DRAFT

Regulatory Support Document

Revised Gaseous Emission Regulations For 1984 and Later Model Year Light-Duty Trucks and Heavy-Duty Engines

September 1981

Prepared By

Office of Mobile Source Air Pollution Control
Emission Control Technology Division

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Chapter I

INTRODUCTION/SUMMARY

A. Introduction

In December of 1979, EPA promulgated gaseous emission regulations for 1984 and later model year heavy-duty engines (HDE). A similar rulemaking affecting 1984 and later model year light-duty trucks (LDT) was promulgated in September of 1980. Although the primary function of these actions was to implement the statutory HC and CO emission standards, these rulemakings implemented several other provisions also to be effective for the same model year. The major provisions common to both rulemakings included:

1. The statutory HC and CO emission standards,

2. Revised useful life definition,

3. Revised certification requirements with respect to durability testing and allowable maintenance,

4. An idle test and an idle emission standard for gasoline-powered light-duty trucks and heavy-duty gasoline-fueled (HDG) engines, and,

5. The implementation of a 10 percent Acceptable Quality Level (AQL) for Selective Enforcement Audit (SEA) testing.

The HDE final rulemaking also included a new emission test procedure and implemented the basic SEA program for HDEs.

This large number of new and revised requirements was promulgated simultaneously, effective for the same model year, to avoid the procedural disruption and waste associated with frequent changes in emission regulations. This comprehensive approach allows manufacturers to deal with the impact of several regulations at once, thus avoiding repeated financial outlays for research and development, tooling changes, and recertification.

In the economic analysis supporting the 1984 HDE final rulemaking, EPA made the finding that "[m]ost engine manufacturers should have little difficulty financing the required investment, <u>barring a post-1980 recession</u>" (emphasis added). When the economic impact of the final rule was being analyzed the industry had just finished a year of record sales (1978), and sales into 1979 continued strong. However, in late 1979 and into 1980 when the general economic downturn became more severe, LDT and HDE sales dropped dramatically. Over the past five to six financial reporting periods (quarters) since late 1979, most companies in the LDT and HDE markets have reported substantial operating losses. In general, 1980 was a year of record losses in the motor vehicle industry.

In response to this economic crisis in the industry, and the need for short-term cash flow improvements, the Administration has announced a number of regulatory relief initiatives. Preliminary analyses indicated that several provisions of the 1984 LDT/HDE final rulemakings which required substantial capital investment could be relaxed without causing a large loss in the emission reductions and air quality improvements expected from the final rulemakings. The three major provisions are: 1) a three-year revision of the HDE gaseous emission standards to levels which heavy-duty gasoline-fueled engines (HDGE) could achieve without catalytic converter technology, 2) deferral of the implementation of the HDE SEA program from the 1984 model year to the 1986 model year, and 3) a relaxation of the AQL required during formal SEA testing of LDTs and HDEs.

Even though this rulemaking will establish no additional requirements and will actually provide cost savings for both the regulated industry and the consumer, EPA has decided to prepare this Rulemaking Support Document to address the issues which will arise in this action. In Chapter II, Technological Feasibility, we address the level of the "non-catalyst" HDE emission standards. Chapter III examines the air quality impacts of the increased emission levels resulting from the revised HDE CO emission standard and the relaxations in the enforcement provisions. Chapter IV estimates the total cash expenditure and cash flow savings which would result if the proposed actions are implemented. The results of these analyses are summarized below.

B. Summary

1. Technological Feasibility

The level of attainable emission standards for HDG engines is influenced by several factors. First, is the limitation to non-catalyst technology. Second, given the nature of this action, the technology used should be less expensive to develop and purchase than a catalyst system. Third, because of the limited time available for development, tooling, and certification, the technology used should not require substantial leadtime. Finally, impacts on fuel economy, driveability, and power must also be considered. Given these constraints, the available technology to gain greater emission reductions becomes limited to the conventional approaches that have been used in the LDV and LDT fleets for several years.

The results of the analysis in Chapter II indicate that the HDE HC, NOx, and idle CO standards in place for 1984 are feasible even under the constraints discussed above. However, the HDE CO emission standard will have to be revised up from the statutory standard to 35 g/BHP-hr.

EPA expects that HDG engines can comply with the HC standard through the use of modifications, components, and recalibrations aimed at reducing cold operation emissions and providing more efficient air-fuel (A/F) mixtures during all operating modes. Compliance with the revised HDE CO standard will be achieved primarily through carburetor recalibrations and components which will reduce cold operation CO, provide leaner A/F mixtures in all operating modes, and increase the amount and efficiency of the air injection system. Emission levels of 35 g/BHP-hr for CO and 1.3 g/BHP-hr for HC have alrady been achieved on current technology engines. Based on the emission levels of current technology engines the idle CO and NOx standards should be achieveable with little difficulty.

Since only the 1984 HDE CO emission standard is proposed for revision, and HDD engine CO emission levels are below even the statutory level, there will be no substantial impact on the technological feasibility for HDD engines.

2. <u>Environmental Impact</u>

Implementation of the proposed relaxations and revisions would result in greater per vehicle emission rates than would occur if the 1984 LDT and HDE gaseous emission regulations remained in effect. These greater emission rates, primarily in HC and CO, would result from all three of the major provisions being considered for change.

The adoption of non-catalyst technology will have two effects on the HC and CO emission rates of HDG vehicles. First, the restriction to non-catalyst technology will force the revision of the HDE CO emission standard. This will have no real effect on heavy-duty diesel (HDD) vehicles, but will cause an increase in CO emissions from HDG vehicles. Second, the low mileage emission levels of HDG vehicles for both HC and CO will increase as a result of the smaller deterioration factors associated with non-catalyst technology.

The two-year deferral of the HDE SEA program could also lead to an increase in the HC emissions from all heavy-duty vehicles (HDV) and the CO emissions from HDG vehicles. When no SEA program is in effect manufacturers do not have to account for emissions variability in their production engines. As a result, the average emission level for any pollutant would be somewhat higher without an SEA program. However, EPA expects some HDE manufacturers will certify in 1984 accounting for the impacts of the 1986 SEA program, thus eliminating the potential need for recertification in 1986 and at the same time minimizing the increase in HC and CO emissions.

The proposed relaxation in the AQL applicable to LDT and HDE SEA will also lead to slight increases in emission levels. Relaxing the AQL from 10 to 40 percent allows a higher degree of noncompliance during any given audit. Under a 40 percent AQL totally accounting for emissions variability is less important than under a 10 percent AQL. Most manufacturers account for emissions variability by lower target emission levels. Thus, the relaxation of the AQL will likely lead to higher target emission levels and overall higher per vehicle emission rates.

As is discussed in the Environmental Impact Chapter, EPA expects that if the proposed changes are implemented, an ozone and CO air quality loss of 1-3 percent will occur as compared to the base case (the 1984 LDT and HDE regulations as promulgated).

3. Economic Impact

EPA expects that the proposed relaxations and revisions will provide the regulated industry with substantial cash flow and cash expenditure savings. In 1981 dollars, discounted to January 1984, the cash expenditure savings sum to $102.7 million dollars and the cash flow savings sum to $43.2 million dollars. Of the $102.7 million dollars in cash expenditure savings, $72.8 million is pre-1984 capital investment. Virtually all of the cash flow savings is capital investment deferred from 1982-83 to 1984-85.

Over the 5-year period 1984-88, the aggregate savings to the nation sum to over $449 million dollars. Most of this savings is attributable to lower purchase and operating costs for HDG vehicles.

CHAPTER II

TECHNOLOGICAL FEASIBILITY/
ATTAINABLE NON-CATALYST STANDARDS

A. Introduction

In this chapter, EPA analyzes available technologies and projects what levels of HC and CO emissions for heavy-duty gasoline (HDG) engines are attainable for 1984, assuming that oxidation catalysts are not employed.

B. Current HC and CO Emission Rates

To properly evaluate potential non-catalyst emission reductions from HDG engines, current emission rates must be reviewed. Because absolute emission levels are inherently affected by the test procedure over which they are measured, a review of the transient emission test is appropriate.

1. Overview: The Transient Test

The transient test is performed on a computer-controlled engine dynamometer. During the test, the engine is driven through continuously-varying speeds and loads according to prescribed cycles. These speed and load cycles were developed from in vehicle performance data taken from 57 urban HDG trucks: 30 in the joint industry/EPA CAPE-21 study in New York City, and 27 in the EPA-conducted Los Angeles CAPE-21 study. These trucks were actual commercial vehicles operated by their own drivers; the performance data was taken in the course of their daily business. These data were then used to generate driving cycles representative of the input data.

There are several key aspects of the transient test:

a. It is engine specific,

b. It is composed of subcycles, each of which retains the characteristic driving patterns of specific urban localities, and,

c. It is performed on a "cold" engine, and then repeated with the engine in a warmed-up state.

Each of the above characteristics is critical in evaluating current and future emission trends.

Engine specific means that the cycles are defined in terms of percent speed and percent load, i.e., any two engines are required to deliver identical percent powers throughout the cycle even though their absolute power levels may be different. This, and the fact that emissions are expressed as mass per output work

(work is simply power multiplied by the time at that power), make emission results between engines comparable, regardless of their specific rated power and varying performance characteristics.

Secondly, the cycle is actually four subcycles joined end to end, each one characteristic of a particular geographic area and type of driving:

Subcycle	Duration (sec)	Characteristics
1. New York Non-Freeway (NYNF)	272	low power; stop-and-go; 45% idle; avg. spd. 7.8 mph
2. Los Angeles Non-Freeway (LANF)	309	moderate power, transient; 26% idle; avg. spd. 15.1 mph
3. Los Angeles Freeway (LAF)	316	high-speed, high-power cruising; avg. spd. 45.54 mph
4. New York Non-Freeway (NYNF)	272	repeat of 1.

Each subcycle demands different performance from the engine, and produces different absolute emission levels. These performance demands can be isolated and their emissions impact reasonably estimated.

Thirdly, the heavy-duty engine dynamometer test is similar to the light-duty vehicle test in that the total emission results are derived from a weighted average of a "cold" engine cycle and a hot engine cycle. For the heavy-duty test, the cold start emission cycle consists of the above four subcycles (NYNF, LANF, LAF, NYNF), and is weighted 1/7 of the total; the hot start cycle is identical to the cold, begins 20 minutes after shut down of the engine from the cold start, and is weighted 6/7 of the total. These weighting factors were derived from the observed in-use ratio of cold starts to hot starts in the CAPE-21 survey. Since a cold engine characteristically emits higher amounts of HC and CO, the cold start cycle is significant when discussing current and future emission levels.

2. Current Technology Engines

Table II-1 presents a list of 1979 MY HDG engines tested by EPA on the transient cycle. Table II-2 presents subcycle by subcycle HC emission breakdowns for each engine, along with a percent contribution of each subcycle to the total emission results. Table II-3 presents the same data for CO.

Table II-1

1979 HDG Current Technology Baseline

Engine	Family	HC* (g/BHP-hr)	CO* (g/BHP-hr)
Ford 400	6.6L "E"	4.89 (H)**	112.4 (H)
Chrysler 440	RBM	3.83 (H)	112.4 (H)
Ford 370	6.1L "E"	3.51 (H)	47.8 (L)
IHC 446	MV8	3.27 (H)	90.4 (H)
GM 350	113	3.14 (M)	118.1 (H)
Chrysler 360	LA1	2.67 (M)	96.1 (H)
GM 350	113	2.48 (M)	64.8 (M)
IHC 345	V345	2.44 (M)	34.4 (L)
GM 454	114	2.30 (M)	51.6 (L)
GM 366	114	2.16 (L)	43.4 (L)
GM 292	112	2.12 (L)	55.0 (L)
GM 454	115	1.31 (L)	78.5 (M)

* Average of several tests.

** Engines are classified as high (H), moderate (M), or lower (L) emitters of a given pollutant. Note that a high HC engine is also usually a high CO engine, but not in every case.

Immediately noticeable in Table II-1 are the high levels of HC and CO emissions. Note that the engines were certified for 1979 at 1.5 g/BHP-hr HC and 25 g/BHP-hr CO, but on the 9-mode steady-state test procedure. In complying with any motor vehicle emission standard, the design approach is to match the engine calibration and emission control system to the test procedure itself. This is the case in light-duty (see Reference 2), and indeed in heavy-duty. Table II-4 presents comparative HC and CO emission data for both transient and 9-mode test procedures for the current technology (1979) engine baseline. The large differences in measured emissions are explainable by the readily identifiable differences in required engine performance under each test.

3. The 9-Mode Test

The 9-mode test procedure consists of nine steady state engine operating modes which are weighted into a composite emission number:

Mode	Speed (RPM)	% Power	Weighting Factor
1	Idle	0	.232
2	2000	25	.007
3	2000	55	.147
4	2000	25	.077
5	2000	10	.057
6	2000	25	.077
7	2000	90	.113
8	2000	25	.007
9	2000	Closed Throttle	.143

The 9-mode is performed with the engine in a warmed-up state, at only one engine speed (except idle). To date, it can be firmly stated that on all current production engines all efforts at emission control on HDG engines have been directed primarily at these modes.

There are three major areas of engine operation which the transient test contains, but not the 9-mode:

a. Full power operation;

b. Transient operation, at all speeds and loads;

c. Cold engine operation.

These areas give rise to the measurable emission differences, and reflect where control technology will need to be directed for 1984. In this analysis we will show that full power (power enriched) LA Freeway modes are the major source of CO emissions in current technology engines, and also a significant source of HC on the higher emitting engines. Secondly, the major source of HC on the lower HC emitting engines will be shown to be the cold engine operation. Finally, on the lower-emitting engines, it will be shown that non-cold start HC and the remaining CO emissions are not as attributable to any one mode or source, and are primarily relatable to inadequately controlled mixture calibration as the engine undergoes transients at all speeds and loads throughout the entire test cycle.

4. Full Power Operation

Under wide open throttle (WOT) conditions, additional fuel is added to the combustion mixture. This power enrichment causes richer than stoichiometric mixtures, thereby promoting power and driveability, but drastically increasing unburned fuel (HC) and partially oxidized fuel (CO) emissions due to lack of oxygen. Present day engines certified to the 9-mode were emission controlled primarily up to 90 percent power (at only a single speed); note that current technology engine power valves are calibrated to cause power enrichment above 90 percent power. Thus, full power emissions on current technology engines are uncontrolled.

This observation is demonstrated by the data presented in Tables II-2 and II-3. In both tables, data from all twelve current technology engines tested at EPA are presented. In addition, the engines are also grouped into three categories: high, medium, and low emitters of a given pollutant. Note mode 7, the LA Freeway (LAF) in the hot-start portion of the test: 29.6 to 65.7 percent of brake specific CO (BSCO) emissions are attributable to this high-power segment. More interesting are the trends observed in segment percentage contributions from the highto the low-emitting engines. As the average composite BSCO emissions go from 105.5 g/BHP-hr (higher emitters) to 46.1 (lower emitters), i.e., a 2.3 fold decrease, all other subcycle model percentages increase by approximately two-fold except for the LAF mode, which decreases in contributing percentage from 56.3 to 36.7 percent (i.e., a lower percentage of a lower composite number). Had all modes decreased proportionally, the model percentages should remain constant. Clearly the major difference between high and lower CO engines is the amount of CO generated during the LAF segment. This is primarily a result of power enrichment in the carburetor during the LAF's characteristic high speed, high power operation. (Perhaps most indicative is the actual mass of CO generated during the LAF segment. Note in Table II-3 that total grams of CO generated in the LAF segment are 50-650 percent higher than those of the next highest hot start segment.)

