EPA, OANR, OMS, ECTD, SDSB to Public Record.

22. Several HDGE models use automatic chokes, EGR, EFE, dual air pumps, etc.

23. Public Docket No. OMSAPC-78-4.

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

25. "Cost Estimations for Emission Control Related Components/Systems and Cost Methodology Description: Heavy-Duty Trucks," EPA-460/3-80-001, February 1980.

26. The labor anticipated over the vehicle lifetime is 1 hour or less.

27. "Staff Report: Issue Analysis - Final Heavy-Duty Engine HC and CO Standards," U.S. EPA, OMS, ECTD, SDSB, March 1983.

28. "Financial Analysis of HDG Engine Manufacturers and Catalytic Converter Component Suppliers," Draft Report, Prepared for EPA by Jack Faucett Associates, p. 9, July 9, 1982.

29. "Issue Paper: Heavy-Duty Durability Testing," Docket No. A-80-81.

30. "Regulatory Analysis and Environmental Impact of Final Emission Regulations for 1984 and Later Model Year Light-Duty Trucks," U.S. EPA, OMS, ECTD, SDSB, p. 72, 1980.

CHAPTER 2

ENVIRONMENTAL IMPACT

In this rulemaking, certain provisions of HC and CO emission regulations for 1985 and later model year HDEs originally promulgated in late 1979 are being revised. This chapter examines the effect these changes may have on the amount of HC and CO emitted from HDEs and how this relates to air quality. This analysis does not discuss the health and welfare aspects of ozone or CO. Such reviews are available from other sources and are beyond the immediate requirements of this analysis. Reference [1] identifies EPA documents dealing with ozone and CO effects.

In doing this analysis, three scenarios are considered. The first scenario forms a reference or base case derived by assuming that the 1984 HDE provisions as finalized in EPA's January 12, 1983 action (48 FR 1406) continue indefinitely rather than reverting to the statutory standards. This means that the current steady state standards are carried over, and implementation of Selective Enforcement Auditing (SEA) is delayed until 1986. The second and third scenarios represent, in order of increasing stringency, the provisions implemented by this rulemaking, or implementation of the full statutory standards in 1985, respectively. It should be noted that Scenario 3 represents the standards and effective dates that would be required if no new revisions were adopted.

In this context, the first scenario provides a reference point from which to measure improvements brought about by the new regulatory provisions of either of the two "control scenarios." It is not itself being evaluated as a regulatory option, since it does not represent a viable future control strategy. Details of the emission standards, SEA provisions and useful-life provisions for all three scenarios are given in Table 2-1.

The focus of the discussion in the remainder of this chapter will be on the emission reductions and air quality impacts of this final rulemaking (Scenario 2) relative to the base case (Scenario 1), in which the HDE emissions standards effective for the 1979-84 model years remain unchanged, and to the 1985 and later statutory standards (Scenario 3), the standards that would be effective were they not being revised.

I. Emission Rates and Lifetime Emissions

A. Introduction

One form of expressing the potential environmental impact of a regulatory action is calculation of the changes in the

Table 2-1

Description of Scenarios for Control of Heavy-Duty HC/CO Emissions

Scenario	Description	HDGE Standards[1] Model Year	HC	CO	UL	AQL[2]	HDDE Standards Model Year	HC	CO	UL	AQL[2]
1	Base case. No change in standards in effect for MY 1979-83.	84-85	Carryover from 83[3]				84-85	Carryover from 83[3]			
		86+	1.5	25	half	40%	86+	1.5	25	half	40%
2	Standards promulgated in this rulemaking. HDDEs: statutory standard in 1985+. HDGEs: interim standards for 1985-87; for 1988+, statutory standards for Classes IIB-III, interim standards for IV-VII. For all HDEs: transient test (1985+).	84	Carryover from 83[3]				84	Carryover from 83[3]			
		85	2.5	40	full	none	85	1.3	15.5	full	none
		86	2.5	40	full	40%	86+	1.3	15.5	full	40%
			Classes IIB and III								
		87+	1.3	15.5	full	40%[4]					
			Classes IV-VIII								
		87+	2.5	40	full	40%					
3	Standards promulgated in original HDE rulemaking. Statutory standards and transient test cycle are in effect for 1985 and beyond.	84	Carryover from 83				84	Carryover from 83			
		85	1.3	15.5	full	none	85	1.3	15.5	full	none
		86+	1.3	15.5	full	40%	86+	1.3	15.5	full	40%

[1] Standards for LDVs and LDTs for each scenario are those standards already promulgated for 1983 and later. Note that this rulemaking will affect the useful life provision for LDTs, changing it from half life (in scenario 1) to full life (in scenarios 2 and 3).

[2] Last four column entries are: HC standard (g/BHP-hr), CO standard (g/BHP-hr), useful life, and SEA acceptable quality level.

[3] Standards are: 1.5 g/BHP-hr HC and 25 g/BHP-hr CO, with half-life useful life and no requirements for AQL in effect, using the steady-state test procedure.

[4] Catalyst required.

per-vehicle emission rates and lifetime emissions which the action is projected to produce. The per-vehicle emission rates are expressed in terms of grams of pollutant emitted per mile (g/mi), while per-vehicle lifetime emissions are expressed in terms of tons of pollutant emitted over the lifetime of the vehicle. By combining the per-vehicle emission rates with the useful life of the vehicle, estimated lifetime emissions can be calculated.

Explanatory remarks concerning the calculation of emission rates and lifetime emissions are presented below, followed by the results for HC and CO HDGE emissions, and then for HDDE HC emissions. (Diesel engine CO emissions are well below even the statutory HDE standard of 15.5 g/BHP-hr, so neither the revisions implemented by this final rule nor the statutory CO standard will have any impact on HDDE CO emissions. Therefore, no analysis of HDDE CO emissions is required.)

B. Methods of Calculation

The emission rate calculations used for these analyses are those produced by the EPA computer model generally known as "MOBILE 2.5." Since the mechanics of this model are already well established, they will not be discussed in detail here. Citations for background information on this model are given in Reference [2]. Instead, a general overview of the process will be given, along with identification where appropriate of specific assumptions used in this analysis.

MOBILE 2.5 is based on a broad base of data on the emission characteristics of in-use vehicles. Considerable work has been done within EPA in an attempt to determine accurate emission factors for mobile sources. This work depends heavily on in-use vehicle testing under EPA's Emission Factor Progrm. To answer the question of how well vehicles perform in actual use, EPA has administered a series of exhaust emission surveillance programs. Test fleets of consumer-owned vehicles within various major cities are selected by model year, make, engine size, transmission, and carburation type in such proportion as to be representative of both the normal production of each model year and the contribution of that model year to total vehicle miles traveled. These programs have focused principally on light-duty vehicles and light-duty trucks.

The data collected in these programs are analyzed to provide mean emissions by model year vehicle in each calendar year, change in emissions with the accumulation of mileage, change in emissions with the accumulation of age, and effect on emissions of vehicle parameters (engine displacement, vehicle weight, etc.). This surveillance data, along with prototype vehicle test data, assembly line test data, and technical judgement, form the basis for the existing and projected mobile source emission factors.

For the purposes of this HDE analysis, it is pertinent to note that the HDE emission factors draw significantly on the LDV and LDT data base for estimating in-use deterioration rates for emission control systems. The LDV/LDT data base has a large amount of information on the in-use performance of control systems of the types being used on current HDEs and anticipated to be used for future engines. In contrast, there is relatively little data available on such systems in actual use on HDEs.

The general form of the mobile source emission factor equations is that of a new vehicle, or zero mile (ZM), emission rate plus a mileage dependent deterioration rate (DR). Mathematically, emissions as a function of ZM and DR can be expressed as:

Emission Rate = ZM + DR (miles/10,000)

The ZM level corresponds to EPA's estimate of manufacturers' designed target emission levels in response to any given emission standard plus, in the case of catalyst vehicles, a correction for the effects of misfueling on new or nearly new engines. Manufacturer's target levels are themselves affected by the presence of an SEA program and the useful-life requirements for certification. Both SEA and full-life useful life lead to the lowering of emission target levels for new engines.

