COST EFFECTIVENESS ESTIMATES FOR MOBILE SOURCE EMISSION CONTROL

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1.0 INTRODUCTION

This document is a final report of an effort conducted by Vector Research, Incorporated, (VRI) to develop cost and effectiveness estimates for alternative mobile source compliance assurance programs for the Environmental Protection Agency (EPA). The estimates are intended to be used as input to a mobile source strategy paper being developed by EPA. This report includes a general description of the approach and assumptions used in developing the estimates (in section 2.0), a detailed description of the procedures used to develop the estimates for each compliance assurance program studied (in section 3.0), and a presentation of the results of the analysis (in section 4.0).

2.0 GENERAL APPROACH AND ASSUMPTIONS

The cost effectiveness computations were performed for a set of alternative compliance assurance programs (referred to as cases) selected by EPA and summarized in table 1. Each of these programs assumes the existence of emission standards, and may also include one or more of the following compliance techniques:

(1) a certification process as currently performed by EPA;

(2) a certification process in which EPA may adjust certain vehicle parameters within manufacturer specifications before testing any vehicle;

(3) EPA's assembly line testing program (Selective Enforcement Audit);

(4) a state-operated inspection and maintenance program involving diagnostic checks on emission-related equipment;

(5) a state-operated inspection and maintenance program involving emissions testing; and

(6) a recall program.

For each case, effectiveness was computed in terms of reduction in 1975 FTP emissions from pre-1968 levels. Separate effectiveness computations were performed for four pollutants (HC, CO, NO_x, and evaporative HC). All analysis was based on 1975 standards in 49 states, and considered low-altitude, non-California light duty vehicles only. Effectiveness is expressed as tons of pollutant over a 100,000-mile vehicle life, while costs are expressed as lifetime costs in 1975 dollars. Both total and government costs are presented for each case.

TABLE 1: COMPLIANCE ASSURANCE PROGRAMS INCLUDED IN THE COST EFFECTIVENESS COMPUTATIONS

CASE[1]	COMPLIANCE TECHNIQUES						
	STANDARDS	CERTIFICATION	CERTIFICATION WITH PARAMETER ADJUSTMENT	SELECTIVE ENFORCEMENT AUDIT[2]	INSPECTION AND MAINTENANCE (DIAGNOSTIC)	INSPECTION AND MAINTENANCE (TESTING)[3]	RECALL[4]
1	X						
2	X	X					
3	X		X				
4	X			X (100%)			
5	X			X (75%)			
6	X				X		
7a	X					X (30%)	
7b	X					X (30%)	
8a	X					X (50%)	
8b	X					X (50%)	
9	X						X (40%)
10	X						X (70%)
11	X		X	X (100%)			
12	X		X			X (30%)	
13	X		X	X (100%)			X (70%)
14	X		X	X (100%)		X (30%)	X (70%)
15	X			X (100%)		X (30%)	
16	X		X	X (100%)		X (50%)	X (70%)
17	X			X (100%)			X (70%)
18	X			X (100%)		X (30%)	X (70%)
19	X	X				X (30%)	

[1]Cases 7a and 8a assume the use of an idle test for inspection; cases 7b and 8b assume the use of a loaded test. All other cases involving inspection and maintenance (testing) assume the use of the idle test.

[2]Parenthetical numbers in this column refer to assumed fraction of test orders which result in rejection of the lot.

[3]Parenthetical numbers in this column refer to failure rate which the states are assumed to enforce.

[4]*Parenthetical numbers in this column refer to assumed response rate to a recall.*

Because of uncertainty regarding the validity of many of the assumptions of this analysis, and scarcity of data for some of the compliance techniques, a range of estimates has been developed for each case. A best estimate is presented as the cost and effectiveness judged most likely to result from implementation of the case. Low and high estimates are presented as "reasonable" lower and upper limits on effectiveness, with corresponding costs. Because these ranges of estimates represent uncertainty in estimating the effectiveness and costs of the various compliance techniques, the range tends to be smallest for cases involving techniques for which substantial data exist (such as certification).

The primary data sources used in this analysis were the 1974 and 1975 Emission Factors Programs. Data from 1975 vehicles from these programs provided a population of in-use vehicles for which to estimate the effectiveness of various combinations of compliance techniques. Other data (such as 1975 certification results, data from the Restorative Maintenance Program, 1975 assembly-line data, and miscellaneous sets of evaporative emission data and cost data) were used where needed;[1] all data sources and computational procedures are described in the following section.

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[1]All data used were current as of July 1977.

3.0 DETAILS OF THE ANALYSIS

This section describes the analytical procedures used in the cost effectiveness calculations. Section 3.1 discusses the effectiveness assessment methodology for each combination of compliance techniques evaluated, while section 3.2 describes the derivation of the cost estimates used in the analysis.

3.1 Effectiveness Computations

Effectiveness results were computed for each case in terms of millions of tons of pollutant saved over a precontrol situation. Precontrol emission rates were assumed to average 7.55 grams/mile for HC, 86.79 grams/mile for CO, 3.40 grams/mile for NO_x, and 3.33 grams/mile for evaporative HC during the life of a given vehicle. In all cases the standards assumed to be in effect for exhaust emissions were 1.5 grams/mile of HC, 15 grams/mile of CO, and 3.1 grams/mile of NO_x. In addition, in-use evaporative HC levels (measured with the SHED technique) were adjusted to give a modified SHED standard for 1975. To do this it was assumed that prototype vehicles actually built for certification in 1975 met the evaporative standard exactly. Cannister test data on twenty 1973 model year vehicles in Los Angeles was examined to develop a relationship between certification and in-use emissions.[1] In particular, the ratio of average in-use emissions to the average certification level was computed to equal 2.11. This relationship

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[1]The particular in-use cannister data used correlated fairly well with SHED data, which was also available for these twenty vehicles.

was used to predict the standard from the average in-use level of 1975 vehicles. The result was a predicted evaporative standard of 0.834 when expressed in units of grams/mile.