The data for HC (Table II-2) is less dramatic with regards to LAF dominance, but the trends are nevertheless the same. Every high CO engine, (i.e, those with LAF dominance of CO emissions) also has dominant LAF HC emissions (ranging from 23.7 to 36.0 percent total contribution). This is logical since in this operational mode both emissions arise primarily from inadequate oxygen for total combustion in the fuel-enriched mixture. Again, the

Table II-2

Engine by Engine Transient HC Emission Breakdown

		Cold Start				20	Hot Start				Composite	High
		1	2	3	4	Minute	5	6	7	8	Test	Medium, or
		NYNF	LANF	LAF	NYNF	Pause	NYNF	LANF	LAF	NYNF	Result	Low Emitter(e)
	1(a)	24.73	17.11	15.10	5.55		9.66	11.14	12.53	5.71	-	
IHC 446	2(b)	23.26	6.97	1.81	5.23		10.65	4.61	1.50	5.36	3.32	H
	3(c)	.289	.188	.166	.061		.677	.736	.830	.373	3.32	
	4(d)	8.7%	5.6%	5.0%	1.8%		20.4%	22.2%	25.0%	11.2%	100%	
	1.	25.50	9.09	4.93	3.80		4.82	6.29	4.84	3.40	-	
IHC 345	2.	64.84	5.51	0.78	5.20		7.14	3.40	0.75	4.38	2.35	M
	3.	.40	.13	.07	.06		.44	.54	.42	.29	2.35	
	4.	17.0%	5.5%	3.0%	2.6%		18.7%	23.0%	17.9%	12.3%	100%	
	1.	47.86	12.73	5.95	2.61		4.96	4.89	5.07	2.62	-	
GM 366	2.	94.7	6.24	0.81	2.69		5.69	2.28	0.69	2.74	2.22	L
	3.	.64	.16	.08	.03		.39	.36	.37	.19	2.22	
	4.	28.8%	7.2%	3.6%	1.4%		17.6%	16.2%	16.7%	8.6%	100%	
	1.	61.49	12.57	6.42	2.81		4.71	6.50	4.56	2.74	-	
GM 350	2.	95.0	6.30	.92	3.06		5.56	3.16	.65	2.95	2.57	M
	3.	.86	.17	.08	.04		.37	.49	.35	.21	2.57	
	4.	33.5%	6.6%	3.1%	1.6%		14.4%	19.1%	13.6%	8.2%	100%	
	1.	32.91	16.16	14.67	6.68		8.62	10.11	13.17	5.69	-	
F 400	2.	46.77	9.66	2.60	9.38		12.10	5.77	2.33	8.02	4.80	H
	3.	.56	.26	.24	.11		.87	.96	1.25	.55	4.80	
	4.	11.7%	5.4%	5.0%	2.3%		18.1%	20.0%	26.0%	11.5%	-	
	1.	20.11	8.13	7.39	1.71		8.05	7.65	6.96	3.46	-	
F 370	2.	52.25	5.29	1.35	2.47		13.37	4.78	1.26	5.02	3.31	H
	3.	.36	.14	.13	.03		.85	.76	.69	.35	3.31	
	4.	10.9%	4.2%	3.9%	.9%		25.7%	23.0%	20.8%	10.6%	100%	

Table II-2 (cont'd)

Engine by Engine Transient HC Emission Breakdown

		Cold Start				20	Hot Start				Composite	High
		1	2	3	4	Minute	5	6	7	8	Test	Medium, or
		NYNF	LANF	LAF	NYNF	Pause	NYNF	LANF	LAF	NYNF	Result	Low Emitter
	1.	8.56	7.18	8.22	3.63		10.23	6.41	7.87	3.52	-	
C 360	2.	13.11	3.42	1.08	3.96		13.54	2.99	1.04	3.77	2.45	M
	3.	.11	.09	.10	.05		.80	.47	.58	.28	2.45	
	4.	4.5%	3.6%	4.0%	2.0%		32.7%	19.2%	23.7%	10.2%	100%	
	1.	17.38	10.57	24.67	7.76		10.25	9.32	22.22	9.10	-	
C 440	2.	20.12	4.10	2.78	7.41		11.32	3.65	2.40	8.69	3.81	H
	3.	.19	.11	.26	.08		.67	.57	1.37	.56	3.81	
	4.	5.0%	2.9%	6.8%	2.1%		17.6%	15.0%	36.0%	14.7%	100%	
	1.	16.38	3.88	5.34	1.68		4.94	2.39	4.95	1.57	-	
GM 454	2.	19.06	1.74	.63	1.83		5.82	1.07	0.60	1.72	1.29	L
	3.	.20	.05	.06	.02		.35	.17	.33	.11	1.29	
	4.	15.5%	3.9%	4.7%	1.6%		27.1%	13.2%	25.6%	8.5%	100%	
	1.	47.31	4.33	2.08	1.64		4.12	3.71	1.95	1.83	-	
GM 292	2.	65.65	2.62	0.39	2.08		6.17	2.20	0.37	2.33	2.12	L
	3.	.80	.07	.03	.03		.43	.37	.20	.19	2.12	
	4.	37.7%	3.3%	1.4%	1.4%		20.3%	17.5%	9.4%	9.0%	100%	
	1.	44.54	15.43	6.80	6.43		11.85	6.97	5.65	5.80	-	
GM 454	2.	62.38	5.75	0.68	5.83		11.24	2.52	0.57	5.25	2.46	M
	3.	.44	.15	.06	.06		.70	.39	.33	.33	2.46	
	4.	17.9%	6.1%	2.4%	2.4%		28.5%	15.9%	13.4%	13.4%	100%	

Table II-2 (cont'd)

Engine-by-Engine Transient HC Emission Breakdown

		Cold Start 1 NYNF	Cold Start 2 LANF	Cold Start 3 LAF	Cold Start 4 NYNF	20-Minute Pause	Hot Start 5 NYNF	Hot Start 6 LANF	Hot Start 7 LAF	Hot Start 8 NYNF	Total Test Composite	High Medium, or Low Emitter	Average HC Emission Level
	1.	21.04	6.13	10.39	3.69		3.66	5.01	9.51	3.71	-		
GM 350	2.	31.48	3.53	1.71	5.34		5.18	2.93	1.57	4.51	2.66	M	
	3.	.34	.09	.16	.06		.34	.46	.87	.34	2.66		
	4.	12.8%	3.4%	6.0%	2.3%		12.8%	17.3%	32.7%	12.8%	100%		
Average: All Engines	4.	17.0%	4.8%	4.1%	1.9%		21.1%	18.4%	21.7%	11.0%	100%	(12 engines)	2.78
Average: High HC Engines	4.	9.1%	4.5%	5.2%	1.8%		20.5%	20.1%	27.0%	12.0%	100%	H (4 engines)	3.61
Average: Med. HC Engines	4.	17.1%	5.0%	3.7%	2.2%		21.4%	18.9%	20.3%	11.4%	100%	M (5 engines)	2.50
Average: Low HC Engines	4.	27.3%	4.8%	3.2%	1.5%		21.7%	15.6%	17.2%	8.7%	100%	L (3 engines)	1.68

[a] Total grams per subcycle.
[b] Grams per brake-horsepower-hour per subcycle.
[c] Subcycle contribution, in effectively-weighted grams per brake-horsepower-hour, to the composite test result. (When added together, all subcycle contributions add up to the composite test result). For methodology, see Reference 1, pp. 4-5.
[d] Relative percentage of subcycle contribution (3) to the total composite test result.
[e] In grams per brake-horsepower-hour: High (H) > 3.3
3.3 > medium (M) ≥ 2.3
Low (L) < 2.2

Table II-3

Engine-by-Engine Transient CO Emission Breakdown

		Cold Start				20-Minute Pause	Hot Start				Composite Test Result	High, Medium, or Low Emitter[e]
		1 NYNF	2 LANF	3 LAF	4 NYNF		5 NYNF	6 LANF	7 LAF	8 NYNF		
	1[a]	236.4	245.2	774.8	127.2		123.3	200.0	708.1	122.7	-	
IHC 446	2[b]	222.4	99.9	93.0	119.9		135.9	82.7	84.7	115.1	92.88	H
	3[c]	2.79	2.73	8.63	1.42		8.73	13.3	47.1	8.20	92.88	
	4[d]	3.0%	2.9%	9.3%	1.5%		9.4%	14.3%	50.7%	8.8%	100%	
	1.	90.3	84.7	153.2	60.0		39.7	60.2	150.6	56.1	-	
IHC 345	2.	229.6	51.4	24.2	79.2		58.9	32.5	23.2	72.3	32.8	L
	3.	1.40	1.24	2.24	.88		3.70	5.29	13.11	4.94	32.8	
	4.	4.3%	3.8%	6.8%	2.7%		11.3%	16.1%	40.0%	15.1%	100%	
	1.	143.7	140.7	187.7	86.1		88.0	113.3	167.0	88.2	-	
GM 366	2.	284.3	69.1	25.5	88.8		100.8	52.9	22.8	92.1	41.9	L
	3.	1.9	1.8	2.4	1.1		6.9	8.7	12.5	6.6	41.9	
	4.	4.5%	4.3%	5.7%	2.6%		16.5%	20.8%	29.8%	15.8%	100%	
	1.	171.2	155.2	404.5	102.6		111.6	130.2	376.6	95.3	-	
GM 350	2.	264.5	77.7	57.8	116.6		131.9	63.4	53.9	102.5	67.8	M
	3.	2.4	2.1	5.3	1.4		9.3	10.1	29.7	7.4	67.8	
	4.	3.5%	3.1%	7.8%	2.1%		13.7%	14.9%	43.8%	10.9%	100%	
	1.	222.9	162.4	620.6	130.6		103.5	161.6	582.3	127.3	-	
F 400	2.	316.7	97.0	109.9	183.5		145.4	92.2	103.0	179.6	113.2	H
	3.	3.8	2.6	10.0	2.1		10.6	15.6	56.2	12.3	113.2	
	4.	3.4%	2.3%	8.8%	1.9%		9.4%	13.8%	49.6%	10.9%	100%	
	1.	85.2	106.6	230.7	21.4		38.8	80.1	206.7	40.3	-	
F 370	2.	221.5	69.4	42.1	30.9		64.4	50.0	37.4	58.4	45.0	L
	3.	1.5	1.8	3.9	.4		4.2	8.1	21.0	4.1	45.0	
	4.	3.3%	4.0%	8.7%	.9%		9.3%	18.0%	46.7%	9.1%	100%	

Table II-3 (cont'd)

Engine-by-Engine Transient CO Emission Breakdown

		Cold Start				20-	Hot Start				Composite	High
		1	2	3	4	Minute	5	6	7	8	Test	Medium, or
		NYNF	LANF	LAF	NYNF	Pause	NYNF	LANF	LAF	NYNF	Result	Low Emitter
	1.	107.5	144.7	868.6	61.2		56.6	127.9	783.0	58.5	-	
C 360	2.	164.7	68.8	113.8	56.7		76.3	59.5	103.3	62.6	92.0	H
	3.	1.4	1.8	10.8	.8		4.6	9.6	58.6	4.4	92.0	
	4.	1.5%	2.0%	11.7%	.9%		5.0%	10.4%	63.7%	4.8%	100%	
	1.	228.3	203.6	1262.0	100.6		75.2	161.1	1217.2	94.1	-	
C 440	2.	264.3	78.9	142.1	96.0		83.0	63.0	131.7	89.9	115.6	H
	3.	2.5	2.1	13.1	1.0		5.0	10.0	75.9	5.9	115.6	
	4.	2.2%	1.8%	11.3%	.9%		4.3%	8.7%	65.7%	5.1%	-	
	1.	250.3	86.2	769.6	65.2		86.9	102.8	714.1	69.7	-	
GM 454	2.	291.3	38.7	91.3	71.1		102.4	45.8	87.2	76.2	81.9	M
(Short	3.	3.1	1.0	9.0	.8		6.4	7.2	49.5	4.9	81.9	
Block)	4.	3.8%	1.2%	11.0%	1.0%		7.8%	8.8%	60.4%	6.0%	100%	
	1.	315.0	115.7	159.4	64.7		89.4	111.0	161.5	70.0	-	
GM 292	2.	437.1	69.9	30.2	81.9		133.7	65.9	30.5	89.1	55.0	L
	3.	5.6	2.0	2.7	1.1		9.6	11.2	16.3	7.1	55.0	
	4.	10.2%	3.6%	4.9%	2.0%		17.5%	20.4%	29.6%	12.9%	100%	
	1.	204.8	175.6	376.1	144.6		153.9	157.1	366.2	138.2	-	
GM 454	2.	286.9	65.5	37.9	131.1		146.1	56.7	36.9	124.9	55.9	L
(Tall	3.	2.1	1.7	3.6	1.4		9.3	9.0	20.9	7.9	55.9	
Block)	4.	3.8%	3.0%	6.4%	2.5%		16.7%	16.1%	37.4%	14.1%	100%	

Table 11-3 (cont'd)

Engine-by-Engine Transient CO Emission Breakdown

		Cold Start				20-Minute Pause	Hot Start				Total Test Composite	High Medium, or Low Emitter	Average HC Emission Level
		1 NYNF	2 LANF	3 LAF	4 NYNF		5 NYNF	6 LANF	7 LAF	8 NYNF			
	1.	196.1	108.9	805.5	68.1		92.1	104.8	640.8	64.8	-		
GM 350	2.	293.3	62.6	132.21	98.6		130.1	61.4	106.0	78.8	101.5	H	
	3.	3.2	1.7	12.1	1.1		8.5	9.7	59.2	6.0	101.5		
	4.	3.2%	1.7%	11.8%	1.1%		8.4%	9.6%	58.3%	5.9%	100%		
Average All Engines	4.	3.9%	2.8%	9.5%	1.7%		10.7%	14.2%	47.9%	9.9%	100%	(12 engines)	75.7
Average High CO Engines	4.	2.6%	2.1%	12.6%	1.2%		7.1%	11.1%	56.3%	7.0%	100%	(5 engines)	105.5
Average Med CO Engines	4.	3.7%	2.2%	9.4%	1.6%		10.8%	11.9%	52.1%	8.5%	100%	(2 engines)	74.9
Average Low CO Engines	4.	5.2%	3.7%	6.5%	2.1%		14.3%	18.3%	36.7%	13.4%	100%	(5 engines)	46.1

[a] Total grams per subcycle.
[b] Grams per brake-horsepower-hour per subcycle.
[c] Subcycle contribution, in effectively-weighted grams per brake-horsepower-hour, to the composite test result. (When added together, all subcycle contributions add up to the composite test result). For methodology, see Reference 1, pp. 4-5.
[d] Relative percentage of subcycle contribution (3) to the total composite test result.
[e] In grams per brake-horsepower-hour: High (H) $>$ 90
90 $\geq$ medium (M) $\geq$ 60
Low (L) $<$ 60

Table II-4

9-Mode Versus Transient Emissions

Current Technology Engines[1][2]

Engine	BSHC		BSCO	
	9-Mode	Transient	9-Mode	Transient
1979 GM 292	0.42	2.12	26.86	54.98
1979 GM 454	0.39	2.30	17.33	51.55
1979 GM 350	0.79	3.14	14.62	118.07
1979 IHC 446	0.42	3.27	24.28	90.40
1979 GM 366	0.50	2.16	17.40	43.43
1979 IHC 345	2.73	2.44	17.68	34.44
1979 GM 350	0.59	2.48	20.40	64.76
1979 Ford 400	2.15	4.89	53.16	112.43
1979 Ford 370	1.20	3.51	37.12	47.75
1979 Chrysler 360	1.18	2.67	21.38	98.14
1979 Chrysler 440	0.83	3.83	10.47	112.38
1979 GM 454	0.47	1.31	20.11	78.49

[1] Engines were tested as received from the manufacturers.

[2] All levels are undeteriorated.

$X = \frac{Trans}{9\text{-}mode}$

$N = 12$

$\bar{X} = 3.916$ $\bar{X} = 3.922$

$s = 1.852$ $s = 2.784$

lower the total HC emissions are, the lesser the percent contribution of the LAF segment to that total.

In summary, power enrichment occurs at the high power points throughout the entire transient test cycle, but the majority of this high power operation is found in the LA Freeway segment. Emissions performance over this segment is the major differentiating factor between lower and higher emitting engines. Control of power enrichment is the first and most effective step in reducing CO emissions with or without a catalyst. This will be discussed further below.