The DR expresses the rate per 10,000 miles at which in-use emissions are expected to increase, due to all causes. This includes not only the deterioration of emissions experienced by even well maintained engines, but also the effects of such things as component failures, inadequate maintenance or tampering with emissions control systems. DRs are derived from consideration of the data available on actual performance of various technology types in-use. In addition, the adoption of full-life useful life will lead to improved in-use performance and has therefore been accounted for in developing DRs.[2d]

There are two aspects of the regulatory provisions which can be expected to affect emissions indirectly, but which have not been specifically included in this analysis. First, in anticipation of the new SEA provisions beginning in 1986, some manufacturers may certify their 1985 engines at levels low enough to comply with SEA provisions even though they will not yet be specifically required to do so. The result of this anticipated practice is that actual HDE emission rates for 1985 engines should be slightly lower than would be expected if no future SEA were required. However, there is no easy way to quantitatively determine the potential decrease in emissions. Therefore, EPA did not attempt to account for this effect in the calculations of emission rates, and the actual per-vehicle emission rates for 1985 HDEs may be slightly lower than the emission rates projected under this analysis. Second, the transient test procedure will become mandatory in 1985. Because of this, some manufacturers are likely to use the optional transient procedure in 1984, certifying at levels low enough to be carried over to 1985. This too will have the effect of lowering emission rates for some engines. Once again, however, EPA did not attempt to incorporate these effects into its calculations on vehicle emission rates, because there was no easy way to accurately measure them.

The remainder of this section will discuss emission rates and lifetime emissions separately for HDGVs and HDDVs. This will be done for each scenario, using the emission standards and accompanying useful life and SEA requirements shown in Table 2-1.

C. Heavy-Duty Gasoline-Fueled Engines (HDGEs)

In order to calculate lifetime HDGE emissions, the expected vehicle lifetime mileage, the DR, and the zero-mile emission rate (ZM) must be known. EPA's analysis of available data on useful-life indicates that the expected vehicle lifetime for HDGEs is 110,000 miles. The derivation of this value can be found in the Summary and Analysis of comments document accompanying this rulemaking.[3] The ZMs and DRs differ for each type of emission and for each model year. A summary of the ZMs and DRs as developed using MOBILE 2.5 is shown in Tables 2-2 and 2-3 for each scenario. The emission rates are shown for both low and high altitude, but most of the remaining discussion will focus on the low-altitude emissions.

1. Hydrocarbon Emissions

The lifetime HDGE HC emissions calculated from the inputs in the tables under each scenario are shown in Table 2-2. Also shown are the percent changes in emissions relative to the base case. For the 1984 model year, the lifetime HC emissions are the same for all scenarios. This is because the 1984 emission standards are simply a carryover from the 1983 model year under all scenarios. For the 1985 and 1986 model years, the average lifetime emissions under this rulemaking (Scenario 2) are between 27 and 28 percent less than under the base case due to the implementation of the interim standards. In 1987 and beyond, this rulemaking would reduce average lifetime emissions of HDGEs by about 40 percent (at low altitude). For Classes IIB-III vehicles, or light heavy-duty gasoline engines (LHDGEs), the vehicle lifetime emission is reduced by 48 percent for 1987 and later compared to the base case.

Table 2-2

HDGE HC Emission Rates

Scenario	Model Year	Zero-Mile Level (ZM) (g/mi)	Deterioration Rate (DR) (g/mi/10,000 mi)	Per Vehicle Lifetime Emissions (tons)	Percent Reduction Relative to Base Case
			Low Altitude		
1	84-85	5.06	0.32	0.826	
	86+	4.45	0.32	0.752	
2	84	5.06	0.32	0.826	0%
	85	4.09	0.16	0.603	27.0%
	86	3.60	0.16	0.543	27.8%
	87+				
	LHDGEs*:	1.44	0.32	0.388	48.4%
	All HDGEs:	2.38	0.25	0.455	39.5%
3	84	5.06	0.32	0.826	0%
	85	1.64	0.32	0.412	50.1%
	86+	1.44	0.32	0.388	48.4%
			High Altitude		
1	84-85	6.90	0.32	1.049	
	86+	6.07	0.32	0.949	
2	84	6.9	0.32	1.049	0%
	85	5.57	0.16	0.782	25.5%
	86	4.91	0.16	0.702	26.0%
	87+				
	LHDGEs*:	2.58	0.32	0.526	44.6%
	All HDGEs:	3.60	0.25	0.603	36.5%
3	87	6.90	0.32	1.049	0%
	85	2.94	0.32	0.569	45.8%
	86+	2.58	0.32	0.526	44.6%

* HDGEs belonging to Classes IIB and III vehicles only.

Table 2-3

HDGE CO Emission Rates

Scenario	Model Year	Zero-Mile Level (ZM) (g/mi)	Deterioration Rate (DR) (g/mi/10,000 mi)	Per Vehicle Lifetime Emissions (tons)	Percent Reduction Relative to Base Case
		Low Altitude			
1	84-85	174.96	8.37	26.77	
	86+	138.22	8.37	22.32	
2	84	174.96	8.37	26.77	0%
	85	66.64	3.98	10.73	59.5%
	86	52.65	3.98	9.04	59.5%
	87+				
	LHDGEs*:	14.06	2.64	3.47	84.5%
	All HDGEs:	30.90	3.23	5.90	73.6%
3	84	174.96	8.37	26.77	0%
	85	17.80	2.64	3.92	85.4%
	86+	14.06	2.64	3.47	84.5%
		High Altitude			
1	84-85	324.55	8.37	44.89	
	86+	256.40	8.37	36.64	
2	84	324.55	8.37	44.89	0%
	85	123.62	5.98	18.98	57.7%
	86	97.67	5.98	15.83	56.8%
	87+				
	LHDGEs*:	44.74	2.64	7.19	80.4%
	All HDGEs:	67.84	3.23	10.38	71.7%
3	84	324.55	8.37	44.89	0%
	85	56.64	2.64	8.63	80.8%
	86+	44.74	2.64	7.19	80.4%

* HDGEs belonging to Classes IIB and III vehicles only.

Scenario 3 shows reductions of about 50 percent for 1985 and about 48 percent for 1986 and beyond, due to the implementation of statutory standards. These reductions are greater than those achieved under Scenario 2, as would be expected. However, beginning in 1987 and beyond the difference in reductions between Scenarios 2 and 3 is relatively small, being about one-fourth as large as the difference in reductions between Scenario 2 and the base case.

2. CO Emissions

The lifetime HDGE CO emissions under each scenario are shown in Table 2-3. Also shown are the percentage reduction of lifetime emissions of Scenarios 2 and 3 relative to the base case.

In general, the reductions of CO emissions when compared to the base case follow the same pattern as that for HC emissions. Scenario 2 shows significant reductions beyond the 1985 model year, particularly for 1987 and later. Scenario 3 shows even greater reductions for 1985 and beyond. The differences in average reductions of all HDGEs between Scenarios 2 and 3 is not large (10-25 percent) when compared to overall reductions of Scenario 2 relative to the base case (60-74 percent).

D. Heavy-Duty Diesel Engine HC Emissions

For HDDEs the statutory standards are implemented in 1985 under both Scenarios 2 and 3. Therefore, Scenarios 2 and 3 are identical and there is no loss of benefits for Scenario 2 compared to Scenario 3. The following discussion applies equally to both scenarios.

The lifetime HC emissions for HDDEs are determined as done for gasoline engines. An average lifetime of 350,000 miles is used, reflecting the fact that most HDDs belong to the heavier classes where long-haul travel predominates. The deviation of this value can be found in the public docket.[4] The ZM and DR values are shown in Table 2-4.

For 1985, no significant emission reductions are shown in Table 2-4. This is because in the air quality model being used here the statutory standards will not, by themselves, cause enough of a change in average fleetwide HDDE emissions to change the model output until the adoption of SEA in 1986. Emission reductions for 1986 and later are estimated to be about 12 percent at low-altitude and 13 percent at high-altitude when compared to the base case.

Table 2-4

HDDE HC Emission Rates

Scenario	Model Year	Zero-Mile Level (ZM) (g/mi)	Deterioration Rate (DR) (g/mi/10,000 mi)	Per Vehicle Lifetime Emissions (tons)	Percent Reduction Relative to Base Case
			Low Altitude		
1	84+	3.49	0.05	1.682	
2	84-85	3.49	0.05	1.682	0%
	86+	2.98	0.05	1.486	11.7%
3	84-85	3.49	0.05	1.682	0%
	86+	2.98	0.05	1.486	11.7%
			High Altitude		
1	84+	8.03	0.05	3.432	
2	84-85	8.03	0.05	3.432	0%
	86+	6.85	0.05	2.978	13.2%
3	84-85	8.03	0.05	3.432	0%
	86+	6.85	0.05	2.978	13.2%

II. Emission Inventory

Whereas the previous section analyzed the per-vehicle HC and CO emission rates and lifetime emissions, this section will review projected changes in annual emissions over certain regions from the entire fleet. These projections were made using EPA's Modified Rollback II model which developes future emission inventory estimates based upon data on current emissions, expected future growth and replacement rates for various source categories, and anticipated source control programs.[5] The following discussion will describe the overall process of making these projections in general terms and then turn to discussion of the results.