Each of the following subsections presents the approach used to compute the effectiveness for a single case or group of similar cases. These presentations generally describe the procedures followed to compute average emission rates in grams per mile under the various strategies investigated. In all cases, these rates were converted to effectiveness values using the following relationship:

$$r_i = (u_i - c_i)\ LPk,$$

where

r_i = reduction in emissions of pollutant i resulting from implementation of a particular case (in tons),

u_i = uncontrolled average lifetime emission rate of pollutant i (grams per mile),

c_i = controlled average lifetime emission rate of pollutant i resulting from implementation of the case (grams per mile),

L = average vehicle life (taken to be 100,000 miles),

P = vehicle population to which the benefit applies (taken to be 10 million vehicles), and

k = conversion factor to convert grams to tons.

3.1.1 Case 1: Standards Only

To estimate the reduction in emissions resulting from promulgation of standards without any additional compliance techniques, it was assumed that manufacturers would respond by designing vehicles which would just meet the standards as prototypes. In order to convert these design emission levels to levels for vehicles in use, regression analysis was performed on data for 570 in-use vehicles from model year 1975 and certification data for corresponding vehicles to develop a relationship between design exhaust emission levels within a given engine family, and 50,000-mile in-use levels experienced by vehicles in that same family. The regression results are given in Table 2. The in-use data were for low-altitude, non-California, light duty vehicles tested in the FY 1974 Emission Factors (EF) Program. Mileage regressions described in section 3.1.2, were used to project these in-use levels to 50,000 mile levels for each vehicle. Because the standard for evaporative emissions was inferred from the 1975 data (as described earlier), the corresponding in-use level is simply the level actually realized in 1975 vehicles of 1.76 grams/mile. No deterioration of evaporative emissions with mileage was assumed.

A range of values around this best estimate was developed by assuming that, at worst, there would be no reduction in emissions from precontrol levels and, at the other extreme, the reduction would be no better than the most optimistic estimate of the reduction achieved in the presence of certification (i.e., the high estimate for case 2).

3.1.2 Case 2: Standards Plus Certification

The effectiveness estimates for the case in which standards and certification are in effect were based on linear regressions of EF data on 1975 model year vehicles. These regressions predict mean exhaust emission rates as a function of vehicle mileage for a population of vehicles subject to

TABLE 2: REGRESSION ANALYSIS OF IN-USE EMISSIONS AS A FUNCTION OF CERTIFICATION EMISSIONS

Relation: $y_{ij} = \alpha_i x_{ij} + \beta_i$ (i = 1, 2, 3)

where

y_{ij} = in-use emission level of pollutant i by a given vehicle j at 50,000 miles;

x_{ij} = average certification emission level (including deterioration) for pollutant i for vehicles in the same engine family as vehicle j; and

α_i, β_i = regression coefficients.

Results:

i	α_i		β_i		R^2
	Value	Significance	Value	Significance	
1 (HC)	0.37177	0.0268	2.1617	0.0000	0.00861
2 (CO)	1.3517	0.0310	24.535	0.0000	0.00816
3 (NO_x)	0.69533	0.0001	1.1748	0.0043	0.02692

the conditions of this case. The data used for these regressions were for low-altitude, non-California, light duty vehicles tested in the FY 1974 and FY 1975 EF Programs. To obtain the best possible fit to the data, two separate sets of regressions were performed and combined into a single emissions-versus-mileage regression for each pollutant.[1] The first set of regressions used data for the 533 vehicles in the data base for which the measured idle CO level (ICO) was less than 1.5 percent; the second set used the remaining 232 vehicles for which the ICO was greater than or equal to 1.5 percent. The results of the regressions, and the composite estimate of emissions for each pollutant, appear in table 3. The best estimate of emissions was then taken as the value of the composite regression equation at 50,000 miles.

To develop an estimate for average evaporative emission rates, 1978 certification data were examined to determine the average percent of the standard at which vehicles were certified. The average evaporative emission rate for vehicles in the field was then assumed to equal the product $s \cdot f \cdot \ell$, where

s = assumed 1975 standard for evaporative emissions (.83 grams per mile);

f = average fraction of 1978 standard experienced on 1978 certification test results (0.30); and

ℓ = ratio of in-use evaporative levels to certification levels (2.11, as computed in the derivation of the assumed 1975 standard).

Upper and lower bounds on exhaust emissions for this case were computed from upper and lower 95 percent confidence limits on the composite

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[1]See [Williams, 1976] for a description of and rationale for the procedures used to combine these regressions.