5. Transient Operation/All Speeds and Loads

As the LAF emissions contribution drops when going from the higher to lower emitting engines, the contribution from other segments tend to increase until no single segment is dominant. (The obvious exception to this is cold start HC, which is discussed below.) Aside from certain physical factors,* these emissions arise from less than accurate fuel metering and mixing as the engine drives over the entire test cycle. If the fuel flow does not precisely match the engine inlet air flow at any instant in time, then too lean or too rich mixture conditions prevail, along with ensuing lean misfire (high HC) or incomplete combustion (high HC and CO). This matching is complicated by the inevitable need to closely match the fuel and air flows at continually varying speeds and loads while also maintaining power and driveability. All current technology engines were emission optimized at idle, and at eight different steady-state power modes at 2000 RPM. This represented a reasonably simple design/calibration problem, as evidenced by the engines' emission performance over the 9-mode test. Once outside that limited regime of emission-optimized modes, however, such as on the road or on the transient test, emissions remain virtually uncontrolled. Little design attention with respect to emissions has been given to the majority of the engines' operating ranges.

Precise matching of fuel and air flows under varying conditions, including transient enrichment by the accelerator pump for driveability, is a major emission-related problem of mixture control. Another is the problem of achieving as homogeneous (perfectly mixed) a fuel/air (F/A) mixture as possible. Incomplete mixing (including liquid fuel deposition on the manifold or combustion chamber walls) produces localized pockets of rich and lean mixtures, resulting in an overall increase in HC and CO emissions. Complete mixing is also critical to achieving uniform A/F ratios from cylinder to cylinder, again to optimize overall emission performance.

* Combustion chamber design affects wall quenching. Inlet manifold design affects mixture distribution between cylinders, fuel deposition in the manifold, and heat exchange characteristics. All of these in turn affect HC and CO emissions.

The above problems are not new, are well recognized, and have already been addressed in the light-duty passenger car fleet. Experience with the light-duty fleet has indicated, however, that there exists a definite limit to the amount of HC and CO emission reductions achieveable through recalibration before power, driveability, and/or fuel economy become unacceptable. For this reason, catalysts become inevitable at lower emission standards, both for their effectivenss and the flexibility in engine calibration their effectiveness permits.

6. Cold Engine Operation

Cold start emissions are substantially higher than those of a fully warmed-up engine, and usually require separate attention during control system design. Again referring to Tables II-2 and II-3, we note that cold start HC contributions are high, and become dominant at lower overall levels of HC emissions. Cold start CO on the other hand has a relatively minor effect on an overall basis. This phenomenom is typical, though perhaps exaggerated by the lack of design control in the past, and is attributable to the fact that a very rich mixture is needed for starting and driveability in a cold engine, to compensate for deposition of a large part of the fuel on cold manifold walls. This rich mixture is provided by the choke mechanism, either manual or automatic. Emissions arise both from this overall rich mixture, misfire, and from the eventual evaporation of the condensed fuel. Emissions have not been a design constraint in the past for cold starting, only startability, driveability, and power. The transient test procedure itself is demanding, requiring both emission control and high power driveability early in the cold start cycle.

C. Available Control Techniques

1. Overview

Widespread introduction of new non-catalyst technologies is assumed to be an unrealistic scenario for the 1984 model year. This is a function of the remaining leadtime, and cost - the intent of this rulemaking is to ease the capital expenditure burden on the industry. Technologies which EPA expects to be implemented for 1984 will not be new, but rather will represent refinements, recalibrations, and optimizations of current technologies.

2. Improvements to Fuel Metering

By and large, fuel metering improvements will be the single most effective strategy for reducing overall HC and CO emissions in 1984 engines, especially when optimized for the transient test. These improvements include modifications to carburetors to achieve more precise F/A ratio control, and recalibration to leaner F/A ratios on an overall basis, and especially under transient conditions and WOT.

Figure II-1 presents the CO emission distribution of the 1979 baseline engines. Note that two mutually exclusive sets of carburetors are found above and below 70 grams/BHP-hr, representing higher and lower emitting engines. Some carburetors (those below 70 g/BHP-hr) meter fuel more accurately under transient conditions even though also optimized for the 9-mode. Power enrichment, sometimes observed at 4-6 percent CO (40,000 to 60,000 ppm in the raw exhaust) contributes substantially to these CO levels, as shown above in Table II-3. At any rate, we infer from Figure II-1 that since two groups of carburetors produce two radically different emission rates on a test procedure for which neither was optimized, the higher emitting group is unrepresentative of current technology and should not be considered a realistic starting point when extrapolating achieveable emission reductions. They represent excessive power enrichment/inaccurate fuel metering producing twice the CO emissions of other engines of equivalent power and displacement. The realistic current technology CO baseline is, therefore, presumed to be in the range of 40-60 g/BHP-hr. It is from this range downward in which development work will be concentrated.

The prime result of recalibration will need to be leaner mixture calibration, and leaner WOT and transient enrichment, thereby reducing both HC and CO emissions.

3. Improved Mixture Distribution

As overall calibrations get leaner, it becomes more important from a power, driveability, and emissions standpoint that the F/A mixture be as homogeneously mixed as possible and the mixture distribution to each cylinder is uniform. Localized rich or lean "pockets" in the mixture should be eliminated by the time it enters the cylinder. Assuring uniform F/A mixture distribution to each cylinder is also important. Too lean a mixture in one or more cylinders will force recalibration to a richer operating point to accommodate the needs in that cylinder, which will in turn cause too rich a mixture in other cylinders.

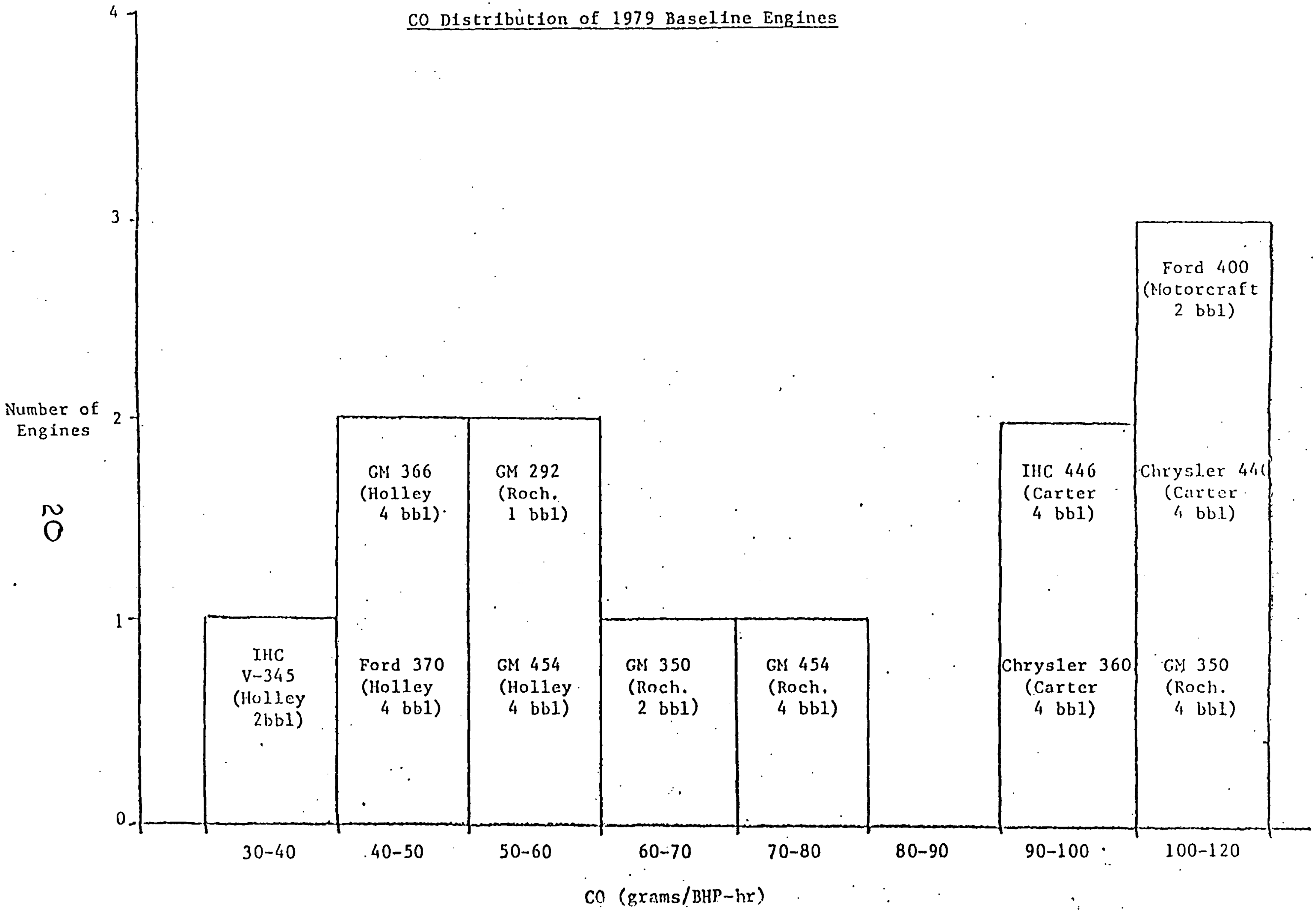
This is essentially a problem of improving the mixing of air and fuel in the manifold prior to cylinder induction. The liquid fuel must be vaporized and then mixed, requiring heat energy and substantial turbulence. Deferring the problem of cold starting until later, heat energy arises from the air itself and from the warm manifold. Improvements would come from redesign of the manifold to increase turbulent mixing, and to increase heat transfer (perhaps by heating intake air by drawing it across the exhaust manifold) to the intake air or air/fuel mixture.

4. Other Physical Modifications

Other physical changes to the engine have been proven to reduce unburned fuel emissions, such as decreasing surface-to-volume ratio of the combustion chamber to minimize wall quenching, reductions in cylinder "dead" volume, etc. Although these may be per

Figure II-1

CO Distribution of 1979 Baseline Engines



formed on some engine families, we do not consider fleetwide physical redesign of engine combustion chambers for all families to be realistic or necessary for 1984.

5. Other Calibration Optimizations

As mixture calibration optimization reaches its limit with respect to attainable reductions, other calibrations - notably spark timing - can be utilized to further reduce HC and CO. Ironically, these reductions are made possible by the other 1984 MY emission standard for heavy-duty engines: the NOx standard of 10.7 grams/BHP-hr. NOx emissions at this level are relatively uncontrolled, and will allow ignition timing calibration to be set near MBT* - the most efficient calibrations. The higher NOx standard permits both lean mixtures and optimum timing advance - both of which increase NOx but decrease HC and CO emissions and fuel consumption.

Furthermore, spark timing can also be optimized for the cold start portion transient test procedure. The light duty fleet currently uses electronically-controlled spark timing to optimize ignition under all engine operating conditions in the Federal Test Cycle to minimize emissions and maximize fuel economy. The methodology and technology is entirely applicable, if necessary, to HDG engines on the transient test.

6. Improved Warm-up Characteristics

As emission levels decrease with mixture and ignition timing optimizations, the limiting factor for HC reductions is clearly the engine's performance on the cold start portion of the transient test. As Table II-2 above indicated, cold start HC emissions are the dominant fraction of engine-out HC.

Two strategies exist for reducing cold start emissions: restrict the amount of cold mixture enrichment, and increase the warm-up rate of the engine. The former is straightforward, and limited by the amount of leaning a cold engine can withstand and still maintain the high driveability and performance both the road and the transient test require. This is done by choke recalibration. Increasing the warm-up rate of the engine can be accomplished in primarily two ways: decrease the efficiency of the overall combustion cycle, and use exhaust gas heat to rapidly warm the intake manifold and/or intake air. Cycle efficiency reductions are best achieved by changing spark timing as a function of engine temperature: less efficient spark timing calibrations reduce engine efficiency, and increase the amount of waste heat rejected to the combustion products and thereby conducted to the engine itself. The result is a faster warm-up; less time spent in a cold state reduces cold emissions.

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* "MBT" denotes the minimum timing retard (i.e. maximum timing advance) at which maximum power is obtained without inducing knock reactions.

Cold start HC emissions, as elaborated above, are presently uncontrolled, and generally dominate at lower overall HC emission levels. Table II-5 lists current technology engines, and the percent increase in composite total transient test HC and CO emissions attributable to the cold start cycle. (The cold start cycle is identical in every way to the hot cycle, with the sole exception of engine temperature.) From this we can infer the amount of emissions generated by the "cold"* engine temperature. Figure II-2 graphically portrays the percentage attributable to cold engine temperature versus the total composite test result, and illustrates the general trend of increasing impact of cold HC emissions with lower overall HC emission rates. (Note that there are exceptions to the trend). All of the 1979 baseline engines tested by EPA were equipped with automatic chokes; the high degree of scatter in the Table II-5 data indicates that varying choke calibrations are possible. Since the varying engine calibrations were not optimized for either a transient test or a cold start, the available data does not lend itself to determining the exact contribution of the cold start to overall test results at any given emission level. The data do indicate, however, that it can be significant (probably 10-40 percent). The real question is to what degree cold start HC emissions can be reduced by choke recalibration/improved warm-up. Experience tells us that significant reductions are achievable from uncontrolled engines.

7. Summary of Possible Control Techniques

Based on the discussion above EPA has identified a number of potential means of reducing HC and CO emissions from HDG engines. These are summarized below.

a. Carburetion - modifications and improvements to the power enrichment, accelerator pump, and general fuel metering systems.

b. Calibrations - spark timing, A/F ratio, and EGR flow rate calibrations.

c. Manifold/Combustion Chamber Redesign - intake manifolds could be redesigned to improve the homogeneity of the F/A ratio. Combustion chamber surface-to-volume ratio could be decreased and cylinder dead volume minimized to lessen fuel quenching on cylinder walls.

d. Air Injection System - Increased air injection to the exhaust manifolds will increase the HC and CO oxidation. This system could be further improved by an air modulation system and possible recalibrations of the pressure relief and diverter valves. Some exhaust manifold modifications may also aid the efficiency of the air injection system.

* "Cold," for laboratory test procedure purposes, is a temperature between 68° and 86°F.

Table II-5

Cold Start Contribution to Composite Emission Results

Engine	HC Composite HS	HC Composite Total Test	HC % Due To CS	CO Composite HS	CO Composite Total Test	CO % Due To CS
Ford 400	4.26	4.80(H)	11.3%	110.4	113.2	2.5%
Chrysler 440	3.70	3.81(H)	2.9%	112.5	115.6	2.7%
Ford 370	3.10	3.31(H)	6.3%	43.5	45.0	3.3%
IHC 446	3.06	3.32(M)	7.8%	90.5	92.9	2.6%
GM 350	1.71	2.57(M)	33.5%	66.0	67.8	2.7%
Chrysler 360	2.46	2.45(M)	neg.	90.0	92.0	2.2%
GM 350	2.36	2.66(M)	11.3%	97.2	101.5	4.2%
IHC 345	1.98	2.35(M)	15.7%	31.3	32.8	4.6%
GM 454	1.14	1.29(L)	11.6%	79.8	81.9	2.6%
GM 366	1.55	2.22(L)	30.2%	40.4	41.9	3.6%
GM 292	1.38	2.12(L)	34.9%	51.2	55.0	6.9%
GM 454	2.04	2.46(M)	17.1%	54.8	55.9	2.0%