The first step in the process is the selection of areas to be analyzed. In this analysis the geographical basis for analyzing HC and CO emissions will be different from those of past analyses where Air Quality Control Regions (AQCRs) and counties were used for analyzing HC and CO emissions, respectively. The effects of both HC and CO will here be measured over Standard Metropolitan Statistical Areas (SMSAs). SMSAs will be used because they represent well defined geographical areas which are being used as a consistent base for organization of EPA's air quality and emission inventory data bases. SMSAs are also a good compromise between large-scale regional areas necessary for measuring the effects of HC emissions and localized areas necessary for analyzing CO emissions.

The SMSAs selected for the HC analysis were those areas whose fourth highest daily maximum ozone hourly value (measured over the 1979-81 period) exceeded the NAAQS standard. This resulted in 88 low-altitude and two high-altitude SMSAs to be analyzed for HC emissions. The HC inventory analyzed is for non-methane HC since methane is non-reactive and does not contribute to ozone formulation.

The SMSAs selected for the CO analysis were those areas with the second maximum non-overlapping 8-hour average concentrations greater than the NAAQS level in at least two of three years (1979, 1980, or 1981). This selection process led to a set consisting of 59 low-altitude and eight high-altitude SMSAs.

Following the selection of areas to be analyzed, an emission inventory for each region was compiled for the most recent year for which the necessary information could be obtained (1980). Baseline emission rates for various source categories were taken from the National Emissions Data System along with projections for future control strategies and growth rates. This base year data was then used as the basis for future projections. Projections for future years are a complex process, but two assumptions underlying these projections are worth mentioning. One is that the I/M program will be in effect in all the areas analyzed. The other assumption concerns the projected growth rates. For the hydrocarbon analysis, a medium-growth rate was assumed, while for the CO analysis, a low-growth rate was assumed, out of a range from low growth to high growth. A medium-growth rate was selected for the HC analysis because HC emissions are a large-scale regional concern, and a medium-growth rate has been traditionally used to estimate the annual VMT growth rate. A low-growth rate has been used for the CO analysis because these emissions are a localized, urban area problem, where the vehicle miles traveled (VMT) is expected to grow slowly.

Projections for both emissions data and air quality data are made on a SMSA-by-SMSA basis. However, the underlying assumptions on emission factors are not region specific, but represent typical nationwide values. Because of this, only the average results for all regions will be used for this analysis.

Tables 2-5 and 2-6 show the annual HC and CO emissions under the three scenarios along with percent reduction figures calculated from the base case. For HC emissions, it can be seen that at low altitude reductions are in the 1 to 1-1/2 percent range, with Scenario 2 achieving almost as large a reduction as could be achieved by Scenario 3. At high altitude, reductions are in the 1-3 percent range, with reductions under Scenario 2 again being almost as great as those under Scenario 3. For CO emissions, reductions under Scenario 2 are about 12-18 percent when compared to the base case at low altitude. These reductions represent about 85 percent of the reductions that could be achieved under Scenario 3. At high altitude, the pattern is similar, with the reductions tending to be 1 or 2 percent greater than they were at low altitude.

III. Ambient Air Quality Analysis

Once projections of future emissions are prepared, the next step is to translate them into changes in ambient air quality. Two modeling methods were used to project future air quality improvements. The Modified Rollback II method discussed earlier was used for the CO analysis, while the Empirical Kinetic Modeling Approach II (EKMA II) was used for the ozone analysis.[6] The EKMA II procedure has been developed by EPA in an attempt to provide an improved analysis (compared to simple rollback) of the relationship between oxidant and precursor emissions while avoiding the complexity of many photochemical dispersion models.

It is important to realize that the use of any air quality model requires a great many simplifying assumptions. This is

Table 2-5

Total Non-Methane Hydrocarbon Emissions*
(1,000 tons/year)

Scenario	1985	1990	1995	2000
		Low Altitude		
1	6,218	6,036	6,274	6,706
2	6,213	5,983 (0.9%)**	6,194 (1.3%)	6,608 (1.5%)
3	6,213	5,974 (1.0%)	6,188 (1.4%)	6,605 (1.5%)
		High Altitude		
1	161	150	156	167
2	161	148 (1.3%)	152 (2.6%)	162 (3.0%)
3	161	147 (2.0%)	152 (2.6%)	162 (3.0%)

* Based on 88 low-altitude and two high-altitude SMSAs. I/M is assumed for LDVs and LDTs. A medium-growth rate in VMT is projected.

** Numbers in parentheses represent percent reduction of emissions from base case.

Table 2-6

Total CO Emissions (1,000 tons/year)*

Low Altitude

Scenario	1985	1990	1995	2000
		Low Altitude		
1	10,125	7,368	6,456	6,273
2	10,125	6,490 (11.9%)**	5,329 (17.5%)	5,170 (17.6%)
3	10,125	6,314 (14.3%)	5,177 (19.8%)	5,024 (19.9%)
		High Altitude		
1	1,085	668	534	516
2	1,085	595 (10.9%)	436 (18.4%)	415 (19.6%)
3	1,085	581 (13.0%)	424 (20.6%)	406 (21.3%)

* Based on 59 low-altitude and eight high-altitude SMSAs. I/M is assumed for LDVs and LDTs. A low-growth rate in VMT is projected.

** Numbers in parentheses represent percent reduction of emissions from base case.

especially true for the models used for this analysis because the detailed data base needed to run elaborate models is simply not available on a nationwide basis. This, of course, affects the model's abilty to predict future air quality accurately. The weakness in a model will have more impact on the absolute levels of future predictions than on relative changes from one modeling strategy to another, since the sources of error will tend to carry through and affect all strategies. Therefore, in this analysis the principal focus of discussion will be on the comparison of strategies and relative changes rather than on absolute levels of air quality.

The air quality data will be discussed in terms of average percent changes of ozone and CO concentrations from the base year (1979), number of areas which experience NAAQS violations, and the total number of NAAQS violations occurring in the selected areas. The following sections summarize the air quality projections from this rulemaking[7] and how they compare to the base case and to Scenario 3.

A. Ozone

The average change in ozone air quality as shown in Table 2-7 would improve by about 1 percent under Scenario 2 when compared to the base scenario at low altitude for the years 1990 and 2000. No improvement is shown for 1995. Scenario 3 does not show further improvement at low altitude. At high altitude, Scenario 2 shows a 1 percent improvement in 1995 and a 2 percent improvement for 2000, while Scenario 3 shows no additional improvement over Scenario 2.

Table 2-8 shows the estimated number of SMSAs which will experience NAAQS violations for ozone. As can be seen, Scenario 2 will reduce the number of SMSAs with violations by one in 1990 and three in 1995 at low altitude. Scenario 3 shows no further reductions in violations. In the year 2000, the total number of SMSAs with violations increases significantly from 1995 under all scenarios. This is because some SMSAs that were barely in compliance in previous years, are now in violation due to the expected growth in emissions from all sources. These projections indicate that more control of HC emissions will be needed in future years. Neither Scenario 2 or 3 will introduce enough control to reduce the number of SMSAs exceeding the ozone air quality standard by the end of the 1990s. At high altitude, neither Scenario 2 nor 3 is projected to bring the one violating area into compliance.

Table 2-9 shows the total number of NAAQS violations within the selected SMSAs (as distinguished from the number of SMSAs exceeding the standard). Scenario 2 reduces the total number of violations by three in 1990, five in 1995, and nine in 2000 when compared to the base case at low altitude.

Table 2-7

Average Percent Change in Ozone Air Quality*
(compared to base year, 1980)

Scenario	1985	1990	1995	2000
		Low Altitude		
1	-23	-24	-23	-19
2	-23	-25	-23	-20
3	-23	-25	-23	-20
		High Altitude		
1	-20	-23	-21	-17
2	-20	-23	-22	-19
3	-20	-23	-22	-19

* Based on 88 low-altitude and two high-altitude SMSAs. I/M is assumed for LDVs and LDTs. A medium-growth rate in VMT is projected.