TABLE 3: REGRESSION ANALYSIS OF IN-USE EMISSION RATES AS A FUNCTION OF MILEAGE FOR CASE 2

Relation: $$e_i(m) = \frac{n_1}{n_1 + n_2}(\mu_{1i}\, m + \eta_{1i}) + \frac{n_2}{n_1 + n_2}(\mu_{2i}\, m + \eta_{2i}) = \bar{\mu}_i\, m + \bar{\eta}_i \qquad (i = 1, 2, 3)$$

where

$e_i(m)$ = average in-use emissions of pollutant i by a vehicle at mileage m;

n_k = number of vehicles in sample k (where k=1 for idle CO less than 1.5 percent, and k=2 otherwise);

m = vehicle mileage, in tens of thousands;

μ_{ki}, η_{ki} = regression coefficients;

$$\bar{\mu}_i = \frac{n_1\mu_{1i} + n_2\mu_{2i}}{n_1 + n_2};$$ and

$$\bar{\eta}_i = \frac{n_1\eta_{1i} + n_2\eta_{2i}}{n_1 + n_2}$$

TABLE 3: REGRESSION ANALYSIS OF IN-USE EMISSION RATES AS A FUNCTION OF MILEAGE FOR CASE 2

(Concluded)

Regression Results:

k	n_k	i	μ_{ki}		η_{ki}		R^2
			Value	Significance	Value	Significance	
1 (ICO<1.5)	533	1 (HC)	0.19280	0.0000	0.89979	0.0000	0.04471
		2 (CO)	1.7824	0.0027	12.872	0.0000	0.01685
		3 (NO_x)	0.17265	0.0002	2,2916	0.0	0.02625
2 (ICO≥1.5)	232	1 (HC)	0.21144	0.0228	1.7917	0.0000	0.02234
		2 (CO)	2.7543	0.1793	39.486	0.0000	0.00783
		3 (NO_x)	0.0072075	0.9249	2.4507	0.0000	0.00004

Composite Results:

i	$\bar{\mu}_i$	$\bar{\eta}_i$
1 (HC)	0.1984	1.1674
2 (CO)	2.0740	19.9562
3 (NO_x)	0.1230	2.3393

emission-versus-mileage regression lines at 50,000 miles (see figure 1). The upper limit on evaporative emissions was taken to be equal to the best estimate (since the best estimate resulted in an in-use value well below the standard), while the lower limit used the in-use evaporative rate actually experienced in 1975.

3.1.3 Case 3: Standards Plus Certification with Parameter Adjustment

To represent the effect of EPA parameter adjustment on the effectiveness of certification, the mileage regressions described for case 2 were repeated on only those 1975 vehicles in the EF data base which were within manufacturer specifications on idle CO, idle RPM, and timing.[1] The regression results are presented in table 4. The high and low estimates again were based on 95 percent confidence intervals around each of these regression lines at 50,000 miles. Under the assumption that parameter adjustment would not affect evaporative emissions, the case 2 estimates for evaporative effectiveness were used for case 3.

3.1.4 Cases 4 and 5: Standards Plus Selective Enforcement Audit

The effectiveness of Selective Enforcement Audit (SEA) was estimated with the use of 1975 assembly-line data provided voluntarily by the manufacturers to EPA's Mobile Source Enforcement Division. Using these data

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[1]A vehicle was considered to be within manufacturer specifications if its idle CO was less than 0.5 percent, and if it was within 150 RPM of the manufacturer's specification for idle RPM and within 2 degrees of specification for timing. There were 314 such vehicles in the data base. Note that the requirement that idle CO be less than 0.5 percent eliminated the need for the kind of composite regression used for case 2.