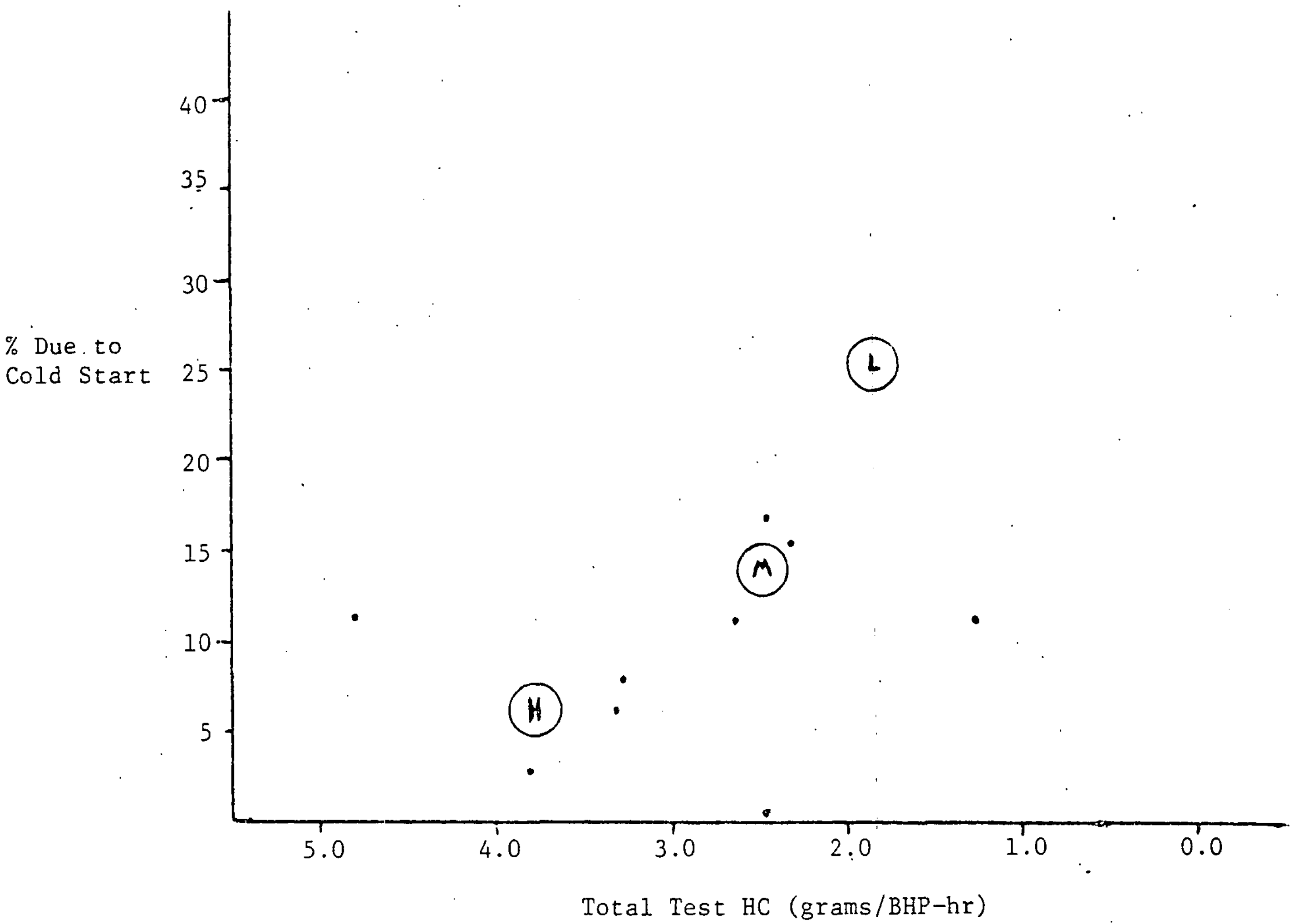
HC Averages:		
	High (H):	6.3%
	Med. (M):	14.2%
	Low (L):	25.6%

* Grams/BHP-hr, results of individual tests, unweighted.

Figure II-2

Cold Start Contribution to Total Test
HC Emissions as a Function of Total Test Emissions

H : Average, All higher emitting engines.
M : Average, All moderate emitting engines.
L : Average, All lower emitting engines.



e. Automatic Choke - the use of a properly calibrated automatic choke would decrease cold start HC and CO emissions and improve warm-up time.

f. Early Fuel Evaporation (EFE) - this system involves the use of exhaust gases to warm the air-fuel mixture by directing some of the exhaust gases through a passage below the carburetor. A warmer A/F mixture improves the fuel distribution to the cylinders and results in lower emission levels and shorter warm-up periods.

g. Heated Air Intake - heated air intake or a modulated air cleaner system uses exhaust gases to warm the intake air to the carburetor. This improves engine warm-up time and reduces emissions by allowing leaner carburetor calibrations.

h. Exhaust Gas Recirculation (EGR) - EGR primarily used for NOx control, can also be beneficial with regards to HC control. Besides its overall leaning effect on the mixture, it also permits recombustion of a percentage of the exhaust gases. Similarily, increased valve overlap works as a form of "internal EGR."

The effectiveness of modifications and hardware of this type has been demonstrated in the light-duty vehicle and light-duty truck fleets for several years. These control strategies should be available for the 1984 model year HDG engines and should provide substantial HC and CO reductions over current levels.

8. Tradeoffs

The emission control strategies discussed above have tradeoffs with respect to fuel economy, power, and driveability. Leaner mixtures, less power enrichment, and quicker engine warm-up all improve fuel economy, but when carried to excessive degree could impair power and driveability. An increase in air injection would also cause a small fuel economy loss. EPA now believes that the fuel economy impacts of these regulations will be basically neutral. The limits to emission reduction will be determined equally by power requirements and driveability needs in addition to any fuel economy concerns.

D. Attainable Reductions/Proposed Emission Standards

As described above, several relatively simple and effective means of emission control are available. At this time, EPA has limited data as to the absolute effectiveness of a given technique on heavy-duty gasoline engines. For example, no testing has been performed to date on a current engine where mixtures were leaned out, spark timing curves optimized, power enrichment limited, and fast warm-ups or fast opening chokes were initiated. It is difficult to quantitatively predict attainable emission reductions without results of such testing.

One approach to deriving achievable standards would be to use an engineering estimate of the efficiencies of the previously described reduction techniques. These efficiency estimates could then be applied to the current baseline emissions data to calculate what emission levels could be reached. Lacking any other substantive data or technique at this time this methodology will be used.

The emission reduction efficiencies used in this analysis are those expected from the lower emitting engines in the current technology baseline (see Tables II-2 and II-3) so the average HC and CO emission rates from the low emitting engines will serve as the baseline levels. One might question the use of the lower emission levels as not being representative of the average emission levels. However for the higher emitting engines the efficiency estimates would in turn be substantially larger. We have chosen to use the lower emitting engines because they already reflect what could easily be achieved on other current technology engines with even minor calibration changes.

Tables II-2 and II-3 clearly indicate that the HC and CO emission levels in certain modes are so large that they require specific attention in this analysis. HC emissions could be divided into "cold/warm start" and "other." CO emissions could be divided into "LAF" and "other." Table II-6 lists the emission reduction techniques together with the modes in which they will be effective in gaining emission reductions. This information will serve as a background for the discussion which follows.

1. Hydrocarbons [3]

As shown in Table II-2 cold/warm start emissions account for 49 percent of the HC emissions. Thus the remaining 51 percent comes from the "other" six portions of the test. In terms of the average of the low emitting engines from Table II-3 the "cold/warm start" portions account for 0.92 g/BHP-hr and the "other" portions account for 0.96 g/BHP-hr.

With the emission control strategies shown in Table II-6 we believe that substantial reductions in HC emission levels are easily achievable. Our current belief is that reductions of 50-60 percent are possible in the "cold/warm start" portions of the test through the means shown in Table II-6. For all practical purposes "start" emissions are uncontrolled on the current test procedure. EPA also believes that reductions of 30-40 percent are also available on the other portions of the test procedure. Assuming the ranges of engineering estimates of reduction efficiencies given above, achievable emission levels can be calculated.

a. Cold/Warm Start Reductions

High Estimate: (0.92 g/BHP-hr)(60%) = 0.55 g/BHP-hr

Table II-6

Test Portions/Emission Reduction Technologies

	HC		CO	
	Cold/Warm Start[1]	Other[2]	LAF[3]	Other[4]
Carburetion	X	X	X	X
Calibrations	X	X	X	X
Manifold/Combustion Chamber	X	X	X	X
Air Injection		X	X	X
Automatic Choke	X			X
EFE	X			X
Heated Air Intake	X			X
EGR		X		

[1] Sample Bags 1 & 5

[2] Sample Bags 2, 3, 4, 6, 7, 8

[3] Sample Bags 3 & ~~4~~ 7

[4] Sample Bags 1, 2, 4, 5, 6, 8

Low Estimate: (0.92 g/BHP-hr)(50%) = 0.46 g/BHP-hr

New Range: 0.37 - 0.46 g/BHP-hr

b. Reductions in Other Portions

High Estimate: (0.96 g/BHP-hr)(40%) = 0.38 g/BHP-hr

Low Estimate: (0.96 g/BHP-hr)(30%) = 0.29 g/BHP-hr

New Range: 0.58 - 0.67 g/BHP-hr

c. Achievable Emission Levels

Using "High Estimate": 1.88 - 0.55 - 0.38 = 0.95 g/BHP-hr

Using "Low Estimate": 1.88 - 0.46 - 0.29 = 1.13 g/BHP-hr

Emission levels in the 0.95 - 1.13 g/BHP-hr range would support an HC emission standard of 1.3 g/BHP-hr.

Using a full life multiplicative deterioration factor of 1.2 and an HC variability of 10 percent, the expected target HC levels are 1.1 g/BHP-hr for 1984 (no SEA) and 1.0 g/BHP-hr when SEA begins in 1986. The range of achievable emission levels shown above supports the feasibility of these targets and thus the 1.3 g/BHP-hr standard.

2. Carbon Monoxide

As shown in Table II-3 the "LAF" (LA Freeway) CO emissions account for 43.2 percent of the total. Thus the remaining 56.8 percent arises from the "other" portions of the test. When these percentages are applied to the average low CO engines of Table II-3, the "LAF" accounts for 19.9 g/BHP-hr and the other portion accounts for 26.2 g/BHP-hr.

With the emission control strategies shown in Table II-6 substantial reductions in CO emission levels are easily achievable. Reductions of 40-50 percent are possible in the "LAF" portion of the test through the means in Table II-6. Emissions under the high-speed, high-power operation characteristic of the LAF portion are relatively uncontrolled because of the limited power demands of the 9-mode test procedure. Reductions of 30-40 percent are also possible from the "other" portions of the test procedure. Given the engineering estimates of reduction efficiencies shown above, achievable emission levels can be calculated.

a. LAF Reductions

High Estimate: (19.9 g/BHP-hr)(50%) = 10 g/BHP-hr

Low Estimate: (19.9 g/BHP-hr)(40%) = 8 g/BHP-hr

New Range: 9.9 - 11.9 g/BHP-hr

b. Reductions in Other Portions

High Estimate: (26.2 g/BHP-hr)(40%) = 10.5 g/BHP-hr

Low Estimate: (26.2 g/BHP-hr)(30%) = 7.9 g/BHP-hr

New Range: 15.7 - 18.3 g/BHP-hr

c. Achievable Emission Levels

Using "High Estimate": 46.1 - 10 - 10.5 = 25.6 g/BHP-hr

Using "Low Estimate": 46.1 - 8 - 7.9 = 30.2 g/BHP-hr

Emission levels in the 25.6 - 30.2 g/BHP-hr range would support a CO emission standard of about 35 g/BHP-hr. Using a full life multiplicative deterioration factor of 1.1 and a CO variability of 20 percent, the expected target CO levels are 31.8 g/BHP-hr for 1984 (no SEA) and 25.5 g/BHP-hr when SEA begins in 1986. The range of achievable emission levels shown above supports the feasibility of these targets and thus the 35 g/BHP-hr standard proposed here.

Considering all of the factors bearing on this analysis (cost, fuel economy, leadtime, power, and driveability), EPA believes that the standards herein discussed are achievable for all HDG engines for the 1984 model year. However if during the comment period further data and information would prove the standards to be infeasible the option for further relaxation for final rulemaking exists.

E. Idle Emission Standard

For heavy-duty gasoline engines, the 1984 idle CO standard is 0.47 percent (raw exhaust composition). Table II-7 presents the current technology idle CO baseline. Note that five of twelve engines already comply. Given the fact that substantial leaning of mixtures will be performed to meet the transient standards, there is no reason to believe the idle circuits of the remaining engines cannot be improved. EPA judges compliance with the idle standard to be relatively straightforward and will pose no problems to manufacturers even considering any small deterioration factor which may need to be included.

Table II-7

Idle CO Current Technology Baseline Emissions

Engine	Idle CO (%)	Complies with 1984 standard?
IHC 446	.299	yes
IHC 345	.402	yes
GM 366	.913	no
GM 350	1.158	no
Ford 400	1.853	no
Ford 370	.515	no
Chrysler 360	.226	yes
Chysler 440	1.279	no
GM 454	.596	no
GM 292	.308	yes
GM 454	.888	no
GM 350	.242	yes

References

1. Cox, Timothy P., "Heavy-Duty Gasoline Engine Emission Sensitivity to Variations in the 1984 Federal Test Cycle," SAE No. 801370.

2. Auiler, J., et. al., "Optimization of Automotive Engine Calibration for Better Fuel Economy-Methods and Applications," SAE Paper No. 770076.

3. Here we are addressing total hydrocarbon emissions and a total hydrocarbon emission standard. EPA intends to propose an optional non-methane hydrocarbon standard for HDEs in a future rulemaking.

4. The terms "High Estimate" and "Low Estimate" refer to the range of reduction efficiencies. The percent figures shown are the actual efficiencies.

CHAPTER III

ENVIRONMENTAL IMPACT

A. Introduction

The 1984 light-duty truck (LDT) and heavy-duty engine (HDE) final rulemakings (FRM) as promulgated were expected to provide significant lifetime per vehicle emission reductions and improve overall air quality. This analysis will examine the impact of the proposed revisions and relaxations of the 1984 FRMs, with the goal of determining the loss in lifetime emission reductions and air quality improvement which could occur if they are adopted.

The base case for our emission reduction and air quality analysis is the 1984 final regulations. In the base case we will determine the per vehicle emission rates and air quality improvements which would be expected. In the comparison case we will incorporate the proposed revisions and relaxations to determine their impact on both the per vehicle emission rates and overall air quality.

It should be noted that this analysis will not include a major review of the health and welfare aspects of HC (ozone) and CO, nor will it include a major discussion of the national HC and CO emission inventories. These reviews can be found in other documents, and are beyond the needs of this analysis.[1][2]

B. Changes in the Per Vehicle Emission Rates

1. Introduction

Perhaps the figure which best expresses the potential environmental impact of a proposed regulatory action is the change in the per vehicle emission rate and lifetime emissions which the action would bring about. In this section of the analysis we will examine the changes in the per vehicle emission rates to determine the loss in HC and CO reductions which would occur under the proposed revisions and relaxations.

Before beginning this analysis a few additional explanatory remarks are necessary. Lifetime per vehicle emission rates are determined using calculated target emission levels. In turn, these target emission levels are calculated using the expected deterioration factor and production line variability. The deterioration factors and variabilities used are the anticipated industry-wide averages. For any one manufacturer the deterioration factor and/or the variability could be significantly different, such that the target emission levels and per vehicle emission rates could also differ. Our analysis is intended only to reflect the expected average deterioration factors and variability and thus cannot be assumed to implicitly apply to a given engine family.[6]

Secondly, as was discussed previously, this action proposes several relaxations to the LDT and HDE SEA programs. These include implementation of a 40 percent AQL for LDTs and HDEs beginning in 1984. Also, the HDE SEA program will be delayed from 1984 to 1986.

As part of this action, EPA is announcing a 2-year deferral period (the 1984 and 1985 model years) for HDE SEA. Since no SEA program will be in place until 1986, manufacturers certifying in 1984 and 1985 will have to account only for the deterioration factor in computing their target emission levels. However, we expect that the manufacturers will begin planning for the impact of SEA before 1986, specifically during 1984 model year certification, and thus will design the engine and emission control systems with the 1986 SEA requirements (40 percent AQL) in mind.

Therefore, we expect that to some degree the 1984 and 1985 model year HDE emission rates will reflect the impact of the SEA requirements. In our previous analyses we anticipated the manufacturers' reactions to SEA would include self-audit testing, increased quality control, and in some cases additional engine modifications and hardware. Although we do not expect the self-audit testing and increased quality control to begin until necessary, the additional modifications and hardware will probably be used when possible beginning in 1984. Therefore, we expect that 1984 and 1985 model year HDEs will have per vehicle emission rates slightly lower than if they accounted only for deterioration, but greater than in 1986 when the SEA requirements must be met. Our air quality analyses of the emission rates of 1984-85 heavy-duty vehicles will not inherently include this impact, so the per vehicle emission rate increases shown for 1984 and 1985 HDEs may be slightly higher than that which will actually occur.