Table 2-8

Estimated Number of SMSAs Above Ozone Standard*

Scenario	1985	1990	1995	2000
		Low Altitude		
1	29	22	27	40
2	29	21	24	40
3	29	21	24	40
		High Altitude		
1	1	1	1	1
2	1	1	1	1
3	1	1	1	1

* Based on 88 low-altitude and two high-altitude SMSAs. I/M assumed for LDVs and LDTs. A medium-growth rate in VMT is projected.

Table 2-9

Total Number of NAAQS Violations of Ozone Standard*

Scenario	1985	1990	1995	2000
		Low Altitude		
1	107	91	104	138
2	106	88	99	129
3	106	87	99	128
		High Altitude		
1	1	1	1	2
2	1	1	1	1
3	1	1	1	1

* Based on 88 low-altitude and two high-altitude SMSAs. I/M is assumed for LDVs and LDTs. A medium-growth rate in VMT is projected.

Scenario 3 would further reduce the number of violations by one for 1990, and 2000. At high altitude, Scenarios 2 and 3 reduce the number of violations by one for the year 2000 compared to the base case.

B. Carbon Monoxide

The average percent change in CO air quality as compared to the base year is shown in Table 2-10. Scenario 2 shows an improvement over the base case of 5 percent in 1990, and 6 and 5 percent in 1995 and 2000, respectively, at low altitude. Scenario 3 shows an additional 1 percent improvement in 1995 and 2000 when compared to Scenario 2. At high altitude, Scenario 2 shows a 4-5 percent improvement between the years 1990 and 2000. Scenario 3 would show an additional 1 percent improvement beyond Scenario 2 for 1995. Thus, the environmental improvement of Scenario 3 is small relative to the improvement of Scenario 2 over the base case.

Table 2-11 shows the SMSAs with NAAQS violations, and the total number of NAAQS violations of CO for those areas are shown in Table 2-12. At low altitude, no exceedences will occur under Scenario 2 after 1985, while the base case shows one area which violates the NAAQS in 1990. At high altitude, neither Scenario 2 nor 3 will have any effect because no exceedences are projected under the base case. Although the Rollback II model predicts that all low-altitude counties will come into compliance with the CO NAAQS under all control scenarios by 1995, caution must be used in interpreting these results in absolute terms. As mentioned earlier, the model better predicts relative change from strategy to strategy, and results from the model should be analyzed in this manner. Therefore, the indication that all low-altitude counties meet the standard is inconclusive. Inaccuracies of the Rollback II model can easily be large enough to change the absolute levels of predictions. However, such inaccuracies would probably be relatively constant from strategy to strategy, and lead to consistent relative effects. While no precise conclusions can be drawn about the overall level of attainment, it is likely that some reductions will take place, because average air quality levels would be improved by about 5-6 percent (at low altitude) under this rulemaking (see Table 2-10). The reductions that could be obtained under Scenario 3 would not be much larger.

IV. Lead Emissions

The use of non-catalyst technology for all HDGVs in 1985-86 and for Classes IV-VIII vehicles for 1987 and later will cause some loss of previously expected reductions in tailpipe lead emissions for HDGVs. Assuming a lead content of 1.1 grams per gallon for leaded fuel,[8] an average fuel

Table 2-10

Average Percent Change in CO Air Quality
(compared to base year - 1980)*

Scenario	1985	1990	1995	2000
	Low Altitude			
1	-53	-65	-69	-70
2	-53	-70	-75	-75
3	-53	-70	-76	-76
	High Altitude			
1	-49	-68	-74	-75
2	-49	-72	-79	-80
3	-49	-72	-80	-80

* Based on 59 low-altitude and eight high-altitude SMSAs. I/M is assumed for LDVs and LDTs. A low-growth rate in VMT is projected.

Table 2-11

Estimated Number of SMSAs Above CO Standard*

Scenario	1985	1990	1995	2000
		Low Altitude		
1	4	1	0	0
2	4	0	0	0
3	4	0	0	0
		High Altitude		
1	4	0	0	0
2	4	0	0	0
3	4	0	0	0

* Based on 59 low-altitude and eight high-altitude SMSAs. I/M is assumed for LDVs and LDTs. A low-growth rate in VMT is projected.

Table 2-12

Total Number of NAAQS Violations of CO Standard*

Scenario	1985	1990	1995	2000
		Low Altitude		
1	16	1	0	0
2	16	0	0	0
3	16	0	0	0
		High Altitude		
1	20	0	0	0
2	20	0	0	0
3	20	0	0	0

* Based on 59 low-altitude and eight high-altitude. I/M is assumed for LDVs and LDTs. A low-growth rate in VMT is projected.

economy of 9.24 mpg,[9] an average vehicle lifetime of 110,000 miles,[3] and a 0.80 ratio of lead in to lead out, the per-vehicle lifetime emissions of lead will be approximately 23.1 pounds for 1985 and 1986 MY HDGVs. For 1987 and later model years only Classes IV-VIII HDGVs will use leaded fuel. As discussed in Chapter 1, an average fuel economy of 5.8 mpg is expected, so lifetime lead emissions for these vehicles are 36.8 pounds.

The total additional lead emitted annually from HDGVs sold between 1985 and 1989 (the first five years of impact of this rule) can be estimated by using the total annual HDGV sales shown in Chapter 1 for 1985 and 1986, and the sales of Class IV and above for 1987 to 1989 (plus the allowable 5 percent reclassification), an average VMT of 13,750 miles per year, and an expected vehicle lifetime of 8 years. Including contributions from both the 1985-86 and 1987-89 vehicle groups alluded to above, the maximum annual nationwide lead emissions would be 1,732 tons from 1989-92 inclusive. However, if no catalysts were required on any HDGVs, then the maximum annual nationwide lead emissions would be approximately 2,150 tons in the same years. Therefore, this rulemaking should reduce lead emissions (by about 19 percent) when compared to the base case, where no catalysts are assumed for HDGVs.

It should be noted that approximately half of the lead from mobile sources is emitted as coarse particles,[10] which settle rapidly to the ground and are unlikely to contribute to air pollution. Thus, not all lead emissions would directly contribute to ambient lead levels.

References

1. For further information on health effects and air quality, refer to the following documents:

a. For ozone:

"Air Quality Criteria for Ozone and Other Photochemical Oxidants," EPA-600/8-78-004, April 1978.

"Revision of the National Ambient Air Quality Standard for Photochemical Oxidants: Staff Summary Paper," EPA Strategy and Air Standards Division, January 1978.

b. For carbon monoxide:

"Air Quality Criteria for Carbon Monoxide," EPA-600/8-79-002, October 1979.

"Preliminary Assessment of Adverse Health Effects from Carbon Monoxide and Implications for Possible Modifications of the Standard" - EPA OAQPS Staff Paper Draft, June 1979.

2. Information on Mobile 2.5 can be found in the following documents:

a. "Compilation of Air Pollutant Emission Factors: Highway Mobile Sources," EPA-460/3-81-005, March 1981.

b. "User's Guide to Mobile 2 (Mobile Source Emissions Model)," EPA-460/3-81-006, February 1981.

c. "Modifications to Mobile 2 which were used by EPA to respond to Congressional inquiries on the Clean Air Act," EPA-AA-IMS-82-2, May 1982.

d. Emission Factors for HC and CO Truck Regulations, EPA Memo from Lois Platte, Project Manager, TEB to John Anderson, Project Manager, SDSB, July 26, 1983.

3. "Summary and Analysis of Comments on the Notice of Proposed Rulemaking for Revised Gaseous Emission Regulations for 1984 and Later Model Year Light-Duty Trucks and Heavy-Duty Engines," U.S. EPA, OMS, SDSB, July 1983. See the "Useful-Life" Issue.

4. "Determination of Useful-Life Values for Light-Duty Trucks and Heavy-Duty Engines," Memorandum from Robert J. Johnson, U.S. EPA, OANR, OMS, ECTD, SDSB to Public Docket.

References (cont'd)

5. Information on the rollback model as used for analysis can be found in the following documents:

"Rollback Modeling: Basic and Modified," J. Air Poll. Control Assoc., deNevers, N. and Morris, J.R., Vol. 25, No. 9, 1975.

Recent HC, CO Truck Regulation Analyses, EPA Memo from Mark Wolcott, TEB to John Anderson, SDSB, July 22, 1983.