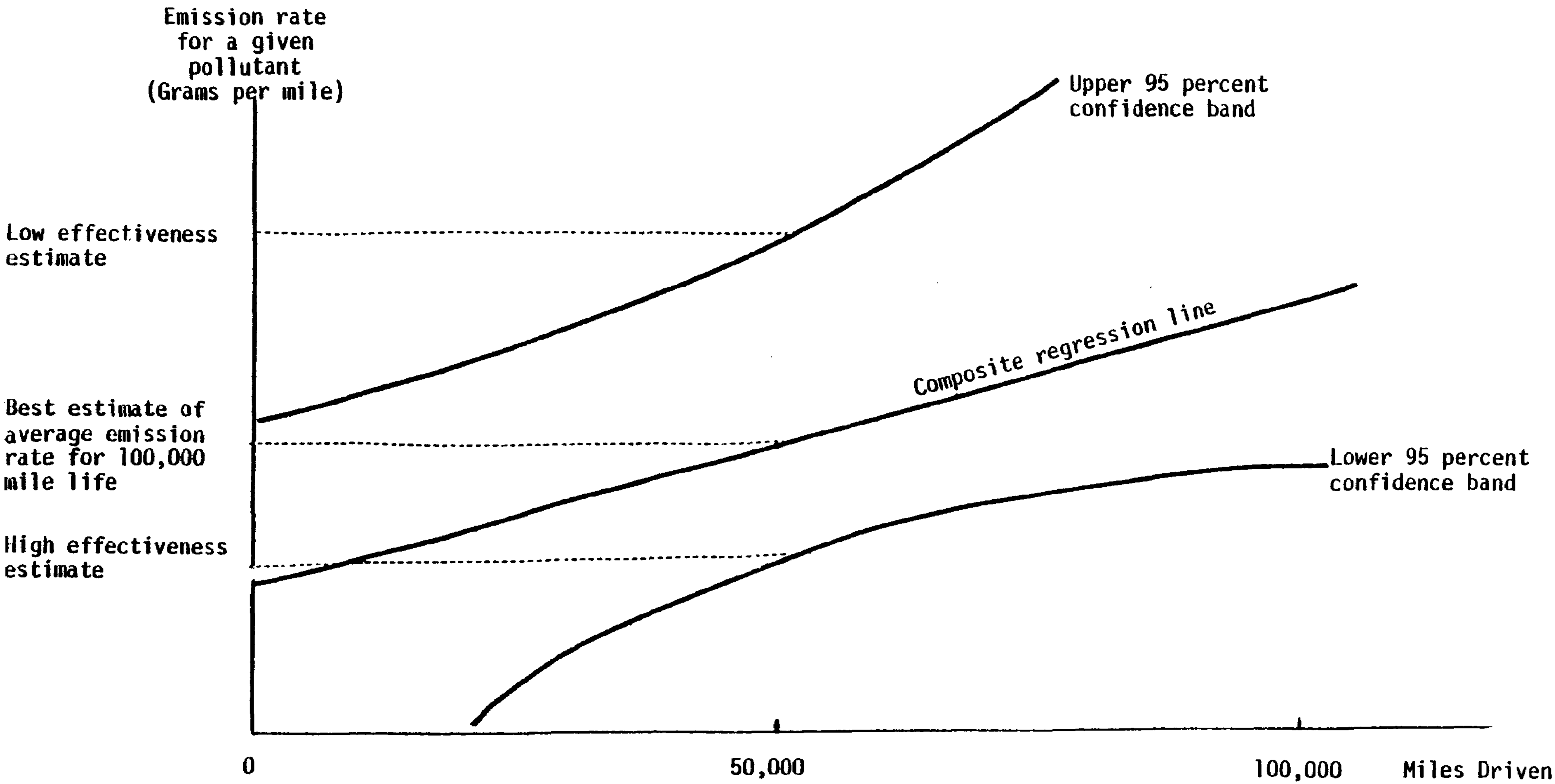

FIGURE 1: DETERMINATION OF BEST ESTIMATE AND RANGE OF VALUES FOR AVERAGE EMISSION RATES FOR CASE 2 (STANDARDS PLUS CERTIFICATION)

TABLE 4: REGRESSION ANALYSIS OF IN-USE EMISSION RATES AS A FUNCTION OF MILEAGE FOR CASE 3

Relation: $e_i(m) = \mu_i\, m + \eta_i$ $(i = 1, 2, 3)$

where

$e_i(m)$ = average in-use emissions of pollutant i by a vehicle at mileage m;

m = vehicle mileage, in tens of thousands; and

μ_i, η_i = regression coefficients

Results:

i	μ_i		η_i		R^2
	Value	Significance	Value	Significance	
1 (HC)	0.21532	0.0000	0.76435	0.0000	0.06059
2 (CO)	1.1438	0.1510	12.071	0.0000	0.00660
3 (NO_x)	0.23168	0.0010	2.2729	0.0000	0.03395

and 1975 EF data for 282 vehicles, regression analyses (summarized in table 5) were performed to estimate the relationships between assembly-line emission levels (with deterioration factors applied) and levels of vehicles in use (converted to 50,000 mile levels using the mileage regression described in section 3.1.2). The best estimate of effectiveness then assumed that manufacturer design, production engineering, and quality control would result in vehicles which just met the standards at the assembly line. The regression relationships were used to convert these assembly-line levels to levels for vehicles in use, and these in-use levels were further reduced to account for the effect of rejections by SEA. This effect was determined by assuming that an SEA failure would result in the emissions of failing vehicles in a class being reduced to the average emission levels of passing vehicles in the same class. The voluntarily submitted data were then used to estimate the average saving per failing class[1] corresponding to this assumption, and these savings were converted to in-use reductions using the regression relations given in table 5. To apply these reductions to overall emissions, it was assumed that

(1) 20 test orders per year would be conducted;

(2) 50 percent of vehicles in a tested class would have been sold (and not subject to the reductions[2]) by the time of the test order;

(3) 100 percent of classes would fail for the case 4 estimate, while 75 percent would fail for the case 5 estimate; and

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[1]Failing classes were identified in the data by assuming a 40 percent AQL for each pollutant.

[2]In cases involving recall as well as SEA, it was assumed that these vehicles would be recalled (see section 3.1.10).

TABLE 5: REGRESSION ANALYSIS OF IN-USE EMISSIONS AS A FUNCTION OF ASSEMBLY LINE EMISSIONS

Relation: $y_{ij} = \gamma_i z_{ij} + \delta_i$ $(i = 1,2,3)$

where

y_{ij} = in-use emission level of pollutant i by a given vehicle at 50,000 miles;

z_{ij} = average assembly-line emission level (including deterioration) for pollutant i for vehicles in the same class as vehicle j; and

γ_i, δ_i = regression coefficients

Results:

i	γ_i Value	γ_i Significance	δ_i Value	δ_i Significance	R^2
1 (HC)	0.55891	0.0107	1.5717	0.0000	0.02306
2 (CO)	1.1101	0.0051	19.699	0.0000	0.02772
3 (NO_x)	0.35857	0.0080	2.2467	0.0000	0.02482

(4) the average sales of a failing class would equal the average for all classes included in the voluntarily submitted data base.

To develop a lower bound on this estimate, it was assumed that SEA would create no deterrent, so that the only benefit of SEA would be in the form of a reduction in the emissions of vehicles in failed classes (i.e., precontrol levels would prevail, except in failed classes). An upper bound on the estimate was developed by assuming that, in addition to the high-estimate deterrent resulting from the existence of standards (see section 3.1.1), a further deterrent from SEA would cause manufacturers to reduce the emissions of vehicles in classes which would otherwise fail to the point at which just 40 percent of the vehicles in each class would fail.[1] In addition to this deterrent effectiveness, it was assumed that random fluctuations in measured emissions would still result in SEA failures, so effectiveness due to reduction in emissions of vehicles in failed classes was also included in the high estimate.