2. <u>Hydrocarbons</u>

The proposed relaxation to the SEA provisions will affect the HC emission rates of both LDTs and HDEs. For LDTs the relaxation of the AQL is the only factor to be considered, but for HDE's both the relaxation of the AQL and the deferral of SEA will have an impact.

a. <u>Light-Duty Trucks</u>

As described in the regulatory analysis supporting the 1984 FRM, the 10 percent AQL caused the HC target emission level to drop from 0.53 g/mile to 0.49 g/mile. Relaxation of the AQL back to the 40 percent level would increase the target to 0.53 g/mile. Over the LDT lifetime this means an increase of about 0.006 tons (12 pounds) in additional HC emissions.[3]

b. <u>HDG Engines</u>

Both the deferral of the HDE SEA program and the relaxation of the AQL would affect HDG engine emission rates. In 1984-85 the engines will not be subject to any SEA, so the only factor manufacturers would have to account for is the expected deterioration. In the 1986-88 period manufacturers would have to account for both deterioration and SEA at a 40 percent AQL.

The changes from catalyst to non-catalyst control technology and the resultant decrease in the deterioration factor will also cause an increase in the total lifetime HC emissions. This will begin in 1984 and continue through the period.

(1) <u>1984-1985 Model Years</u>

In the 1984 and 1985 model years manufacturers will have to deal only with deterioration. Based on a non-catalyst control strategy, a full life multiplicative deterioration factor of 1.2 is consistent with past analyses.[4] This would give a target emission level of about 1.1 g/BHP-hr.

Assuming a brake specific fuel consumption of 0.7 and a fuel economy of 5 miles/gallon these emission levels are 1.9 g/mile for the target level and yield a deterioration factor of .031 g/mile/ 10,000 miles.

(2) <u>1986 and Later Model Years</u>

The only change in the 1986 and later model years is that manufacturers will have to deal with SEA at a 40 percent AQL. The impact of this is to slightly lower the target emission level. Using an HC variability of 10 percent, the new target level becomes 0.97 g/BHP-hr. In terms of g/mile this figure is 1.69 g/mile.[4]

We do not expect the implementation of the SEA program in 1986 will cause any new hardware or engine modifications. Therefore, the deterioration rate should be the same as that of the 1984-85 model years.

Table III-A compares the emission rates of the 1984-85 and 1986 and later model year HDG engines (non-catalyst) to the emission rates expected from the original 1984 final rulemaking. The per vehicle lifetime increases in the 1984 and 1985 model years shown are probably larger than will occur because some manufacturers will opt to comply with the R&D/hardware needs of SEA and the 40 percent AQL beginning in 1984, to avoid replicate efforts in 1986.

c. <u>Heavy-Duty Diesel Engines</u>

(1) <u>1984-1985 Model Years</u>

In the 1984-85 model years no SEA program will be in effect, so the manufacturers would have to account for only deterioration over the lifetime. Based on past analysis this factor is 1.05 (multiplicative) for a target level of about 1.24 g/BHP-hr.[4]

Assuming a brake specific fuel consumption of 0.43 and a fuel economy of 5.8 miles/gallon these figures become 3.53 g/mile for the target level and .007 g/mile/10,000 miles for the deterioration factor.[4]

(2) 1986 and Later Model Years

In the 1986 and later model years, the manufacturers will have to deal with SEA at a 40 percent AQL as well as lifetime deterioration. The major impact of the SEA program is to slightly lower the target emission levels, but since no major hardware related changes are expected, the deterioration factor should remain unchanged. Using an HC variability of 16 percent the new target emission level for HC is 1.05 g/BHP-hr or about 3.00 g/mile.[4] The deterioration rate will remain unchanged.

The data shown in Table III-B compares the lifetime emission rates for the three cases being considered in the heavy-duty diesel engine analysis. As before with the HDG engines, EPA does not expect that the actual increase in the per engine HC lifetime emissions will be as large as shown for the 1984-85 model year HDD engines. We expect that most manufacturers will design their engines for 1984 certification to be consistent with the demands of the 1986 and later model year SEA program.

d. Summary and Discussion

Especially for LDTs and HDG engines, the long term increases in lifetime HC emissions as a result of the proposed action are not large. The HDD engine HC emission rates are higher than the others because of the higher variability, lower deterioration factor, and longer average lifetime. Clearly, the expected increase in HC emissions from these vehicles will result in less of an ozone air quality improvement than was expected in the original 1984 final rulemakings. However, it is our inital judgment that the expected losses are not adequate to warrant a complete ozone air quality impact analysis for this proposal. Depending upon additional information uncovered in the formal public comment period the ozone air quality analysis may be included in the final rulemaking analysis.

3. Carbon Monoxide

All aspects of the proposed relaxations and revisions will affect the CO emission rates from LDTs and HDG engines. The proposed relaxations to the AQL will effect both LDTs and HDG en-

Table III-B

HDD Engine HC Emission Rates

	Low Mileage[1]		Deterioration Factor[2]		Lifetime Emissions	Increase
	g/BHP-hr	g/mile	g/BHP-hr	g/mile/10,000 mi	Tons[3]	Tons
1984 FRM (SEA at 10% AQL)	0.89	2.53	1.05	.007	1.368	-
1984-85 (No SEA)	1.24	3.53	1.05	.007	1.891	.523
1986+ (SEA at 40% AQL)	1.05	3.00	1.05	.007	1.614	.246

[1] Target level.

[2] Multiplicative; 250,000 miles to rebuild.

[3] 475,000 miles.

gines. The two year deferral of the HDE SEA program and the proposal to relax the HDE CO emission standard emission rates to non-catalyst levels will also effect HDG engines.

As is generally known, CO emission levels from diesel engines are well below even the statutory HDE emission standards, so the proposed relaxations and revisions will have no impact. Therefore no further analysis of HDD CO emissions will be included.

a. Light-Duty Trucks

The major impact on the LDT CO emission rates is caused by the relaxation of the AQL. As was described in the regulatory analysis supporting the 1984 LDT final rulemaking the expected CO target level would rise from 5.5 g/mile to 6.4 g/mile if the AQL were relaxed from 10 percent to 40 percent. Assuming the same basic control technology with either AQL, the per LDT increase amounts to 0.2 tons of CO.[3]

b. HDG Engines

HDG engines are affected by all three of the proposed relaxations and revisions. HDG engine emission rates will be affected by the proposed revision to the CO emission standard and the smaller deterioration factor associated with non-catalyst control technology. In addition, the deferral of the HDE SEA program and the relaxation of the AQL will also cause increased emission rates. These will be addressed below for the appropriate years.

(1) 1984-1985 Model Years

With no SEA program in effect for these years, the manufacturers will only have to deal with the emission standards and deterioration. HDG CO lifetime emission rate increases will be large because the proposed standard is more than twice the statutory level and the non-catalyst deterioration factor is substantially less than the catalyst based factor.

Based on data gathered for the 1984 FRM analysis, the target level for a 35 g/BHP-hr CO standard is 31.8 g/BHP-hr. This assumes a multiplicative full life deterioration factor of 1.1.[4] In g/mile these figures are 55.42 for the target level and .418 g/mile/10,000 miles for the deterioration factor.

(2) 1986 and Later Model Years

In 1986, manufacturers will also have to consider the impact of SEA at a 40 percent AQL. Since we would expect no fundamental hardware changes, the deterioration factor would change little. Therefore, the major impact would be a lower target emission level. Using a CO variability of 20 percent, the new target emission level is 25.1 g/BHP-hr or about 43.81 g/mile.

Table III-C compares the emission rates of the 1984-85 and 1986 and later model year HDG engines (non-catalyst) to the rates expected from the original 1984 final rulemaking (catalyst-based). As before with HC, the per vehicle lifetime emission rate increase shown for 1984-85 are likely larger than will occur. We expect that in as much as is possible manufacturers will produce their engines to comply with the SEA requirements beginning in 1984, so that the 1986-88 emission rate could be a more representative rate.

c. Summary and Discussion

Even though the proposed relaxations and revisions affect only 2 of the 3 vehicle/engine groups, the absolute magnitude of the increases in lifetime CO emission rates is substantially larger for CO than for HC. This is especially true for HDG engine CO. Therefore, we have included a formal CO air quality analysis to measure the loss in the air quality improvements which could occur if the proposed relaxations and revisions are implemented.

C. Ambient Air Quality Impact: Carbon Monoxide

1. Introduction

This section will address the CO air quality improvement losses which could occur if the proposed relaxations and revisions are adopted. The basic approach used here will be similar to that used for the emission rates, in that the focus will be on the losses in air quality improvements and not on absolute air quality levels.

A CO air quality analysis was conducted using the Modified Rollback method. Separate analyses were conducted for both low and high altitude regions. The low altitude analysis covered 102 counties and the high altitude analysis covered 17 counties.[2] In preparing the air quality projections, baseline emission rates for various source categories were taken from the National Emissions Data System (NEDS) and projections for future control strategies plus growth ratios were made. In combination with the mobile source projections, the data allowed an evaluation of the air quality losses to be expected.

2. Scenarios Analyzed

In total six scenarios have been analyzed, four low altitude and two high altitude.[2] As shown in Table III-D, scenarios 1-4 are low altitude, 5 and 6 are high altitude. All scenarios include I/M for all LDVs and LDTs beginning in 1982.

Scenario 1 is the base case and represents the 1984 LDT and HDE final rulemakings as promulgated. Scenario 2 is the prime comparison case, as it incorporates the proposed relaxations in the SEA programs and the revisions of the HDE CO emission standard.

Table III-C

HDG Engine CO Emission Rates

	Low Mileage[1]		Deterioration Factor[2]		Lifetime Emissions	Increase
	g/BHP-hr	g/mile	g/BHP-hr	g/mile/10,000 mi	Tons[3]	Tons
1984 FRM (catalyst)[4]	5.9	10.30	1.7	0.63	1.74	-
1984-85[5] (non-catalyst)	31.8	55.42	1.1	0.418	7.26	5.52
1986+ [6] (non-catalyst)	25.1	43.81	1.1	0.418	5.80	4.06

[1] Target level.

[2] Full life - multiplicative.

[3] 114,000 miles.

[4] SEA at a 10% AQL.

[5] No SEA.

[6] SEA at a 40% AQL.

Table III-D

Air Quality Analysis Scenarios[1][2]

Scenario	LDV CO Std/Life/SEA(AQL)	LDT CO Std/Life/SEA(AQL)	HDGE CO Std/Life/SEA(AQL)
1	3.4/ 1/2/40%	10/ 1 /10%	15.5/ 1 /10%
2	3.4/ 1/2/40%	10/ 1 /40%	35 / 1 /none: 40%
3	7.0/ 1/2/40%	10/ 1 /10%	15.5/ 1 /10%
4	7.0/ 1/2/40%	10/ 1 /40%	35 / 1 /none: 40%
5	prop./ 1/2/40%	14/ 1 /10%	15.5/ 1 /10%
6	prop./ 1/2/40%	14/ 1 /40%	35 / 1 /none: 40%

[1] All scenarios include I/M for all LDVs and LDTs.

[2] For more detail on each scenario reference 2.

Scenarios 3 and 4 are identical to 1 and 2 respectively, except that both 3 and 4 set the LDV CO emission standard at 7.0 g/mile instead of 3.4. This was done to gauge the sensitivity of the air quality impact of the proposed changes to possible changes in the level of the LDV CO emission standard.

Scenarios 5 and 6 apply to high altitude regions, and accomplish the same fundamental analysis at high altitude as scenarios 1 and 2 at low altitude. The LDV and LDT emission rates reflect proportional CO standards at high altitude.

3. Results and Discussion

a. Average Percent Change in CO Air Quality

Table III-E presents the air quality improvement data for the 102 low altitude and 17 high altitude counties analyzed. Even though the scenario by scenario results alone present some interesting and useful information, the real impact of the proposed revisions and relaxations is found by comparing the results for the different scenarios.

All three comparisons (scenario 1 vs. 2, 3 vs. 4 and 5 vs. 6) show the same general trends. The proposed relaxations and revisions would cause a 1-3 percent loss in the overall air quality improvements which would occur with the base case. All of the scenarios also show hints of air quality degradation beginning by the year 2000. So at either low or high altitude, the average CO air quality improvement is 1-3 percent less than would occur with the base case.

b. Counties Above the Ambient Air CO Standard

Table III-F shows the data relative to the number of counties projected to be above the standard. In this case, the impact of the proposed changes is small. For both the low and high altitude counties, all are in compliance by 1995. At low altitude the proposed relaxations and revisions do seem to cause a delay in several counties achieving the CO ambient air quality standard. At high altitude there is no apparent impact.

c. Total Number of Exceedances

The exceedances data in Table III-G basically shows the same impact as the violations data of the previous table. Simply stated, the proposed relaxations and revisions will allow several more exceedances per year at low altitude during the 1985-1990 time period. At high altitude there is only a small impact for the years studied. After 1995, no exceedances were computed at low or high altitude.

4. Conclusions

Table III-E

Average Percent Change in CO Air Quality

Low Altitude

Scenario	1985	1988	1990	1995	2000	
1	-58	-70	-73	-77	-77	
2	-58	-68	-71	-75	-74	
	0%	2%	2%	2%	3%	improvement foregone
3	-58	-68	-72	-74	-74	
4	-57	-67	-70	-72	-72	
	1%	1%	2%	2%	2%	

High Altitude

Scenario	1985	1988	1990	1995	2000
5	-59	-72	-77	-81	-82
6	-58	-70	-75	-79	-80
	1%	2%	2%	2%	2%

Table III-F

Counties Exceeding the CO NAAQS

Low Altitude

Scenario	1985	1988	1990	1995	2000	
1	6	1	0	0	0	
2	6	2	0	0	0	
	0	1	0	0	0	violating counties
3	6	1	0	0	0	
4	6	2	1	0	0	
	0	1	1	0	0	

High Altitude

Scenario	1985	1988	1990	1995	2000
5	2	0	0	0	0
6	2	0	0	0	0
	0	0	0	0	0

Table III-G

Total Number of Exceedances

Low Altitude

Scenario	1985	1988	1990	1995	2000
1	25	1	0	0	0
2	31	2	0	0	0
extra exceedances	6	1	0	0	0
3	28	2	0	0	0
4	32	4	1	0	0
extra exceedances	4	2	1	0	0
High Altitude					
5	4	0	0	0	0
6	5	0	0	0	0
extra exceedances	1	0	0	0	0

A cursory review of the data shown in Table III-E, F, and G would lead to the conclusion that the proposed relaxations and revisions would have a small negative impact in the mid and late eighties, but none thereafter. This is essentially correct if the accuracy of all of the assumptions and data that went into the modified rollback could be guaranteed. Given that there are a significant number of parameters needed by the model which must be estimated by the user, it would be unwise to conclude that the results of the model are precisely accurate. However, the model predicts trends quite well. For example, in Table III-F the number of counties exceeding the NAAQS could easily be off by one or more in any year in the mid to late eighties. However it would be correct to say that the analysis clearly shows that the potential negative impact is likely very small.

One other extremely important judgment that went into this analysis should be highlighted. This analysis assumed that I/M would be implemented where required, beginning in 1982, for all LDVs and LDTs. If the I/M programs were delayed or scaled down in geographical area or scope, the air quality analysis would likely reflect less total improvement with time, as well as more exceedances and more counties above the standard. The impact of the proposed relaxations and revisions would then probably be somewhat larger. However, we expect that the overall impact of this proposal would remain small, but would probably be noticeable into the 1990's.

D. Other Environmental Impacts

1. Lead

The relaxation back to non-catalyst technology will also cause the loss of the expected reductions in tailpipe lead emissions from HDG vehicles. Assuming a lead content of 1.1 grams per gallon in leaded fuel and a tailpipe out emission rate of 80 percent, the benefit foregone amounts to approximately 22.3 lbs. per HDG vehicle over its lifetime.[5] This calculation assumes an average HDG vehicle lifetime of 114,000 miles and an average class-wide fuel economy of 9.9 miles/gallon.[4]

2. Sulfuric Acid

With the implementation of catalytic converter technology on HDG engines, EPA expected a slight increase in the per HDG vehicle sulfuric acid emission levels. With the move back to non-catalyst technology this slight increase will no longer occur.

3. Misfueling

Since 1975 and 1976 respectively, most LDVs and LDTs have required the use of unleaded fuel. Given an average lifetime of 10 years for LDVs and 12 years for LDTs, EPA expects a substantial decrease in the demand for leaded fuel by 1984. We expected this demand would be even less as a result of the new requirement for unleaded fuel use in HDG engines. At some point in the mid-to-late eighties demand for leaded fuel would have dropped to the point that its production and distribution might have become cost prohibitive for some companies. A decrease in the available supply of leaded fuel would have led to a decrease in the misfueling rate.