Clarification of Ozone and Carbon Monoxide Modeling Issues, EPA memo from Warren P. Freas to Mark Wolcott, June 3, 1983.

6. "Uses, Limitations and Technical Basis of Procedures for Quantifying Relationships Between Photochemical Oxidants and Precursors," EPA-450/2-77-021a, U.S. EPA, Research Triangle Park, N.C.

7. Transmittal of HC, CO Regulation Air Quality Analyses, EPA memo from Mark Wolcott, TEB to John Anderson, SDSB.

8. EPA Public Hearing for the Notice of Proposed Rulemaking of Lead Phasedown by E.I. DuPont de Nemours and Co., Inc., Docket No. A-81-36, Washington, D.C., April 15-16, 1982.

9. "The Highway Fuel Consumption Model," Eighth Quarter Report prepared for the U.S. Department of Energy, Office of Policy, Planning, and Analysis, July 1, 1982.

10. "Air Quality Criteria for Lead," U.S. EPA Office of Research and Development, Washington, D.C., EPA - 600/8-77-017, December 1977.

CHAPTER 3

USEFUL-LIFE COST EFFECTIVENESS AND AIR QUALITY IMPACTS

I. Introduction

There have been at least three opportunities for interested parties to submit comments pertaining to light-duty truck/heavy-duty engine (LDT/HDE) useful life since the full-life requirement was first reopened for study and comment in the spring of 1981. The January 12, 1983 proposal to modify the full-life definition was the direct result of issues that were raised in a number of such comments. One of the major concerns raised in the course of the various comment periods has been the issue of cost effectiveness and benefits of full-life useful life. A number of industry commenters have questioned both the air quality benefits accruing from full life and EPA's analysis of the cost of compliance with the full-life useful-life requirement. In response to these comments, EPA has included this update of the useful-life analyses in the Regulatory Support Document.

II. Cost Effectiveness

This analysis will utilize a 2-pronged approach. In the first portion, a conservative analysis of the LDT and HDE costs and emission reduction benefits of the full-life requirement will be developed and the cost effectiveness will be calculated. The second portion contains a qualitative discussion of the benefits of full life that are not easily quantified. In the last portion of this analysis the useful-life cost-effectiveness values are compared to those of other strategies.

A. Quantitative Aspects

1. Methodology

The basic methodology for determining cost effectiveness remains unchanged from earlier analyses. EPA will weigh the estimated costs (derived primarily from the latest manufacturer-supplied data) against projected emission reduction benefits developed from EPA emission factor data. A cost-effectiveness figure will be calculated for hydrocarbons (HC) and carbon monoxide (CO) for LDTs, heavy-duty gasoline engines (HDGEs) under the interim non-catalyst standards, and HDGEs under the longer term standards (assuming catalysts will be used on Classes IIB and III trucks only). Since heavy-duty diesel engine (HDDE) CO emissions are already below the statutory level, only HC cost effectiveness will be calculated for HDDEs.

Costs will include the cost per engine for improving the durability of emission-related components and in some cases for additional quality control (QC) efforts. Cost will also include those expected for increased recall liability, although we anticipate manufacturers will make efforts to keep their full-life recall liability the same as that now experienced under half life. They also include costs for increased certification durability testing, although under the full-life provisions the manufacturers are essentially free to determine durability for certification purposes by any manner they choose. However, it is not expected that they will choose a method that is any more costly than the present system of durability testing, so this would represent a worst case estimate. For the sake of consistency with the comments, all costs will be in terms of 1982 dollars.

Emission reductions for a full-life versus a half-life requirement will be estimated using the EPA emission-rate equations developed for use in the MOBILE2.5 emission factor model. The rates used represent projected in-use emissions and are adjusted for factors such as assembly-line testing and misfueling for catalyst-equipped engines. These equations take the form:

$$ER = ZM + DR(M) \qquad (1)$$

Where ER is the emission rate, ZM represents zero-mile emissions, and DR(M) is the projected deterioration rate per 10,000 miles multiplied by the mileage (in tens of thousands). Both deterioration rates and zero-mile emissions are lower under the full-life requirement which reflects the manufacturers' design efforts for full-life compliance of a well-maintained vehicle/engine. To model the effects of a full-life requirement on lifetime vehicle emissions, in-use emissions are assumed to deteriorate no farther in terms of absolute levels during the full life of a vehicle/engine than they would during the half life under a half-life requirement. Zero-mile emissions are lowered to reflect reduced low-mileage targets for certification.

The difference in average emission rates between the half-life and full-life scenarios will be calculated and the result multiplied by the full-life mileage figure to determine the difference in total lifetime emissions. When the cost per engine determined above is divided by this difference in tons of total lifetime emissions, the result equals the cost per ton of emission reduction which can then be compared with the cost effectiveness of other emission control strategies. This approach will be used for both HC and CO emissions with the costs being shared equally by both. The only exception is HDDEs, where as noted above, only an HC cost effectiveness will be determined.

2. Light-Duty Trucks

a. Costs

The original analysis for the cost of full-life useful-life projected costs on the basis of 30 percent of the projected increase in hardware and research and development (R&D) costs for improved catalysts ($4.27 + $5.06 per engine, respectively), plus $1.44 projected additional certification costs for increased durability testing, or a total of $10.77 per engine.[1] Since that time, noble metal prices have increased about 9 percent, increasing the hardware cost to $4.65. Adding a 25 percent inflation factor to the R&D and certification costs (based on the 1982 Bureau of Labor Statistics (BLS) Producer Price Index of Truck Prices) brings that portion of the increase to $8.13. The adjusted total is $12.78 in 1982 dollars.

Detailed estimates of the cost of full-life useful life by manufacturers are limited to data supplied by General Motors Corporation (GM). In their comments on the useful-life issue, GM submitted LDT costs for the original full-life requirement as follows:[2]

Improved hardware	$ 27
Fuel economy penalty	111
Warranty and recall costs	168
TOTAL	$306

Hardware costs included the cost of increased catalyst loading, increasing the durability of the converter housing, valve stem seals for improved oil control, and an increase in air pump durability. GM's cost estimate for hardware is more than double EPA's estimate. However, the EPA estimate was for increasing catalyst durability only, so the increase may be justified. GM maintains that these modifications would still not result in full-life durability and so the additional warranty and recall costs were projected.

The $111 fuel economy penalty is the result of a projected loss of approximately one mile per gallon (mpg) in fuel economy due to more stringent low-mileage targets. GM based this projection on the difference in fuel economy between its 1980 Federal and 1980 California vehicles. This fuel economy issue was first raised in the course of the initial LDT rulemaking. EPA concluded at that time that the California fuel economy loss was due to the "quick-fix" strategy employed by the industry for a market that represented a fairly small part of the total sales picture. A "quick-fix" approach such as this is not appropriate or necessary for the manufacturers' nationwide sales. In addition, it should be noted that reduced low-mileage targets due to useful life comprise only a very small portion of the total reduction in emission levels. As a matter of fact, most current LDT configurations are far enough below the 1985 emission standards to accommodate any small downward shift in low-mileage targets due to the full-life requirement.[3] Therefore, GM's fuel economy concerns do not seem well-founded.

No breakdown of the $168 projected additional warranty and recall expense (as to percentage of warranty and recall) was given. GM submitted a similar estimate ($160) for increased warranty and recall expenses for HDGEs, however, wherein the additional recall exposure cost was calculated to be $21 per engine. Breaking down the LDT total on the same percentage basis would yield a cost of $22 for LDT recall expenses. Since the modified full-life strategy would limit a manufacturer's warranty liability to the current 5-years/50,000-miles, no additional warranty expense would be incurred, leaving only the $22 for additional recall exposure. Adding the $27 hardware cost and the $22 recall exposure cost results in a total cost of $49 per truck. To avoid any increase in net recall liability in full life versus half life, some manufacturers may wish to devote some additional effort in the QC area. Additional QC inspections could cost an additional $3-5 per engine (based on 10-15 minutes each at $20/hr labor cost) or manufacturers may choose to select additional vehicles/engines for audit testing at an average per vehicle cost of about $10. Increased QC efforts could probably be accomplished for less total cost than assuming greater recall liability, but this analysis will conservatively use the larger figure.