Best, low, and high estimates of the effectiveness of SEA in controlling evaporative emissions (assuming the use of a hot soak SHED test) were computed in a similar manner to the computation of exhaust emission effectiveness. However, lack of assembly line data for evaporative emissions required assuming that

(1) slippage of evaporative emission from assembly line to in-use conditions is in the same proportion as the slippage from certification to in-use conditions and

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[1]This assumes 40 percent to be the AQL for SEA, and that manufacturers are deterred to the point of reducing emissions to this level before test orders are conducted.

(2) the percentage reduction in evaporative emissions resulting from failure of a class on an SEA test order is equal to the average percentage reduction assumed for exhaust emissions.

3.1.5 Case 6: Standards Plus Inspection and Maintenance (Diagnostic)

The best estimate for case 6 assumes that a diagnostic inspection consists of checks on idle limiter caps, idle RPM, timing, EGR, and hoses. Restorative Maintenance (RM) data were examined to estimate percent reductions from in-use levels resulting from bringing these items within manufacturer specifications. There were only 26 vehicles in the RM data base which met the conditions of this analysis. Of these vehicles, six were within manufacturer specifications on the above parameters. The average emissions of these six vehicles were lower than the average for the entire 26 vehicles by 56 percent for HC, 69 percent for CO, and 38 percent for NO_x. These percentages were applied to actual 1975 emission levels, and the results were then adjusted for the fact that case 6 assumes no certification program exists. This adjustment was made by adding the difference between case 1 and case 2 emissions to each result.[1] To combine these first-year benefits with the effects of deterioration and multiple annual inspections, yearly deterioration factors developed from a run of EPA's inspection and maintenance (IM) simulation [EPA, 1977] were applied to the first-year emissions predicted from the RM data to produce an estimate of total emissions throughout a vehicle's life. In particular, the following

[1]This and other adjustments for the absence of a certification program assume that the effect of certification on emissions is constant over all mileages.

relationship was used to predict the deterioration factor (DF) in a given year:

$$\text{DF for year } n = \frac{(\text{tons emitted in year } n)/(\text{miles driven in year } n)}{(\text{tons emitted in year } 1)/(\text{miles driven in year } 1)},$$

where all values on the right-hand side of the equal sign were taken from the simulation.

To develop a high effectiveness estimate, the above process was repeated under the assumption that the diagnosis included everything in the RM diagnostic check. Because the results for the best and high estimates were based on data for a very small set of vehicles, the low estimate assumed that no benefit would accrue from the program. For all three estimates, the diagnostic checks were assumed to have no direct effect on evaporative emissions, but only the deterrent effect resulting from the existence of standards.[1]

3.1.6 Cases 7 and 8: Standards Plus Inspection and Maintenance (Testing)

The best effectiveness estimates for cases 7a, 7b, 8a, and 8b were developed using EPA's IM simulation [EPA, 1977]. (The version of the simulation used was that available in July 1977.) Input to the simulation consisted of 1975 EF data adjusted for the assumed absence of certification. (These adjustments were made by adding the difference between case 1 and case 2 emissions to the measured emissions of each vehicle in

[1]Although a diagnostic inspection could produce an evaporative benefit, data were not available to evaluate the magnitude of such a benefit.

the data base.) Additional assumptions and procedures used in conjunction with the simulation were that:

(1) the idle test was used for cases 7a and 8a, while a loaded test was used in cases 7b and 8b (the loaded test used was the Federal Short Cycle);

(2) the loaded test (but not the idle test) was used to measure NO_x emissions;

(3) cutpoints were set to force a first-year failure rate of 30 percent in cases 7a and 7b, and 50 percent in cases 8a and 8b; and

(4) failure of an inspection would result in reduction of emission levels to the FTP equivalent of the short test standards.

Equations used to relate short test results to FTP levels in the simulation appear in table 6. The short test cutpoints used and the resultant benefits are summarized in table 7.

Effectiveness of IM at controlling evaporative emissions assumed the use of a hot soak SHED procedure in all cases. Because evaporative emissions are assumed not to deteriorate, it was not necessary to use the IM simulation to estimate effectiveness. Instead, the evaporative cutpoint was assumed to be set at the same fraction above the standard as was the cutpoint for exhaust HC. A sample of evaporative test results was then approximated using 1978 certification data in order to predict a fraction of vehicles which would fail, and therefore have their emissions lowered to the cutpoint. The result was a 4 percent failure rate for cases 7a and 8a, and a 6 percent rate for cases 7b and 8b. The resulting emission reduction was applied to the case 1 (no certification) emission levels.

TABLE 6: REGRESSION EQUATIONS USED TO RELATE SHORT TEST RESULTS TO FTP LEVELS IN THE IM SIMULATION

TEST	POLLUTANT	RELATION
IDLE[1]	HC	FTP HC = .0035396 · ST HC + .87178
	CO	FTP CO = 4.7936 · ST CO + 15.668
LOADED[2]	HC	FTP HC = .84449 · ST HC + .53378
	CO	FTP CO = 1.1067 · ST CO + 7.4225
	NO_x	FTP NO_x = .88995 · ST NO_x + .80015

[1]These idle test equations were used with cases 7a, 8a, 12, 14, 15, 16, and 18.