This move back to non-catalyst technology for 1984-1986 model year HDG engines could extend by several years the general availability of leaded fuel in the marketplace. Unfortunately, as a result the opportunity for misfueling would also be extended.

References

1. For a current review of this data, as well as citations to other reports on health effects of HC and CO, see "Health Effects of Exposure to Low Levels of Regulated Air Pollutants - A Critical Review," Benjamin A. Ferris, Jr., M.D., Journal of the Air Pollution Control Association, Vol. 28, no. 5, May 1978.

2. Air Quality Analysis for the Revised Gaseous Emission Regulations for 1984 and Later Model Year Light-Duty Trucks and Heavy-Duty Engines, September 1981.

3. "Regulatory Analysis and Environmental Impact of Final Emission Regulations for 1984 and Later Model Year Light-Duty Trucks," U.S. EPA, OMSAPC, May 1980.

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

5. The average lead content of leaded regular gasoline was obtained from Robert Summmerhayes of EPA/FOSD, May 15, 1981.

6. This portion of the analysis uses certification-based deterioration factor estimates, not in-use deterioration estimates such as are used in MOBILE II emission factors.

CHAPTER IV

ECONOMIC IMPACT

A. Introduction

This chapter will examine the cost impacts of the proposed changes to the 1984 LDT and HDE final rulemakings previously detailed in Chapter I. Rather than reexamining in detail the entire cost analyses of both final rulemakings, this analysis will evaluate only the cost impacts of the proposed changes. Of necessity, much data from the previous analysis will be used to develop the incremental cost savings.[1][2]

The areas to be evaluated are: the revised HDE CO emission standard, relaxation of the AQL for LDT and HDE SEA, and the two year delay of the implementation of SEA requirements for HDEs.

This analysis is divided into two main sections. In the first section we will examine the cost implications of the proposed revisions to identify and quantify the cash expenditure savings and cash flow savings associated with each action. Cash expenditure savings simply means that the need to spend that sum will be eliminated; cash flow savings means that the need to spend these funds will be deferred. After these savings have been identified and quantified in each category, they will be summarized for each vehicle/engine grouping being considered.

In the second section we will identify in aggregate terms 1) the net cash expenditure savings, 2) the net cash flow savings and 3) the net impact on both the first price increase and the operating costs.

All cost figures used in this analysis are expressed in 1981 dollars unless otherwise noted. Costs carried over from the 1984 HDE final rulemaking (developed mid-late 1979) and the 1984 LDT final rulemaking (developed early-mid 1980) will be inflated at 8 percent per annum.[3] The LDT and HDE sales projections used in the 1984 final rulemakings will also be used in this analysis so that valid per vehicle/engine cost comparisons can be made to gauge the incremental impact of the proposed revisions (Table IV-A). These projections reflect the significant increase in the use of diesel engines which is expected in both LDTs and HDEs.

B. Cost Implications of the Proposed Revisions

1. Revision of the HDE Gaseous Emission Standards

a. Introduction

As has been described previously, the major thrust behind the revisions to these rulemakings has been to provide short-term economic relief to the automotive and related industries. Toward

Table IV-A

LDT Sales Projections (millions) [1]

All States

	0-10,000 GVW	0-8,500 GVW	Domestic LDT	Import/ Captive LDT	LDDT
1984	3.97	3.45	2.69	0.43	0.33
1985	4.25	3.70	2.82	0.46	0.42
1986	4.42	3.85	2.84	0.48	0.53
1987	4.58	3.99	2.83	0.50	0.66
1988	4.81	4.18	2.81	0.52	0.85

49 States (Excludes California)

	0-8,500 GVW	Domestic LDT	Import/ Captive LDT	LDDT
1984	3.13	2.50	0.32	0.31
1985	3.35	2.62	0.34	0.39
1986	3.49	2.64	0.36	0.49
1987	3.61	2.63	0.37	0.61
1988	3.79	2.61	0.39	0.79
	17.37	13.00	1.78	2.59

Heavy-Duty Engine Sales [2]
1984-1988

Year	Gasoline-Fueled	Diesel
1984	366,991	266,161
1985	360,888	284,255
1986	354,287	302,854
1987	347,171	321,966
1988	339,547	341,583
Total	1,768,884	1,516,819

[1] Regulatory Analysis and Environmental Impact of Final Emission Regulations for 1984 and Later Model Year Light-Duty Trucks, U.S. EPA, OMSAPC, May 1980, pp. 31-33.

[2] Regulatory Analysis and Environmental Impact of Final Emission Regulations for 1984 and Later Model Year Heavy-Duty Engines, U.S. EPA, OMSAPC, December 1979, pp. 39-46.

that end, preliminary analyses indicated that much of the capital investment and R&D costs related to the 1984 HDE FRM were tied directly to the implementation of catalytic converter technology on HDG engines. As a result the decision was made to propose a revised CO emission standard beginning in the 1984 model year, which could be achieved without the use of catalytic converter technology.

The technological feasibility discussion in Chapter II supports the proposed emission standards for HC (1.3 g/BHP-hr) and CO (35 g/BHP-hr) assuming compliance with the 40 percent AQL beginning in 1986. These proposed revisions represent no relaxation in the HC standard but do represent a 125 percent increase in the CO standard. Because the relaxation of the CO standard will not affect the expected compliance strategies for HDD engines, their compliance costs will basically require no further analysis over what was contained in the regulatory analysis supporting the 1984 final rulemaking. Therefore this analysis of the costs of compliance with the proposed emission standards will be limited only to HDG engines.

b. Review of the 1984 Final Rulemaking Costs

(1) Aggregate and Per Engine Costs

In late 1979 EPA promulgated final rules implementing new emission standards and compliance requirements for 1984 and later model year heavy-duty engines. In support of this final rule, EPA developed an economic analysis to determine the aggregate cost and first price impact.

To determine the potential economic savings associated with the proposed revisions it is necessary to review the final cost estimates calculated in the past economic analysis. The figures shown in Table IV-B give both the per engine and aggregate cost estimates for the HDG engine portion of the analysis. The figures are given in both 1979 and 1981 dollars and are discounted to January 1984. These figures will be used later in this analysis to determine the potential savings of the proposed revisions to the HDE emission standards and regulations.

(2) Capital Cost Estimate for the 1984 Final Rule: HDG Engines

At the time when the economic analysis supporting the 1984 final rule was conducted (mid-late 1979) the heavy-duty engine industry had just ended a year of record sales (1978). With one exception, there was little question that the heavy-duty engine industry would be able to finance the required investment. As a result, less attention was given to determining the capital cost requirements of the final regulations than might otherwise have been under less favorable economic conditions.

The aggregate cost figures given in Table IV-B do include some capital cost estimates, as some of these investments would be required before production begins. These include certification facilities, research and development, SEA facilities, and certification testing. The area which did not receive explicit attention is the tooling costs associated with the manufacturing of the emission control hardware. Although these costs were stated in an amortized manner as part of the manufacturing cost, they were not stated explicitly as capital investment costs. Identification of these costs now is important, as they represent a major portion of the potential savings associated with the proposal to revise the HDE CO emission standard. Our initial estimate of the tooling capital costs associated with the 1984 HDG final rule as promulgated is shown in Table IV-C.[4] For future reference, the R&D capital costs of the 1984 final rule are also included in Table IV-C.

Having now reviewed the 1984 final rule costs for HDG engines and laid the proper background in relation to capital costs, we can proceed with the analysis of the cost implications of the proposed changes.

c. Non-catalyst Technology Compliance Costs

The technological feasibility discussion of Chapter II outlined the emission control techniques and strategies which are most likely for HDG engines. Costs for achieving compliance with the proposed 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

Phase I of each manufacturer's pre-production R&D program would most likely be a complete characterization of the emission characteristics of each family on the transient and idle tests. This would include emissions characteristics at different calibrations as well as initial optimization of the engine's emissions performance prior to any modifications or additions. This would be accomplished using steady-state mapping techniques as well as hot start and cold start tests. A more limited number of idle tests would also be necessary. Given this test information, the manufacturers would have the information necessary to make decisions as to which modifications and emission control components will be necessary to reach the target emission levels. Considering the leadtime plans submitted by the manufacturers in their comments to the 1979 HDE proposal, we expect that some manufacturers have already completed this phase.

With this initial data Phase II of the R&D program would be the development and application of the emission control systems and engine/component modifications. This task would fall on the

Table IV-B

HDG Engine Compliance Costs: 1984 Final Rule [1]

	Per Engine 1979	Per Engine 1981 [2]	Aggregate 1979	Aggregate 1981
1. Certification Facilities	$ 8.06	9.40	$11,918K	$13,901K
2. Research and Development	15.18	17.71	22,435K	26,168K
3. SEA Facilities	10.98	12.81	16,228K	18,928K
4. Certification Testing	2.45	2.86	3,620K	4,222K
5. SEA Testing	.81	.94	1,196K	1,395K
6. SEA Self Audits	5.06	5.90	7,475K	8,719K
7. Manufacturing	253.00	295.10	373,924K	436,145K
8. Quality Control	10.00	11.66	14,780K	17,239K
9. Overhead and Profit	88.61	103.35	130,957K	152,748K
TOTAL	$394.15	$459.73	$582,533K	$679,465K
Operating Costs				
Unleaded Fuel [3]	$258.72	$258.72	$382,373K	$382,373K
Exhaust System and Spark Plugs	-$176.13	-$205.43	-$260,319K	-$303,636K
Potential Fuel Savings [4]	$422.00	$540.00		

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[1] Regulatory Analysis and Environmental Impact of Final Emission Regulations for 1984 and Later Model Year Heavy-Duty Engines, U.S. EPA, OMSAPC, December 1979, pp. 133-34.

[2] Inflated at 8% per year for two years.

[3] Assumes 3 cent/gallon unleaded-leaded fuel price differential.

[4] Erroneously calculated in the original analysis.

Table IV-C

HDG Emission Control Hardware Tooling Costs
1984 FRM (1981 Dollars) undiscounted [1]

Catalytic Converters	$ 7.0M
Larger Air Pumps	38.5M
Air Modulation System	1.6M
Chassis Heat Shields/ Stainless Steel Exhaust	1.5M
Parameter Adjustment	2.2M
Deceleration Fuel Shut-off	6.5M
Engine Modifications	50.6M
Total	$107.9M
R&D (Table IV-B, undiscounted) [2]	26.2M
Grand Total	$134.1M

[1] See footnote 4 for more detail.

[2] Initially expected to be invested in 1981 and 1982.

four manufacturers of HDG engines and those companies which supply the related components. 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 emission test (transient and idle) is estimated to cost $500, which yields a total testing cost of about $20,000 per family. This methodology could overestimate the full 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 IV-D when other fixed costs are included this cost becomes $36K 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 modification of some other present features. Fortunately, virtually all of the additions and modifications we anticipate will be employed have been used in the LDV/LDT fleets for several years, and some are already used in HDG engine families. As an initial estimate, a figure of $15K per family 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 $20,000 per engine family bringing Phase II costs to $35K per family, (Table IV-E).

Total Phase I and Phase II costs per family sum to $71K per engine family and $1.136 million industry-wide. EPA anticipates that this amount may overestimate the total cost impact of preproduction R&D. This is due primarily to an anticipated decrease in the number of HDG engine families over the next three years. Preliminary 1982 certification data and informal conversations with manufacturers indicate that the number of Federal HDG engine families could drop from 16 to 11 or less by 1984 due to decreasing market demand for HDG engines.

(2) <u>Emission Control System Costs</u>

(a) <u>Modifications and Improvements</u>

The emission-related modifications and improvements which will be necessary to meet the 1984 emission standards will vary by engine family primarily according to its emission characteristics. The costs of control for each family will vary according to the emission characteristics and the currently used

Table IV-D

Pre-Production R&D Testing Costs

Phase I

Manufacturer	(a) # Engine Families [1]	(b) Fixed Costs per Family [2]	(c) Testing Costs per Family [3]	(d) Phase I R&D Total [4]
Chrysler	2	$16K	$20K	$ 72K
Ford	6	$16K	$20K	$216K
GM	4	$16K	$20K	$144K
IH	4	$16K	$20K	$144K

[1] Based on 1981 Federal Certification Families.

[2] Engine: $2000, Break-in: $9000, Engineering Overhead: $5000.

[3] 40 transient tests at $500 per test.

[4] (a) (b + c).

Table IV-E

Pre-Production R&D Testing Costs

Phase II

	(a)	(b)	(c)	(d)
Manufacturer	# Engine Families	Fixed Costs per Family [1]	Testing Costs per Family	Phase II R&D Total [2]
Chrysler	2	$15K	$20K	$ 70K
Ford	6	$15K	$20K	$210K
GM	4	$15K	$20K	$140K
IH	4	$15K	$20K	$140K

[1] Prototype emission control hardware and engine modifications.

[2] (a) (b + c).

emission control hardware. Our analysis will assume that when possible the manufacturers design and build their emission control systems to comply with the requirements of the 40 percent AQL beginning in 1984, even though under the proposed revisions HDE SEA would be delayed until 1986. This would allow the manufacturers to avoid the replicate costs of repeated R&D, retooling, and recertification, and is thus the most efficient use of resources.

EPA expects that the greatest emission reductions will be gained in engine and component modifications. The cost of the necessary modifications is difficult to estimate. Some are nothing more than a recalibration, but others may require more extensive redesign and retooling.

The expected modifications are shown in Table IV-F. The costs to implement new calibrations of spark timing, EGR, and A/F ratio are negligible. Improvements to the air injection system are primarily related to optimizing the diverter and pressure relief valves to the demands of the transient test. The use of air modulation would probably be beneficial.

Carburetion modifications present the largest potential improvements. The analysis in Chapter II described the need for the improvements and recalibrations in general fuel metering, accelerator pump operation, and power enrichment. 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. As an initial estimate, a per engine cost of $10 is reasonable to amortize these costs over a five-year production period. Using a 10 percent discount and amortization rate beginning in 1984, this allows an investment of about $11.6 million dollars if the investment is split evenly between 1982 and 1983. This allows an investment of $725,000 per engine family to cover costs for carburetor redesign, optimization, and retooling if necessary. Finally, for the sake of completeness, an additional $5 should be added to the initial $10 figure. This covers the other carburetor related modifications expected in the original 1984 final rulemaking analysis such as parameter adjustment.

There are other modifications which could be used to gain further reductions. Both manifold configuration changes and combustion chamber modifications would be effective. Changes to the design of the intake manifold could improve air-fuel distribution to the cylinders. Decreases in the combustion chamber surface-to-volume ratio and dead volume would aid in reducing HC emissions. Modifications of this type are not difficult or innovative, but they are more leadtime intensive. Costs for modifications to manifolds or combustion chambers could run $20 per engine in the short-term to recover design and retooling costs. This would allow an average investment of $1.5 million dollars per

Table IV-F

Emission Control Related Modifications/Improvements

Carburetion	$15
- idle emission std	
- power enrichment	
- accelerator pump	
- general fuel metering	
- other modifications	
Manifold and/or Combustion Chamber Redesign	$20
Miscellaneous	
air injection system (diverter and pressure relief valves)	-
spark timing, A/F ratio, EGR recalibrations	-
	$35
Sales-Weighted Cost:[1]	$30

[1] Based on estimated need for manifold/combustion chamber redesign in 75 percent of the fleet.

engine family. However, it is unlikely that all engine families will implement manifold and/or combustion chamber revisions. As a conservative estimate we will assume that 12 of the 16 engine families do incorporate these modifications.

In summary, as an initial estimate we will use a per engine modification/improvement cost of $35 if all modifications are implemented. This would cover the recalibrations, carburetion improvements and manifold/combustion chamber improvements. Although we expect most families will require the carburetion improvements, it is unlikely that all will require manifold and/or combustion chamber revisions. The actual per engine cost would be $30 using our assumption that 75 percent of the families do use these modifications.

(b) Emission Control Hardware

The emission control hardware anticipated for compliance with the proposed standards is similar to that used in the LDV/LDT fleets. Much of the technology and performance experience will be readily transferable to HDG engines and has been in some cases.[5] Table IV-G lists the hardware which we believe will be used, beginning in 1984.