EPA estimates the additional certification cost to be $3 per engine, which would bring the total cost per truck for full life to $52, based upon GM's figures.

b. Benefits

Utilizing the basic emission factor equation and discussion given above and a midpoint mileage of 60,000 miles for average lifetime emissions, the calculations for HC are as follows:

Half Life: ER = 0.74 + .26(6) = 2.30 grams per mile (g/mi),

Full Life: ER = 0.63 + .12(6) = 1.35 g/mi.

The difference (0.95 g/mi) multiplied by the full useful life (120,000 miles) gives a total lifetime emissions difference of 114 kg, or .126 tons of HC.

For CO, the calculation becomes:

Half Life: ER = 8.06 + 2.35(6) = 22.16 g/mi, Full Life: ER = 7.13 + 1.05(6) = 13.43 g/mi.

The difference (8.73 g/mi) multiplied by 120,000 miles equals 1,048 kg, or 1.15 additional tons of CO removed over the lifetime of the vehicle.

c. Cost Effectiveness

Having derived the emission reductions and the costs, it becomes a fairly straightforward calculation to divide the costs by the emission reduction benefits to determine a cost per ton of HC and CO. As has been the practice in previous analyses, costs will be equally apportioned between HC and CO.

For HC, the cost/ton = $26/.126 tons = $206/ton.

For CO, the cost/ton = $26/1.15 tons = $23/ton.

A cost-effectiveness figure was not calculated for nitrogen oxides (NOx), since both the costs and benefits of full life are largely attributable to prevention of catalyst failures, and oxidation catalysts are presently the primary control technology for HC and CO. Catalyst failure would therefore have little effect on NOx levels, assuming current standards and technology. In the event a more stringent NOx standard is adopted at some future date and the technology balance shifts toward increased catalytic control of NOx emissions, the costs and benefits involved could then be factored into the analysis.

Finally, there is the question of light-duty diesel trucks (LDDTs). LDDTs are relatively new in the market place and high-mileage emission control system-performance data are scarce. EPA expects that LDDT emissions performance and durability should be at least as good as the gasoline-powered vehicles they are intended to replace. In addition, many of the same considerations found in the discussion of HDDEs below will apply to LDDTs as well. Therefore, both benefits and costs should be relatively small and will likely affect only HC emissions. Since LDDTs comprise only 5-10 percent of total LDT sales, the impact of LDDTs on the total LDT cost effectiveness should be minimal. For simplification, this analysis will assume that the overall LDT HC cost-effectiveness value will be unchanged whether LDDTs are included or not. Therefore, the figures derived above stand for all LDTs.

3. Heavy-Duty Gasoline Engines - Interim Standards

a. Costs - Non-Catalyst Engines

Since the original statutory standards for 1984 and later HDEs assumed the need for catalysts on gasoline engines, no estimate was given for the cost of full-life useful life for non-catalyst engines in the original Regulatory Analysis. However, a general description can now be given of the technology necessary for compliance with the interim standards and the effect of useful life. EPA envisions the use of larger air injection pumps, perhaps in conjunction with air modulation, fuel metering refinements, induction air preheating, EGR systems, and other similar engine modifications. Improving the durability of the components involved consists of generally heavier construction and/or better quality materials for all moving parts and use of improved bearings and seals, and better lubricants for air pumps.

General Motors submitted estimates for non-catalyst HDGEs, presumably including modifications of this nature, stating that components would be "designed to last considerably longer than the average useful life of the engine."[4] GM presented estimates for both full-life and half-life non-catalyst scenarios. The full-life scenario represented costs under the original full-life definition promulgated in late 1979; the half-life provision represented the current 5-year/50,000-mile requirement. Although the GM costs for compliance with the interim standards seem excessive under either useful-life requirement, the increased costs of full life presented by GM (shown below) are useful in that they represent somewhat of an upper limit on the costs of full life.

Hardware costs:	
Materials and labor	$30
Overhead	30
Engineering	3
Subtotal:	$63
Warranty and recall costs:	
Emissions-related engine overhauls	$90
Emission-control system warranty	49
Increased recall liability	21
Subtotal	$160
TOTAL ADDITIONAL COST FOR FULL LIFE:	$223

Since the manufacturer is under no obligation to pay for engine overhauls under the current modified full-life provision, and since emissions warranty liability under modified full life is no greater than it is under the 1983 and earlier half-life regulations, only the $21 increase in recall cost remains in the warranty and recall costs category. If GM's emission control components in fact do last longer than the useful life of the engine, there should actually be no increase in recall costs for full life compared to half life. However, for the sake of being conservative, adding this $21 to the $63 hardware cost yields a total of $84 per engine for the cost of full-life components. Adding $3 per engine for additional certification costs (even though no increase was projected by GM) brings the total to $87 per engine. GM did not include any additional QC effort in their estimate. However, as before with LDTs, EPA estimates this cost to be $13-15, but to be conservative the higher recall costs provided by GM will be used. Thus total costs are $87, which should be looked upon as an upper limit.

b. Benefits

The emission factor equations for the 1985-86 non-catalyst standards are given below. Since emissions change slightly when SEA is introduced in 1986, an average factor representing both 1985 and 1986 is used here. Using a midpoint mileage of 55,000 miles for average lifetime emissions, the calculations for HC and CO are:

Half-Life HC emission rate = 4.005 + .32(5.5) = 5.765 g/mi,

Full-Life HC emission rate = 3.845 + .16(5.5) = 4.725 g/mi.

Half-Life CO emission rate = 61.36 + 8.37(5.5) = 107.395 g/mi,

Full-Life CO emission rate = 59.65 + 3.98(5.5) = 81.540 g/mi.

The difference in lifetime emissions for HC is given by the difference in average emission rates (1.04 g/mi) times the full useful life (110,000 miles). The result is 114.4 kg or 0.126 tons.

Similarly, the difference in lifetime emissions for CO is 25.86 g/mi times 110,000 miles which equals 2,844.6 kg or 3.133 tons.

c. Cost Effectiveness

The total cost of $87 is allocated equally to HC and CO reduction. The cost-effectiveness calculations then become:

HC = $43.50/0.126 tons = $345/ton.

CO = $43.50/3.133 tons = $14/ton.

4. HDGEs - 1987 and Later Catalyst Standards

a. Costs

The original Regulatory Analysis for 1984 and later model year HDEs projected compliance costs with the statutory standards for HDGEs that included the development of catalytic converters for <u>all</u> engines. The current rulemaking prescribes statutory standards for Classes IIB and III vehicles only, however, with Classes IV-VIII vehicles continuing to meet non-catalyst standards. These Classes IIB and III vehicles are primarily LDT derivatives and should, therefore, benefit from the LDT component development that has previously been done in response to the 1985 LDT regulations. EPA sees no reason why the additional costs of full life for Classes IIB and III HDGEs should be significantly greater than the additional costs for LDTs (i.e., $52). However, knowing the manufacturers' concern about catalyst durability, cost effectiveness will also be evaluated assuming additional costs of double the LDT amount or $104.

b. <u>Benefits</u>

The calculation of benefits will cover only Classes IIB and III trucks, since non-catalyst standards for Classes IV-VIII represent no change in costs or benefits from the interim standards. Accordingly, using the midpoint mileage of 55,000 miles for average lifetime emissions, the emission factor equations for HC are:

Half-Life HC emission rate = 1.82 + 0.64(5.5) = 5.34 g/mi,

Full-Life HC emission rate = 1.44 + .32(5.5) = 3.20 g/mi.

Multiplying the difference (2.14 g/mi) by 110,000 miles yields 102.3 kg, or a total lifetime difference of .259 tons HC.

For CO the calculation becomes:

Half-Life emission rate = 17.70 + 5.16(5.5) = 46.10 g/mi,

Full-Life emission rate = 14.06 + 2.64(5.5) = 28.58 g/mi.

The difference in rates (17.52 g/mi) X 110,000 mi = 1,927.2 kg = 2.122 tons CO over the lifetime of the vehicle.

c. <u>Cost Effectiveness</u>

Splitting the cost ($52) between HC and CO and dividing by the HC and CO benefits yields the following cost-effectiveness figures:

HC = $26/.259 tons = $100/ton.

CO = $26/2.122 tons = $12/ton.

If, as mentioned above, double the cost is assumed, these values become $200/ton for HC and $24/ton for CO.