[2]These loaded test equations were used with cases 7b and 8b.

TABLE 7: SHORT TEST CUTPOINTS AND CORRESPONDING PERCENT SAVINGS FROM APPLICATION OF IM SIMULATION

CASE	SHORT TEST CUTPOINTS[1]			RESULT[2] (PERCENT BENEFIT)		
	HC	CO	NO_x	HC	CO	NO_x
7a	478.0	4.8	-	29	32	-
7b	2.4	30.6	5.3	30	30	1
8a	348.0	3.5	-	38	40	-
8b	1.9	24.1	4.2	38	39	4
12	55.0	0.5	-	41	30	-
14	41.2	0.1	-	42	35	-
15	255.4	2.5	-	38	39	-
16	21.2	0.1	-	45	36	-
18	255.4	2.5	-	38	40	-

[1]Idle test cutpoints are in units of parts per million for HC and percent for CO. Loaded test cutpoints are all in units of grams per mile.

[2]Results for cases 14, 16, and 18 also include benefits from recall, which were computed in conjunction with the IM simulation computations.

The low estimate in these cases assumed that IM would have no deterrent effect (so that vehicles with uncontrolled emissions would be subject to IM) and that deterioration between inspections would occur more rapidly than in the best estimate case. (Figure 2 illustrates the two alternative assumptions regarding deterioration.) To approximate this effect, one-half of first-year percentage reductions from [EPA, 1977] were applied to uncontrolled emission levels to develop a HC and CO benefit in grams per mile. Low NO_x benefits in the loaded-mode cases were taken to be zero. Low evaporative benefits in all cases applied the percentage reduction in the best estimate to uncontrolled levels.

High estimates did not use the simulation but assumed that average emission levels met the FTP standards at 50,000 miles in the field.[1]

3.1.7 Cases 9 and 10: Standards Plus Recall

The best estimate for recall was developed by matching vehicles in the EF data base with classes identified on EPA's current list of potential recalls [MSED, 1977]. (Emissions in the EF data base were first adjusted for the absence of a certification program, as described earlier.) All vehicles so identified were assumed to be recalled at 25,000 miles.[2] Those vehicles responding to the recall were assumed to have their emissions for pollutants causing the recall reduced to the average emissions of unaffected cars at 25,000 miles. (In case 9, 40 percent of all vehicles were

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[1]However, see section 4.0 for a discussion of situations in which these (and other) high estimates were revised to maintain internal consistency among the estimates.

[2]Note that this use of the EF data base (as well as other uses) assumes that the data consist of a sales-weighted sample from the national population.