The costs shown in Table IV-G have been taken from two sources: manufacturers' comments to the 1979 HDE NPRM and two reports prepared by an EPA contractor.[6][7][8] In both cases the costs reflect the economies of scale expected in HDG engine production and have been inflated at 8 percent per annum to reflect 1981 dollars.[9] The hardware costs represent what EPA expects for the average engine. In some cases these component costs may be slightly greater, in other cases slightly less. At this point in the analysis the component costs shown in Table IV-G do not reflect an adjustment for the fact that some of these components are already used on HDG engines.

If any engine family cannot meet the target emission levels with the conventional modifications and hardware described above, manufacturers may choose to incorporate less conventional control technologies such as port liners or thermal reactors. These would require more development and leadtime, as well as more expense to both the manufacturers/vendors in short-term capital costs and the consumers in first price increase. The use of these components is not considered likely, but they are available if desired by the manufacturers.

(3) Total Emission Control System Costs and Savings

Costs for compliance with the standards can be divided into three main areas: pre-production R&D, engine and emission control system modifications, and emission control hardware.

Table IV-G

Emission Control System Hardware Costs [1]

Automatic Choke (electric)	$ 4
Early Fuel Evaporation	$18
Heated Air Intake	$ 8
Increased Air Injection	$39
EGR (light-load)	$17
Air Modulation	$ 8
	$94

[1] See reference 10.

Engine and emission control system modification costs and emission control hardware costs shown in Tables IV-F and IV-G sum to $124. Per engine pre-production R&D cost is estimated at $1.32 at the consumer level, bringing the total emission control system cost to $125 per engine if all modifications and components are incorporated.

Realistically, not all engine families will need to incorporate all of these components and modifications. Also, some families already use items such as EGR, automatic chokes, and heated air intake so these costs will not be incurred again. A reasonable average per engine cost is probably in the $95-$105 range. This analysis will use the high end of this range ($105) as the average per engine cost. This $105 includes all profit and overhead and is in 1981 dollars.

On a per engine basis this figure should be compared against EPA's anticipated costs for the 1984 Final Rulemaking (Table IV-B). In the regulatory analysis we projected costs in 1979 dollars (including profit and overhead) of $20 for R&D and $326 for emission control hardware, for a total of $346. Inflated at 8 percent per annum this figure becomes $404. Compared against the anticipated non-catalyst compliance costs, the savings is $299 per engine for the emission control system portion of the first price increase.

(4) <u>Capital Costs of the Proposed Revisions to the HDG Emission Standards</u>

The proposed revision to the HDE CO emission standard and the move to non-catalyst technology will still have capital cost requirements. These are related to engine and component modifications, pre-production R&D, and tooling costs associated with emission hardware.

As shown in Table IV-H these costs sum to $60.1 million dollars.[4] This includes $1.2 million for pre-production R&D, $29.6 million for carburetor and manifold/combustion chamber redesign, and $42 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 obtained from currently existing production capacity thus eliminating the need for new tooling and equipment. Since the amount of component carryacross available could not be precisely quantified the tooling costs estimates HDG engines have not been adjusted downwards. It should be highlighted that many of the emission control and engine components are built by vendors and not the manufacturers themselves, so the capital costs are spread over more than just the four major manufacturers. The move to non-catalyst emission standards leads to a 46 percent decrease in the capital costs (tooling/R&D) over that which was expected with catalyst technology. Component carryacross will decrease this amount even further. Given these facts, plus the number of

Table IV-H

Capital Costs of the Proposed Revisions to the HDE Emission Standards (1981 Dollars) [1]

Pre-production R&D	$ 1.2M
Engine/Component Modifications	$29.6M
Tooling	
- Automatic Choke	$ 3.5M
- Early Fuel Evaporation	$ 2.1M
- Heated Air Intake	$ .4M [2]
- Increase Air Injection	$31.3M
- Air Modulation System	$ 1.6M
- EGR (1 manufacturer)	.9M
- Parameter Adjustment	$ 2.2M
Total	$72.8M

[1] See footnote 4 for more detail.

[2] No estimate available, but should be small, so we have included 100K for each of the four manufacturers.

manufacturers and vendors over which the costs are spread, EPA believes these capital costs are manageable for the industry.

(5) Operating and Maintenance Costs

In the 1984 FRM EPA estimated that HDG vehicle operating costs would rise about $83. This was comprised of $259 for unleaded fuel less $176 for improved exhaust system and spark plug longevity. The $83 figure (1979 dollars) incorporates an unleaded-leaded fuel differential of 3 cents per gallon, predicted for the mid-eighties.

Assuming that the costs of spark plugs and exhaust systems have increased at 8 percent per year, the savings associated with these becomes $205, bringing the net cost increase to $54. The accuracy of the $54 (1981 dollars) hinges on the prediction of the 3 cents per gallon unleaded-leaded price differential. If the differential rises, the operating cost increase would also rise. The reverse is also true. For this analysis we will assume the 3 cents per gallon differential remains valid, and the net operating cost increase is $54 dollars in 1981 dollars.

In the 1984 final rulemaking we also identified the potential for a 4 percent fuel economy improvement for a lifetime savings of $540 (1981 dollars and unleaded fuel cost).[11] The move to non-catalyst control technology will eliminate this anticipated improvement. EPA expects that the proposed emission standards will have a neutral fuel economy effect on a fleetwide basis. Many of the modifications and hardware additions expected should have no fuel economy impact. The potential fuel consumption impacts of increased air injection should be offset by improved fuel distribution and improved engine warm-up time. EPA requests the manufacturers' comments on the fuel economy impacts of the proposed emission standards.

Finally, the fleetwide use of heated air intake and automatic chokes will 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. We will include $20 to cover these costs over the vehicle lifetime.[12]

d. Idle Emission Standard

The idle emission standard should be feasible for no cost increase over that discussed above. Costs for the idle standard are included in the necessary carburetor modifications.

e. Cost Comparison: Catalyst vs. Non-Catalyst Systems

Having now reviewed and updated the costs associated with the 1984 FRM and identified and developed the costs associated with the proposed revisions to the 1984 HDE emission standards, 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 cost.

Comparing Tables IV-C and IV-H the capital cost savings of the proposed changes to the HDE emission standards is $61.3 million dollars. As was expected, the major portion of this savings is due to the elimination of the use of catalytic converter technology and the need to develop full life catalyst systems.

As a result of the change in emission control strategies the hardware portion of the first price increase will drop. The expected hardware/R&D portion of the first price increase will drop from $404 (1981 dollars) for the 1984 FRM to $105 for the proposed revisions, for a savings of $299 per HDG vehicle.

Operating and maintenance costs will not be affected as dramatically. Increased costs are expected to drop from $54 (1981 dollars) to $20, for a savings of $34 per vehicle. This assumes the 3 cent per gallon unleaded-leaded fuel differential. If the potential fuel economy improvement impact is included the operating cost impact is substantial ($540 per HDG vehicle or its lifetime). These costs are summarized in Table IV-I.

2. Revisions to the LDT/HDE Enforcement Provisions

a. Relaxation of the Acceptable Quality Level (AQL) during Formal SEA Testing (10% to 40%)

Relaxation of the AQL has cost implications in four different areas: self audit testing, quality control, formal SEA testing, and compliance hardware. Relaxation of the AQL would decrease the manufacturers' internal auditing levels and would thus provide a savings. A 40 percent AQL would allow more production variability (and noncompliance) than a 10 percent AQL, so quality control procedures could be less stringent. The relaxation of the AQL will actually lead to a slight increase in formal SEA testing costs as the number of LDTs/HDEs required to reach a pass/fail decision in formal SEA testing increases slightly. Finally, as shown in Chapter III, the 40 percent AQL will allow higher target emission levels than were demanded under the 10 percent AQL. This will be reflected by potentially lower emission control system costs. The cost impacts in these areas for LDTs, HDG engines, and HDD engines are discussed below.

(1) Light-Duty Trucks

In the final rulemaking process implementing the 10 percent AQL for LDTs it was difficult to identify specific costs associated with the 10 percent AQL. An analysis of California audit

Table IV-I

Cost Impact of the Proposed Revisions to the HDE Gaseous Emission Standards

		1984 FRM	Proposed Revision	Undiscounted Savings
1.	Capital Costs (Tooling/R&D)	$121.4 M	$ 60.1 M	$ 61.3 M (industry-wide)
2.	Emission Control (Hardware/R&D)	$404	$105	$299 (per vehicle)
3.	Operating/ Maintenance	$ 54	$ 20	$ 34 (per vehicle)

data indicated that most manufacturers were already meeting the more stringent AQL.[13] When the manufacturers were queried as to the cost impacts of the 10 percent AQL little detailed response was received.

Although most manufacturers routinely conduct some self audit testing at the 40 percent AQL, only Chrysler responded that the 10 percent AQL might increase self auditing. They estimated additional equipment costs of $1.7 million dollars and annual manpower costs of $300,000. Over a five year period this sums to $3.2 million dollars.

Formal SEA costs would increase slightly as a result of the relaxation of the AQL. The number of LDT tests required to make a pass/fail decision would rise from 13 to 16. This would lead to a cost increase of about $1200 per audit or about $4800 per annum assuming the current rate of about 4 audits per year (1980 dollars). Over a five year period this means a cost increase of only $24,000 industry-wide.

Finally, because all emission target levels will rise, the implementation of the 40 percent AQL will allow a reduction in the costs of compliance related to emission control hardware. As was shown in the economic analysis supporting the 1984 LDT FRM, these costs were estimated at $3.40 per engine. The largest impact fleetwide is the elimination of the need for anything but minor reductions in NOx levels. The impact of the 10 percent AQL on the NOx low mileage emission target was one of the reasons EPA considered an unsophisticated electronic control system as a likely control strategy for 1984 LDTs. Even though the need for these NOx reductions has been decreased, we continue to believe that most manufacturers will choose some form of electronic controls due to the need for reductions in cold start emissions and the demands of the 1984 and 1985 LDT fuel economy standards.

(2) Heavy-Duty Gasoline Engines

In the regulatory analysis supporting the 1984 HDE final rulemaking EPA identified costs in the areas mentioned in the paragraphs introducing this section. These are discussed below.

The 1984 analysis assumed that beginning in 1986 manufacturers would audit their production at an annual rate of 0.4 percent.[14] Using the sales data shown in Table IV-A this comes to 4164 audit tests over the three years (1986-1988). In the cost effectiveness portion of the 1984 HDE regulatory analysis, EPA used an audit rate of 0.2 percent per annum or 2082 tests over the three year period (1986-1988) under a 40 percent AQL. Over the three year period the relaxation of the AQL would save 2082 audits. At $1072 per audit this savings is $2.23 million dollars (1979 dollars). No additional testing facilities over that which was required for formal SEA testing were necessary under the 10 percent AQL, therefore no facility savings are included.

Quality control costs are likely to remain relatively unaffected by a change in the AQL. Going from no SEA program to even a 40 percent AQL would require some tightening of internal quality control procedures over the current levels. The production of HDG engines has not been subject to SEA before, so some quality control increases are likely.

As before with LDTs, increasing the AQL would result in an increase in the number of HDG engines tested in each formal SEA. An increase from 12 engines per audit to 15 would mean a per audit cost increase of $5250, or $262,000 for the 50 audit tests anticipated in the 1984 HDE regulatory analysis for the 1986-1988 time period of the original analysis.

Relaxing the AQL under the catalyst-based emission control approach would have allowed a cost savings. In the regulatory analysis supporting the 1984 FRM we estimated an additional hardware cost of $13 due to the effect of the 10 percent AQL. This $13 is already reflected in the emission control hardware savings described previously.

For the non-catalyst based emission control system being assumed in this action, the standards setting approach being used is different from that in the original rulemaking. In this action we have proposed emission standards which we consider to be achievable under a 40 percent AQL and the other technology and lead time constraints. If the decision were made to maintain the 10 percent AQL under the same constraints, the approach used would be to propose the emission standards at a level achievable at the 10 percent AQL. Under these constraints and this approach to setting standards an incremental hardware cost attached to the 10 percent AQL has no definition.

(3) Heavy-Duty Diesel Engines

As before with HDG engines EPA has identified costs in all areas mentioned in the introductory paragraphs. These are discussed below.

The 1984 final rulemaing analysis assumed that manufacturers would audit their production at 0.4 percent per annum beginning in 1986.[15] Using the sales data of Table IV-A this comes to 3866 audit tests over the three year period being considered (1986-1988). In the cost effectiveness chapter of the regulatory analysis EPA assumed an audit rate of 0.2 percent per year or 1933 audit tests over the three year period if a 40 percent AQL were in effect. Therefore, relaxation of the AQL would save 1933 audits. At $1274 per audit this savings is $2.46 million dollars (1979 dollars) over the three year period. In the original 1984 FRM economic analysis no manufacturers of HDD engines needed additional facilities and equipment for self audit testing. Therefore no savings in facility costs are included as a result of the AQL relaxation.

As before with HDG engines, quality control costs are likely to remain unaffected by the change in the AQL. The heavy-duty diesel industry has little experience with the impacts of SEA on its product lines and will probably choose to implement tighter quality control procedures as part of its reaction to the new SEA requirements.

Relaxing the AQL would mean that more engines would have to be tested in formal EPA SEA to make a pass/fail decision. The expected increase from 12 to 15 engines per audit would mean a per audit cost increase of $5250, or $336,000 for the 64 audit tests anticipated in the 1984 HDE regulatory analysis for the 1986-1988 model years (1979 dollars).

In the cost effectiveness analysis of the 1984 HDE regulatory analysis the incremental emission control compliance costs for the 10 percent AQL were estimated on a family by family basis. This was done by comparing the projected transient test hydrocarbon emission levels of each engine family against the expected low mileage emission targets of the 10 and 40 percent AQLs. Compliance costs for each case were then estimated. The bottom line of this analysis was that the average per engine emission control system cost of the 10 percent AQL was about $3 per engine (1979 dollars). This is roughly the per engine savings which could be expected from adoption of the 40 percent AQL.

(4) <u>AQL Relaxation Cost Impact Summary</u>

Table IV-J summarizes the potential cost savings in all areas as a result of the AQL relaxation. As can be seen, the total savings for the five year period 1984-1988 for LDTs and HDEs is at least $77.3 million dollars (undiscounted). Of this $77.3 million, the short term capital cost savings to the manufacturers is at least $8.2 million. This savings plus the emission control system cost saving can be passed on to the consumers. These represent real savings, and not just cash flow savings, since these costs will not occur again, unless the 10 percent AQL were reimplemented.

b. <u>Delay Implementation of the SEA Program for HDEs</u>

EPA has announced that implementation of Selective Enforcement Auditing (SEA) for HDEs will be delayed until the 1986 model year. This will yield short-term (1984 and 1985) cost savings in three areas and cash flow savings for two years. For the 1984 and 1985 model years no costs will be incurred in the areas of self audit tests, formal EPA SEA tests, and increased quality control.

Table IV-J

Cost Savings Due to the Relaxation of the AQL: Summary [1]

Light-Duty Truck (1984-1988); Heavy-Duty Engines (1986-1988)

	Self Audit Testing	Formal SEA Testing Increases [3]	Emission Control System Costs [4]	Total
LDT	$3.46M	-$ 26K	$63.78M	$67.2M
HDG	$2.60M [2]	-$306K	- [5]	$ 2.3M
HDD	$2.87M [2]	-$392k	$ 5.39M	$ 7.8M
Total	$8.93M	-$724K	$69.17M	$77.3M

[1] 1981 dollars, undiscounted.

[2] Decrease in self audit rate.

[3] Shown as negative, because these costs will increase slightly with the 40% AQL.

[4] Five year aggregate sales multiplied by the per vehicle/engine savings.

[5] Not included as per discussion in text.

Cash flow will be improved by a two year delay in the purchase of SEA related facilities and equipment. (Deferred cash investment does in fact provide a small savings in the form of an opportunity cost, but this will not be considered here.) No emission control hardware cost savings are expected, as EPA expects that when possible manufacturers will certify their 1984 model year engines with consideration to the impact of the 40 percent AQL and SEA on the target emission levels. These cash expenditure and cash flow savings are discussed below for HDG and HDD engines.