5. Heavy-Duty Diesel Engines

a. Costs

Heavy-duty diesel manufacturers have repeatedly stressed the durability and low emissions deterioration characteristics of HDDEs. Comments have stated that since control of emissions in HDDEs is generally a function of basic engine design, rather than of add-on components, there should be few, if any, catastrophic emission control failures late in the life of an engine that could result in large-scale increases in emissions. Moreover, such failures as might affect emissions would also tend to have a deleterious effect on performance, thereby giving the owner a strong incentive to repair the failure.

EPA generally concurs that HDDEs tend to be fairly durable, and is not aware of any widespread emission problems with HDDEs. With the exception of smoke-limiting devices and other purely emission control components such as EGR or mechanical variable timing used occasionally, HDDE emission control systems are integrated into the basic design of the engines. Emission-control problems therefore tend to be self-correcting, assuming proper maintenance is done on the remainder of the engine. Therefore, EPA is not projecting any large emission benefits or costs associated with full life for HDDEs. Should problems surface which lead to greater costs, the benefits would also increase.

Recall also should present few problems to manufacturers since recall is limited to well-maintained engines. Likely action on the part of manufacturers to safeguard against a possible recall might be to concentrate on eliminating production defects through increased quality-control inspections during component and engine development and assembly. Increased manufacturer self-auditing for emissions is a similar possibility.

EPA estimates that manufacturers could spend $10-15 per engine on increased QC and certification. Any recall exposure increase should be minimal in any event, given the maintenance and durability of components as discussed above. Virtually all HDDE families are adequately below the 1985 HDDE HC standard to accommodate the very small downward shift in low-mileage targets associated with full life, so no costs in this area are expected.

b. Benefits

The methodology used to calculate the full-life HC emission rate for HDDEs is essentially the same as that for LDTs and HDGEs with a slight variation. The recognized half-life DR for HDDEs is very small, being only 0.04 grams HC per 10,000 miles. For comparison, the LDT half-life DR is 0.74 and the HDGE half-life DRs are 0.32 and 0.42 (for non-catalyst and catalyst engines, respectively). While the HDDE DR may in fact be slightly reduced under full life, this reduction would be very difficult to quantify. Furthermore, since the DR reduction would be very small, its impact on the full-life emission rate would be very small. Therefore, the same HDDE DR has been used for both the half-life and full-life emission rates. This is a conservative approach since any reduction in the DR would lead to a reduction in the full-life emission rate as shown by Equation 1. Reducing the full-life emission rate increases the benefits of the full-life requirement because benefits are defined as the difference between the half-life and the full-life emission rates.

The only HDDE HC benefit that will be projected under the full-life requirement is that due to the reduction in the ZM. The full-life ZM was calculated in the standard way from the MOBILE 2.5 emission factor model. Both the half-life and full-life ZMs are shown in the equations below.

The HDDE class is split into three subclasses with estimated total lifetime periods and estimated sales fractions as follows:

Subclass	1985 Projected Percent Sales	Average Lifetime Usage Period
LHDDE	28%	110,000 mi
MHDDE	23%	268,000 mi
HHDDE	49%	529,000 mi

The heavy heavy-duty diesel engine (HHDDE) and medium heavy-duty diesel engine (MHDDE) subclasses have total usage periods greater than the assigned useful-life values due primarily to the fact that many MHDDEs and most HHDDEs are rebuilt at least once. Using these figures, a sales weighted composite lifetime usage period of 350,000 miles was calculated to represent the three HDDE subclasses.[5]

Using the midpoint mileage of 175,000 miles for average lifetime emissions, the emission factor equations for HC are:

$$\text{Half-Life emission rate} = 3.05 + .04(17.5) = 3.75 \text{ g/mi},$$

$$\text{Full-Life emission rate} = 2.97 + .04(17.5) = 3.67 \text{ g/mi}.$$

Multiplying the sales-weighted composite lifetime usage period by the difference in average emission rates (.08 g/mi) yields 28 kg, or .031 total tons of HC.

c. Cost Effectiveness

Since the CO emissions of HDDEs are already well below the final standard, the cost is allocated to HC only. Dividing the cost by the projected benefit yields an HC cost effectiveness of $323 per ton at a cost of $10 per engine, or $484 per ton at a cost of $15 per engine.

B. Qualitative Aspects

Although this discussion has thus far concentrated on the quantitative aspects of full life (i.e., the cost per ton of emissions reduction), it is important to realize that there are benefits involved in the comparison of the full life and half life which are not easily quantified. EPA agrees that most manufacturers' current emission control systems function past half life. We do not know exactly how far past half life they presently function, however, and there is no guarantee that in the face of pressure to cut costs they will continue to do so in the future. A full-life recall provision could provide the insurance that durability will not be sacrificed in the face of mounting pressures to reduce costs, or that in lieu of durability, manufacturers would not simply specify additional maintenance (i.e., components could be made less durable and more frequent replacement could be specified to make up for the decreased durability).

As technology becomes more sophisticated, indications are that the increase in emissions resulting from component failure(s) is likely to be more significant. For example, EPA's emission factor program tested a late model light-duty vehicle (LDV) with a failed catalyst and electronic control module at 10.55 g/mi HC and 254.87 g/mi CO, or more than 25 and 36 times the respective HC and CO standards. Yet when the defective components were replaced, the vehicle tested well within the standards for that model year.[6] This example is an extreme case, but it nevertheless illustrates the possible effects that can result from compound failures of emission control components.

With the potential use of more sophisticated and expensive technologies on LDTs and HDEs (e.g., three-way catalysts with closed-loop control on LDTs, oxidation catalysts and possibly electronic controls on HDGEs, electronic controls and possibly particulate traps and EGR on HDDEs) whose in-use performance has not been fully demonstrated, a full life requirement will ensure durable design and construction. In addition, it will ensure that the money invested by the consumer in emission control hardware actually brings about the reduction in emissions which was intended. Given increasing complexity, the durability of components becomes a more important issue. EPA believes that full life can help ensure continued component durability.

Finally, full life is important for HDEs, because for the forseeable future EPA's in-use efforts in this area must of necessity be fairly limited in scope. A large HDE recall program, particularly for HDDEs, will be difficult and costly to conduct. There will be difficulties involved in locating engines for testing, obtaining their owners' consent for testing (which will likely involve compensating the owner for lost service time), and assuring that the engines have been properly maintained. The amount of effort, and consequently cost, involved in engine removal, testing, and reinstallation is also extensive. Budgetary constraints alone may preclude any large-scale effort. It will therefore be increasingly important to ensure that manufacturers focus significant initial efforts on designing and producing durable engine/emission control components to prevent emission-related problems from developing later in the useful life.

C. Comparison of Cost Effectiveness of Full Life with Other Emission-Control Strategies

For convenience, the costs, emission reduction benefits, and cost-effectiveness values developed above are summarized in Table 3-1. Tables 3-2 and 3-3 present cost-effectiveness data on various emission control strategies for reductions in HC and CO emissions. As can be seen from Table 3-2, the cost per ton for removal of HC ranges from a low of $112 for heavy-duty gasoline vehicle (HDGV) evaporative emissions regulations to a high of $15,767 per ton for transit improvements. Table 3-3 shows a cost per ton for CO ranging from $0 to $1,493. In general, full-life useful life falls into the lower end of these ranges and thus appears to be very cost effective in comparison with other generally accepted emission control strategies.

Industry comments have repeatedly stressed the minimal impact of full life on total ambient air quality. It is true that if the durability of emission components could be assured in the second half of the vehicle's life without full-life useful life, then absolute improvements in total air quality due to full life would be small. However, our best efforts in controlling emissions from all sources will be insufficient to meet air quality standards in regions containing millions of people, particularly in the case of ozone. For the forseeable future, improvements in air quality will result from many small actions, no one of which will yield results as dramatic as some of the previous measures. Based on the quantitative and qualitative considerations noted above, full-life useful life appears to be a cost-effective addition to the overall emission control strategy.