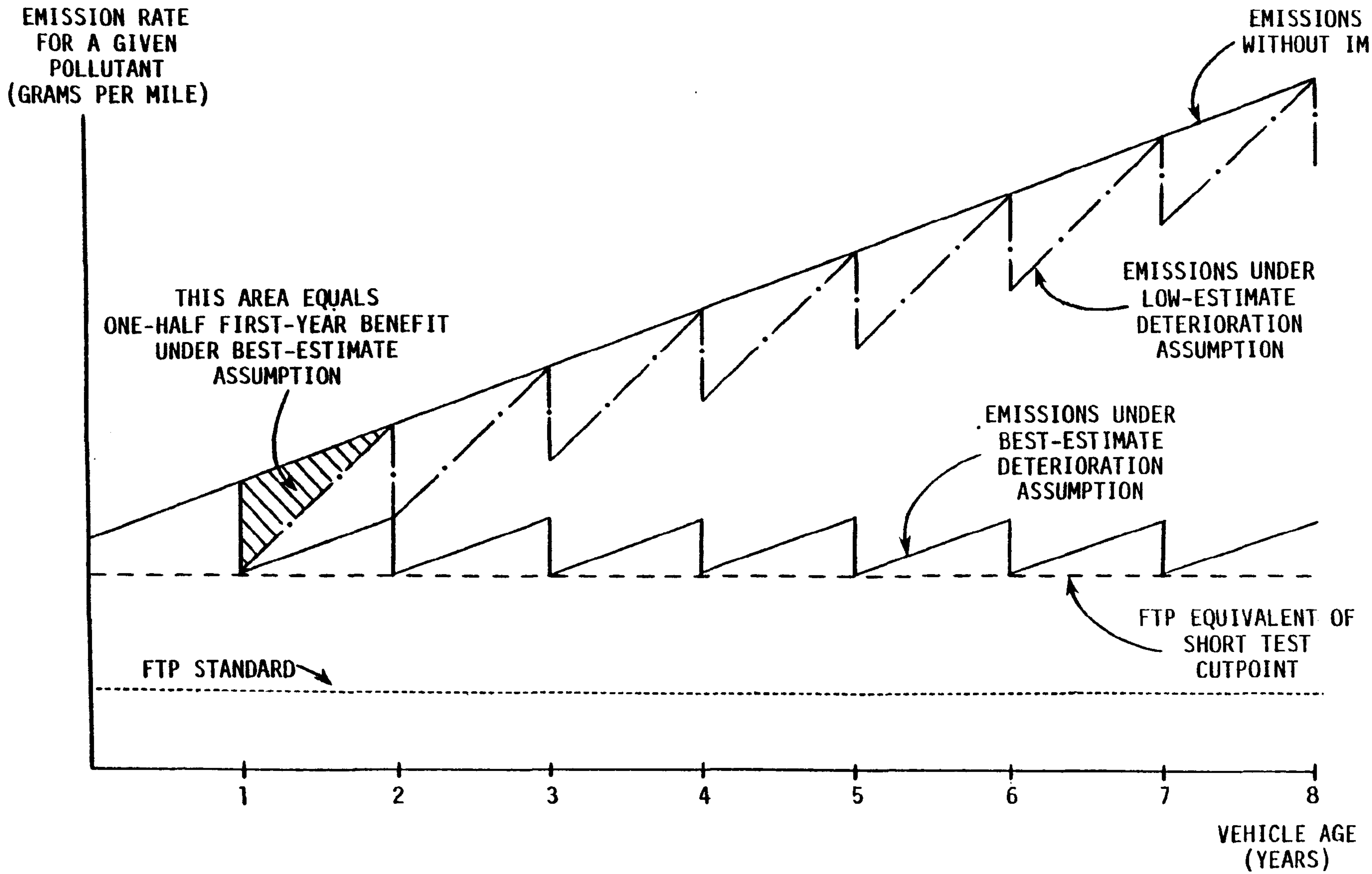

FIGURE 2: ALTERNATIVE DETERIORATION ASSUMPTIONS FOR BEST ESTIMATES AND LOW ESTIMATES OF IM EFFECTIVENESS FOR A SINGLE VEHICLE

assumed to respond, while case 10 assumed a 70 percent response rate.) Deterioration after a recall was assumed to occur at the same rate as before the recall. (See figure 3 for an illustration of the assumed emission rates of a recalled vehicle.) Deterioration rates were developed from mileage regressions with 1975 EF data (see section 3.1.2).

Low effectiveness estimates assumed no deterrent effect, and assumed that recalls would reduce uncontrolled emission levels to the same level to which they were reduced in the best estimate. The same vehicles were assumed to be recalled as for the best estimate. High effectiveness estimates assumed that standards plus the threat of recall would cause average emission levels to be at the FTP standards at 50,000 miles in the field. As a result, no recall actions were assumed necessary.

3.1.8 Case 11: Standards Plus Certification with Parameter Adjustment Plus Selective Enforcement Audit

The best and low estimates for this case began with emission rates for certification with parameter adjustment (see section 3.1.3) and subtracted an average benefit associated with SEA failures. This latter benefit was developed from the manufacturer-submitted assembly-line data describing the effectiveness of an SEA program in the presence of certification, and was converted to an in-use benefit using the regression relationships developed for cases 4 and 5 (see section 3.1.4). It was assumed that, even in the presence of certification with paramenter adjustment, EPA would still be able to identify 20 classes which would fail an