(1) Heavy-Duty Gasoline Engines

All 1984 and 1985 model year costs related to self audits, formal EPA SEA tests, and increased quality control will be saved. As determined in the 1984 final rulemaking economic impact analysis and shown in Table IV-K these savings come to $14.2 million dollars (1981 dollars). In addition to this real cost savings, delaying the implemention of the HDE SEA program will improve the manufacturers' cash flow requirements. For HDG engines the cash flow savings is estimated at $16.4 million 1981 dollars, delayed from 1982-83 to 1984-85.[16]

(2) Heavy-Duty Diesel Engines

For the 1984 and 1985 model years, cost savings for the HDD engine industry will occur in similar areas as for HDG engines. In the economic impact analysis supporting the 1984 HDE final rulemaking costs were determined in these areas. As shown in Table IV-K the savings related to the two year elimination of self audits, EPA formal SEA tests, and quality control come to $11.9 million 1981 dollars. In addition, the delay of the investment in facilities and equipment for SEA will improve the major domestic manufacturers' cash flow by $21.1 million 1981 dollars. The delay will allow this investment in 1984 and 1985 instead of 1982 and 1983.[17] The original FRM analysis assumed that the smaller domestic and foreign manufacturers would allow their certification facilities to double as SEA facilities. Thus these manufacturers will not incur the cash flow savings as their transient certification facilities must be prepared for 1985 model year certification.

c. Summary of the Enforcement Related Cost Implications

(1) Light-Duty Trucks

The only part of the enforcement related proposals affecting LDTs is the relaxation of the AQL. The self audit testing cost of Table IV-J, $3.43 million dollars, represents a cost expenditure savings. The remaining $63.78 million dollars in emission control system costs is primarily a consumer savings, although some small manufacturer savings will occur as a result of the elimination of

Table IV-K

Cost Savings from Delaying Implementation of the Heavy-Duty Engine SEA Program [1][2]

	Self Audits [3]	Formal EPA SEA Tests [3]	Quality Control [3][4]	Facilities & Equipment [5]
HDG Engines	$5010K	$686K	$8490K	$16.39M
HDD Engines	$4481K	$980K	$6420K	$21.05M
Total	$9.49M	$1.67M	$14.91M	$37.44M

[1] 1984 and 1985 model years.

[2] 1981 dollars, undiscounted.

[3] Cash expenditure savings.

[4] 1984 and 1985 sales multiplied times the per engine quality control cost.

[5] Cash flow savings; deferred two years.

the need for short term investment in the emission control system components.

(2) Heavy-Duty Gasoline Engines

All enforcement related aspects of the proposal affect HDG engines. Cash expenditure and cash flow savings will occur as a result of the AQL relaxation and the delay of HDE SEA. These are summarized by year and category in Table IV-L in 1981 dollars.

(3) Heavy-Duty Diesel Engines

The HDD engine industry is affected by all enforcement related proposed revisions. The relaxation of the AQL and the delay of HDE SEA will provide both cash expenditure and cash flow savings for the industry. The emission control hardware savings associated with the AQL will primarily benefit the consumers, but the manufacturers will also see a small savings as they will be able to forego the short-term investment in emission control systems and R&D. The expenditure and cash flow savings for the proposed relaxation of the enforcement provisions are shown in Table IV-M by year and category in 1981 dollars.

C. Total Economic Impact of the Proposed Revisions

Having now identifed the cost savings related to the proposed changes to the HDE CO standard and the LDT/HDE enforcement provisions, the remaining task is to calculate the final cost savings impacts of the entire proposal. This will be done for LDT, HDG and HDD. In this analysis we will determine the cash expenditure savings, the cash flow savings and the per vehicle/engine purchase and operating cost impacts.

1. Light-Duty Trucks

a. Cash Expenditure Savings

Since LDTs are affected only by the AQL relaxation portion of the proposal the major savings will be in the area of self audit testing. EPA estimates a cash expenditure savings of about $3.43 million dollars over the five year period.

b. Consumer Cost Savings

As a result of the relaxation of the AQL, EPA estimates a consumer savings of about $3.87 per engine. Over the five year period this sums to about $67.2 million dollars (undiscounted).

2. Heavy-Duty Gasoline Engines

Table IV-L

Enforcement Related Cost Expenditure
and Cash Flow Savings: HDG Engines [1]

	1982	1983	1984	1985	1986	1987	1988	Total	Discounted Total [4]
Self Audits [2]	-	-	$2754K	$2256K	$886K	$868K	$849K	$ 7613K	$ 6769K
Formal SEA Testing [2]	-	-	$ 343K	$ 343K	(-$ 86K)	(-$ 80K)	(-$ 80K)	$ 440K	469K
Quality Control [2]	-	-	$4281K	$4209K	-	-	-	$ 8490K	8107K
SEA Facilities and Equipment [3]	$8194K	$8194K	-	-	-	-	-	$16388K	18928K
Total	$8194K	$8194K	$7378K	$6808K	$800K	$788K	$769K		

Total Cash Expenditure Savings: $15,345K [4]
Total Cash Flow Savings: $18,928K [4]

[1] 1981 dollars, undiscounted.

[2] Cash Expenditure Savings.

[3] Cash Flow Savings.

[4] Discounted at 10 percent to January, 1984.

Table IV-M

Enforcement Related Cost Expenditure and Cash Flow Savings: HDD Engines [1]

	1982	1983	1984	1985	1986	1987	1988	Total	Discounted Total [4]
Self Audits [2]	-	-	$2367K	$2114K	$900K	$957K	$1015K	$ 7353K	$ 6445K
Formal SEA Testing [2]	-	-	$ 490K	$ 490K	(-$129K)	(-$129K)	(-$135K)	$ 587K	$ 640K
Quality Control [2]	-	-	$3105K	$3316K	-	-	-	$ 6421K	$ 6120K
SEA Facilities and Equipment [3]	$10527K	$10527K	-	-	-	-	-	$21054K	$24317K
Total	$10527K	$10527K	$5962K	$5920K	$771K	$828K	$880K		

[1] 1981 dollars, undiscounted

[2] Cash Expenditure Savings.

[3] Cash Flow Savings.

[4] Discounted at 10 percent to January 1984.

Total Cash Expenditure Savings: $13205K
Total Cash Flow Savings: $24317K

a. Cash Expenditure Savings

As a result of the proposed revisions, HDG engine manufacturers will accrue substantial cash expenditure savings. As detailed in Table IV-N these savings come from decreased R&D/Tooling costs, decreased costs associated with the AQL relaxation, and costs eliminated as a result of the delay of the implementation of the HD SEA program. Cash expenditure savings sum to $86.1 million dollars (discounted).

b. Cash Flow Savings

The major cash flow savings are associated with the deferral of the HD SEA program. As shown in Table IV-N this will allow a two year deferral of the capital investment necessary to construct the necessary SEA facilities. The total cash flow savings are $18.9 million dollars (discounted).

c. Consumer Cost Savings

Purchasers of HDG vehicle will benefit from both lower first price increases and lower operating costs.

(1) First Price Increase Savings

The first price increase will vary in the analysis period. Using the applicable data from Table IV-B (items: 1, 4, and portion of 8) plus the $105 R&D/hardware cost discussed previously the 1984-85 first price increase comes to $121. The savings is $339 per engine.

When SEA begins in 1986 the first price increase savings will drop to $302. The savings will decrease because of the need to cover amortization of SEA facilites, self audit testing, quality control, and formal EPA SEA testing. The savings in the 1987-88 time period depend upon the outcome of the revision process applicable to the 1987 model year HDE emission standards. The hardware savings could range from approximately the same as expected in 1986 to virtually zero depending on the standard promulgated for 1987. Since this decision has not been made, we will conservatively assume no hardware savings in 1987 and 1988. Thus the only savings in this year will be $3.50 related to the AQL relaxation. The components of these savings for the appropriate years are shown in Table IV-O.

(2) Operating/Maintanenace Costs

Referring to the previous discussion, these costs would drop by $34 per vehicle beginning in 1984 as a result of the proposed revisions and the move to non-catalyst technology. As above we will assume no savings in 1987 and 1988

Table IV-N

Total Economic Savings to the
Industry of the Proposed Revisions: HDG Engines [1]

	1982	1983	1984	1985	1986	1987	1988	Total	Discounted Total [4]
R&D/Tooling [2]	$30650K	$30650K	-	-	-	-	-	$61,300K	$70802K
SEA Facilities [3]	$ 8194K	$ 8194K	-	-	-	-	-	$16,388K	$18928K
Self Audits [2]	-	-	$2754K	$2256K	$886K	$868K	$849K	$ 7,613K	$ 6769K
SEA Testing [2]	-	-	$ 343K	$ 343K	(-$86K)	(-$80K)	(-$80K)	$ 440K	$ 469K
Quality Control [2]	-	-	$4281K	$4209K	-	-	-	$ 8,490K	$ 8107K
Total	$38844K	$38844K	$7378K	$6808K	$800K	$788K	$769K		

Total Cash Expenditure Savings: $86,147K

Total Cash Flow Only Savings: $18,928K

[1] 1981 dollars, undiscounted

[2] Cash Expenditure Savings

[4] Cash Flow Savings

[5] Discounted at 10 percent to January 1984.

Table IV-O

HDG Engine First Price Cost Savings Components [1][2]

	1984-1985	1986	1987-1988
SEA Facilities	$ 16.52	$ 0	$ 0
SEA Testing [3]	1.22	-.31	-0.31
Self Audits [4]	7.61	3.81	3.81
Quality Control	15.05	0	0
Emission Control Hardware/R&D	$299.00	$299.00	0
Total Savings:	$339.40	$302.50	$3.50

[1] Original costs were taken from Table V-LL of the "Regulatory Analysis and Environmental Impact of Final Emission Regulations for 1984 and Later Model Year Heavy-Duty Engines, December 1979, U.S. EPA, OMSAPC.

[2] Original costs were inflated at 8% per year to get 1981 dollars. These figures also include overhead and profit.

[3] SEA testing costs go up slightly as a result of the 40% AQL.

[4] Average per engine costs will be reduced by about 50% over the 10% AQL audit rate of 0.4%.

3. Heavy-Duty Diesel Engines

a. Cash Expenditure Savings

Heavy-duty diesel engine manufacturers should gain substantial cash expenditure savings as a result of the proposed changes to the enforcement provisions. As shown in Table IV-M these savings will occur in lower self audit costs and elimination of SEA testing and quality control costs for two years.

b. Cash Flow Savings

The major cash flow savings occur as a result of the two year delay of HD SEA. As shown in Table IV-M, this will allow delaying this investment in SEA facilities to 1984-1985 from 1982-1983.

c. First Price Increase Savings

The first price increase will vary through the analysis period. Beginning in 1984 the first price increase savings will sum to about $64 per engine. The components of these savings are taken from Table IV-P. Referring to the same table, beginning in 1986 the per engine savings will drop to $7. This is a result of the implementation of the SEA program for HDD engines.

4. Aggregate Savings

a. Cash Expenditure and Cash Flow Savings to the Industry

The aggregate savings to the manufacturers is comprised of the cash expenditure and cash flow savings for each group of vehicles/engines affected. These two types of savings are shown in Table IV-Q by year for each vehicle/engine group. Both the cash expenditure and cash flow savings are large. The undiscounted totals are $95.6 million dollars and $37.4 million dollars respectively. If these savings are discounted, their present value in 1984 (the first model year of production affected by these regulations) is $102.7 million dollars for the cash expenditure savings and $43.2 for the cash flow savings.

b. Aggregate Savings to the Nation

The best means of determining the net impact on the consumers and the economy as a whole is to express the aggregate cost as a function of the total per vehicle lifetime savings. This allows the inclusion of overhead and profit and hardware, as well as the impact of the changes in operating costs. These per vehicle/ engine impacts at the consumer level are shown in Table IV-R. If the per vehicle engine savings are multiplied by the appropriate sales the aggregate net impact on the economy is found. In this case the net reduction for all three vehicle/engine groups sums to $449.4 million dollars.

Table IV-P

HDD Engine First Price Cost Savings Components [1][2]

	1984-1985	1986+
SEA Facilities	$34.14	$ 0
SEA Testing [3]	2.18	-.55
Self Audits [4]	8.87	4.43
Quality Control	15.05	0
Reduced R&D (AQL Relaxation)	3.45	3.45
	$63.69	$7.33

[1] Original costs were taken from Table V-LL of the "Regulatory Analysis and Environmental Impact of Final Emission Regulations for 1984 and Later Model Year Heavy-Duty Engines, December 1979, U.S. EPA, OMSAPC.

[2] Original costs were inflated at 8% per year to get 1981 dollars. These figures also include overhead and profit.

[3] SEA testing costs go up slightly as a result of the 40% AQL.

[4] Average per engine costs will be reduced by about 50% over the 10% AQL audit rate of 0.4%.

Table IV-Q

Aggregate Savings to the Industry

Cash Expenditure Savings

	1982	1983	1984	1985	1986	1987	1988	Undiscounted Total	Discounted Total [1]
LDT [2]	-	$ 1,836K	319K	319K	319K	319K	319K	$ 3,431K	$ 3,350K
HDG [3]	$30,650K	$30,650K	7,378K	6,808K	800K	788K	769K	$77,843K	$ 86,147K
HDD [4]	-	-	5,962K	5,920K	771K	828K	880K	$14,361K	$ 13,204K
	$30,650K	$32,486K	$13,659K	$13,047K	$1,890K	$1,935K	$1,968K	$95,635K	$102,701K

Cash Flow Savings

	1982	1983	Undiscounted Total	Discounted Total [1]
HDG [5]	$ 8,194K	$ 8,194K	$16,388K	$18,928K
HDD [6]	$10,527K	$10,527K	$21,054K	$24,317K
	$18,721K	$18,721K	$37,442K	$43,245

[1] 10 percent discount to January 1984
[2] As per discussion in text
[3] All but SEA Facilities, Table IV-N
[4] All but SEA Facilities, Table IV-M
[5] SEA Facilitfes, Table IV-N
[6] SEA Facilities, Table IV-M

Table IV-R

Aggregate Savings to the Nation: 1984-1988

Group	Years	Sales[1]	Average Savings (First Price)[2]	Average Savings (Operating/Maint)	Discounted Total [3]
LDT	1984-88	17.37M	$ 3.87	-	$ 55.6M
HDG	1984-85	727,879	$339.40	$34	$259.5M
	1986	354,287	302.50	$34	$98.5M
	1987-88	686,718	$3.50	-	$1.7M
HDD	1984-85	550,416	$ 63.69	-	$ 33.4M
	1986-88	996,403	$ 7.33	-	$ 0.7M
					$449.4M

[1] Table IV-A.
[2] Text and Tables IV-O, P.
[3] Discounted at 10 percent to January 1984.

References

1. See "Regulatory Analysis and Environmental Impact of Final Emission Regulatons for 1984 and Later Model Year Light-Duty Trucks," U.S. EPA, OMSAPC, May 1980.

2. See "Regulatory Analysis and Environmental Impact of Final Emission Regulations for 1984 and Later Model Year Heavy-Duty Engines," U.S. EPA, OMSAPC, December 1979.

3. Based on the new car CPI for 1979 and 1980, 7.4% and 8.0% respectively.

4. EPA memo: Tooling Cost Calculations for HDG Engine Emission Control Components.

5. Several HDG engine models use automatic chokes, EGR, EFE, dual air pumps, etc.

6. See Public Docket OMSAPC 78-4.

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

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

9. Cost figures from either the public comments or the contract reports were inflated at 8% per year from the applicable base years of 1979 and 1977 respectively.

10. EPA memo: Emission Control System Component Cost Calculations for HDG Engines.

11. In the economic analysis supporting the 1984 HDE FRM the per engine potential fuel savings was erroneously calculated using the 5.4 mpg dynamometer figure instead of the 9.9 mpg average HDGE road mileage figure. The unleaded fuel cost used here is $1.40/ gallon. See pages 125-127 of [2] above.

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

13. See Public Docket OMSAPC 79-2, Analysis of California Two Percent Audit Data.

14. See Table V-AA of [2] above.

15. See Table V-BB of [2] above.

References (cont'd)

16. See Table V-T of [2] above, and factor in inflation.

17. See Table V-U of [2] above, and factor in inflation.