Table 3-1

Summary of Cost Effectiveness of
Full-Life Useful Life by Vehicle/Engine Class

	Costs	Benefits (tons) HC	Benefits (tons) CO	Dollars/Ton HC	Dollars/Ton CO
LDT	$52	0.126	1.15	$206	$23
HDGEs - Interim Standards	$87	0.126	3.133	$345	$14
HDGE Catalyst Standards (Classes IIB & III only)	$52-104	0.259	2.122	$100-200	$12-24
HDDEs	$10-15	0.031	--	$323-484	--

Table 3-2

Cost Effectiveness of Emission
Control Strategies - Hydrocarbons[7]

Control Strategy	HC Cost Effectiveness Dollars/ton
HDGE Evaporative Control	$112
HDGE Useful Life (1987 and beyond)	$100-200
LDT Useful Life	$206
LDT Statutory Standards	$207
HDDE Useful Life	$323-484
HDGE Useful Life (1985-86 interim standards)	$345
Gasoline Refueling Regulations	$353
Interim HA Standards (1982-83)	$416
LDV Statutory Standards (1981)	$508
Motorcycle Standards	$616
Traffic Control	$666
I/M	$943
Auto Coatings	$1,301
Transit Improvements	$15,767

Table 3-3

Cost Effectiveness of Emisssion
Control Strategies - Carbon Monoxide[7]

Control Strategy	CO Cost Effectiveness Dollars/Ton
Motorcycle Standards	Neg.
HDGE Useful Life (1987 and beyond)	$12-24
Interim HA Standards (1982-83)	$13
LDT Statutory Standards	$14
HDGE Useful Life (1985-86 interim standards)	$14
LDT Useful Life	$23
LDV Statutory Standards	$44
Traffic Controls	$55
I/M	$57
Transit Improvements	$1,493

III. Air Quality Analysis

Using the emission rate equations described above, the air quality impact of full life versus half-life can be estimated. The methodology for doing so is that presented earlier in Chapter 2. This section will present and discuss the results for impacts on the HC and CO emission inventory and the ozone and CO ambient air quality, for the same areas as analyzed in Chapter 2.

A. Emission Inventory

Table 3-4 presents HC and CO emission inventory projections for both the case of the current half-life useful life and the case of full-life useful life. These same projections are expressed as percent reductions in overall emissions in Table 3-5.

Table 3-5 indicates a sizeable improvement in HC and CO emissions due to the full-life requirements. In fact, examination of the table indicates that the relative benefit of full-life versus half-life appears to be somewhat overstated, particularly for HC. A review of the emission-factor equations behind these projections leads to the conclusion that the half-life benefits are being understated because they fail to fully account for the implementation of parameter-adjustment provisions. Parameter-adjustment provisions are expected to improve in-use emissions significantly, regardless of whether full or half-life useful life is in effect. This is especially true for catalyst-based emission control systems where a large portion of in-use emissions are due to in-use deterioration. For example, recent emission test data on 1980 model year LDVs, some of which had parameter-adjustment controls installed, shows a sizeable reduction in the DR derived from parameter-adjustment vehicles compared to other vehicles.[8] The DR for HC changes from 0.136 for 259 non-parameter-adjustment vehicles to 0.049 for 246 parameter-adjustment vehicles. Data such as this indicate that the parameter-adjustment provisions will bring the half-life emission benefits into a more appropriate range for comparison with full-life.

There is insufficient data to accurately estimate the effects of parameter adjustment on HDEs at this time. The non-catalyst systems on all 1985-86 HDEs and heavier 1987 and later HDEs will respond less to parameter adjustment than will catalyst systems. In addition, the method of applicability of the available LDV data to HDEs is not clear. Parameter adjustment will shift some of the benefits of this rulemaking from the full-life provisions to the half-life provisions.

B. Air Quality Levels

Table 3-6 shows the effect of changing useful life on projected future reductions of ozone, both in terms of the

Table 3-4

Effects of Useful Life on HC and CO Emissions

Total Non-Methane Hydrocarbon Emissions*
(1,000 tons/year)

Low-Altitude Areas Only

	1990	1995	2000
Half Life	6,015	6,247	6,675
Full Life	5,983	6,194	6,608

Total Carbon Monoxide Emissions**
(1,000 tons/year)

Low-Altitude Areas Only

	1990	1995	2000
Half Life	6,706	5,661	5,525
Full Life	6,490	5,329	5,170

* Based on 88 low-altitude SMSAs. I/M is assumed for LDVs and LDTs. A medium-growth rate in VMT is projected.

** Based on 59 low-altitude SMSAs. I/M is assumed for LDVs and LDTs. A low-growth rate in VMT is projected.

Table 3-5

Percent Reductions in HC and CO Emissions*

Total Non-Methane Hydrocarbon Emissions

Low-Altitude Areas Only

	1990	1995	2000
Half Life	0.35%	0.43%	0.46%
Full Life	0.87%	1.28%	1.46%

Total Carbon Monoxide Emissions

Low-Altitude Areas Only

	1990	1995	2000
Half Life	9.0%	12.3%	11.9%
Full Life	11.9%	17.5%	17.6%

* Percent reductions calculated from base case as defined in Chapter 2.

Table 3-6

Effects of Useful Life on
Ozone Ambient Air Quality*

Average Percent Change in Ozone Air Quality
(compared to base year, 1980)

	1990	1995	2000
Half Life	-25	-23	-19
Full Life	-25	-23	-20

Estimated Number of SMSAs Above Ozone Standard

	1990	1995	2000
Half Life	22	26	40
Full Life	21	24	40

* Based on 88 low-altitude SMSAs. I/M assumed for LDVs and LDTs. A medium-growth rate in VMT is projected.

average percent change for the areas analyzed and in terms of the number of areas exceeding the ozone air quality standard. The average percent reduction figures of Table 3-6 indicate little or no apparent change in the average ozone air quality even though, as was shown from the emission inventory data, there is a change in emissions. This seemingly inconsistent result is due to the fact that when preparing outputs the model rounds off the air quality reductions to the nearest whole percent. Therefore, changes in air quality of less than one percent may or may not be reflected in the output, depending upon whether they change the rounded off values.

On the other hand, Table 3-6 also projects that implementation of full-life useful life will serve to bring more areas into compliance with the ozone air quality standards in the 1990-1995 period. For example, the number of violating areas in 1995 is projected to be reduced from 26 to 24. These results illustrate the potential benefit of even a small improvement in air quality in being sufficient to bring a marginally non-compliant area into compliance. By the year 2000 the projections indicate that the useful-life benefit will be overtaken by the rapid increase in violating areas resulting from the overall growth in HC emissions.

Overall, the air quality analysis indicates that a small but discernable ozone air quality benefit will result from the implementation of full-life useful life. The earlier portions of this chapter have shown that this benefit, when balanced against the anticipated costs, is a cost-effective strategy for HC control. This latter fact is in some ways more important than the absolute size of the reductions gained. Since HC emissions arise from a large number of generally small sources, it is not surprising that any single control item by itself has only a small effect. So long as the benefits are commensurate with the costs, and so long as a number of regions are projected to exceed the standards, even small control programs should be implemented.

Air quality data for CO is presented in Table 3-7. Here it can be seen that full-life useful life is projected to produce a 1 to 2 percent overall improvement in CO air quality throughout the 1990's. Since the model projects that all areas will be brought into compliance even under half-life useful life, no change in the status of any regions is projected due to full life. As discussed in Chapter 2, some caution is needed in interpreting the lack of violations projected by the CO model since the absolute levels projected by the model are not as accurate as are the predicted differences between scenarios. The reader is referred to the CO air quality discussion of Chapter 2 for further details.

Table 3-7

Effects of Useful Life on
Carbon Monoxide Ambient Air Quality*

Average Percent Change in CO Air Quality
(compared to base year, 1980)

	1990	1995	2000
Half Life	-68	-73	-74
Full Life	-70	-75	-75

Estimated Number of SMSAs Above CO Standard

	1990	1995	2000
Half Life	0	0	0
Full Life	0	0	0

* Based on 59 low-altitude SMSAs. I/M assumed for LDVs and LDTs. A low-growth rate in VMT is projected.

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6. Listing of High-Emitting New Technology Vehicles, EPA Memo From R. B. Michael to P. Lorang, Chief, Technical Support Staff, March 2, 1983.

7. See Reference 1, pp. 104-105; see also: "Update on the Cost Effectiveness of Inspection and Maintenance," EPA-AA-IMS-81-9, April 1981, p. 21; EPA Memorandum I/M Cost Effectiveness, from Phil Lorang, Technical Support Staff, to Charles. L. Gray, Jr., Emission Control Technology Division, July 22, 1982; "Evaporative Emission Regulation and Test Procedure for 1985 and Later Model Year Gasoline-Fueled HDVs," U.S. EPA, OANR, OMS, ECTD, SDSB, 48 FR 1437, January 12, 1983; "Issue Analysis - Final HD Engine HC and CO Standards," U.S. EPA, OANR, OMS, ECTD, SDSB, March 1983. Figures are adjusted for inflation to 1982.

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