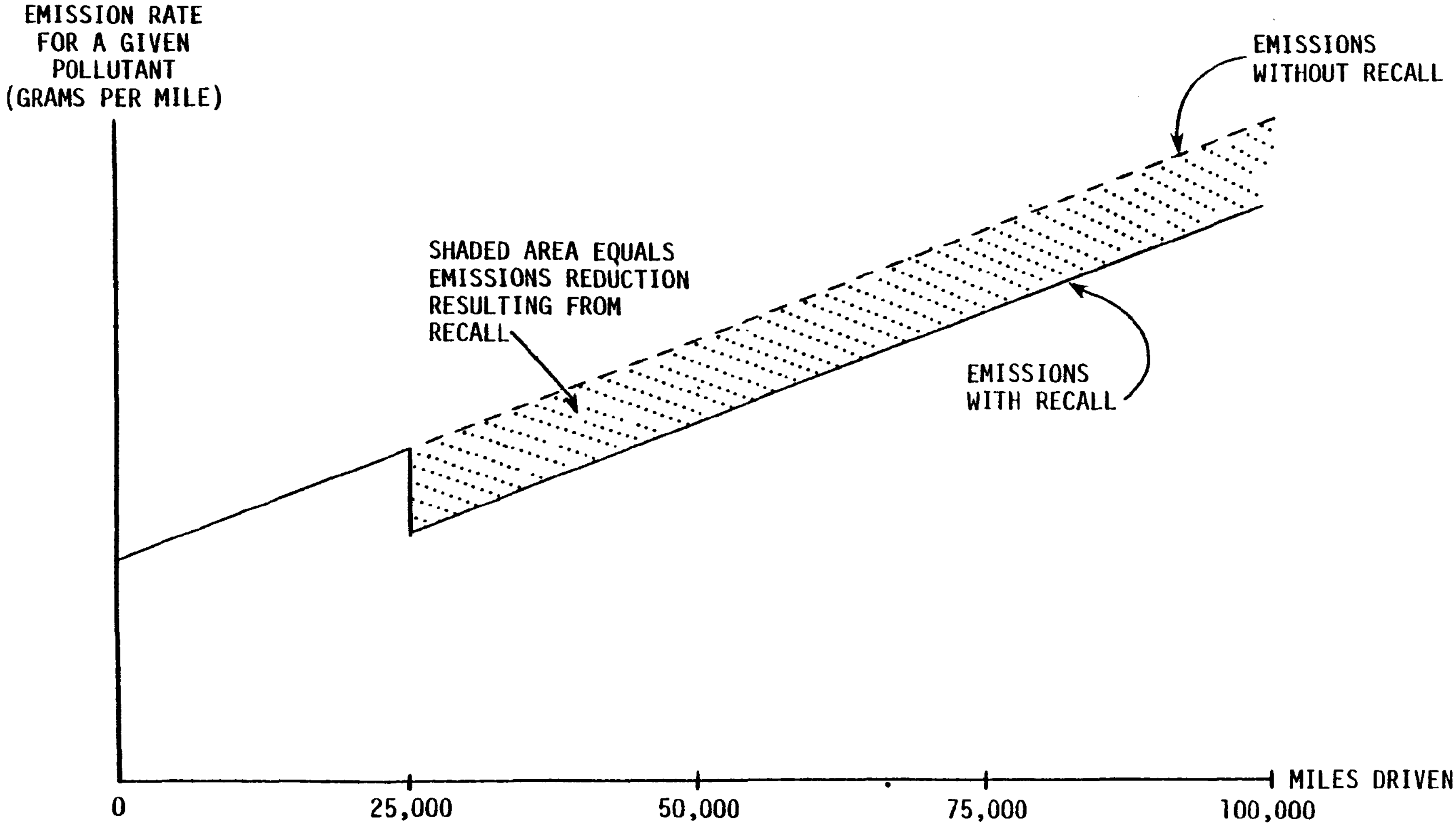

FIGURE 3: EFFECT OF RECALL ON EMISSIONS OF A RECALLED VEHICLE

SEA test order.[1] The high estimates used the same approach but assumed a further SEA deterrent which would cause manufacturers to reduce emissions in potentially-failing classes to the point at which just 40 percent of the vehicles in each such class would fail (see section 3.1.4).

3.1.9 Case 12: Standards Plus Certification with Parameter Adjustment Plus Inspection and Maintenance (Testing)

The best estimate for exhaust emissions in case 12 used 1975 EF data for vehicles within manufacturer specifications on idle CO, idle RPM, and timing as input to the IM simulation. (See tables 6 and 7 for a summary of the simulation run.) The low estimate applied half the first year percent emission reductions from this simulation run to the low estimate for certification with parameter adjustment (case 3, see section 3.1.3).[2]

For evaporative emissions, the best estimate was equal to the best estimate for certification with parameter adjustment (case 3). Since the results for this case were well below the derived evaporative standard, and because of the assumption that evaporative emissions do not deteriorate with mileage, it was assumed few or no IM failures would occur. The low evaporative estimate applied the low IM benefit derived for case 7a to the low estimate for evaporative emissions in case 3.

All high estimates assumed that emissions met FTP standards at 50,000 miles in the field.

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[1] Note that this SEA benefit was not applied to particular vehicles in the EF data base, but was computed separately and the result used to reduce overall emissions in the field.

[2] See section 3.1.6 and figure 2 for an indication of the rationale of this approximation.

3.1.10 Case 13: Standards Plus Certification with Parameter Adjustment Plus Selective Enforcement Audit Plus Recall

The best estimate in this case began with the 1975 EF data for vehicles within manufacturer specifications on idle CO, idle RPM, and timing. These emission rates were adjusted for an average in-use benefit associated with SEA failures[1] (see sections 3.1.4 and 3.1.8). Vehicles in this data base were then matched with classes identified in [MSED, 1977], and the benefit of recall of these vehicles was computed (see section 3.1.7). The net emission rates including this benefit provided the case 13 best estimate. Evaporative emissions were assumed to equal the case 3 level minus a reduction due to SEA. (Recall was assumed to have no direct effect on these emissions, since there are no evaporative recalls in [MSED, 1977]. In the future, of course, more stringent evaporative emission standards may result in some evaporative recalls.

Low estimates were developed by subtracting average effects due to SEA failures (see section 3.1.4) and recall (see section 3.1.7) from the low estimates of emission rates for certification with parameter adjustment (see section 3.1.3). High estimates assumed that all vehicles meet FTP standards on all pollutants at 50,000 miles in the field.

3.1.11 Cases 14 and 16: Standards Plus Certification with Parameter Adjustment Plus Selective Enforcement Audit Plus Inspection and Maintenance (Testing) Plus Recall

The best estimate in these cases used a modified version of the IM simulation which included a dynamic representation of the effects of a

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[1]Because recall was also present as a compliance technique in this case, 95 percent of the vehicles sold before any SEA test order were assumed to receive the SEA benefit, as a result of responding to a recall. This also is true of cases 14, 16, 17 and 18. (The 95 percent response rate reflects the fact that the vehicles are new at the time of the recall and their owners are therefore likely to be located and to respond.)

recall campaign. Recalls were assumed to occur after two years of the IM program. The effects of recall were computed as described in section 3.1.7. Input to the simulation consisted of 1975 EF data for vehicles within manufacturer specifications on idle CO, idle RPM, and timing.[1] These input values were modified to account for the average effect of SEA failures (see sections 3.1.4 and 3.1.8). Recalls were assumed to affect those vehicles in this data base corresponding to the classes identified in [MSED, 1977]. The best estimate for evaporative emissions assumed no benefit for IM or recall, since emissions in the field were already predicted to be well below the standard and since no evaporative recalls appear in [MSED, 1977].

Low estimates were approximated by applying half the reduction computed for the first-year best estimate (in percent) to the low estimate for this situation without IM and recall (represented in case 11). The low estimate for evaporative emissions applied the low IM benefit derived for case 7a to the low estimate for evaporative emissions in case 3. High estimates for all pollutants assumed FTP standards were met in the field at 50,000 miles.

3.1.12 Case 15: Standards Plus Selective Enforcement Audit Plus Inspection and Maintenance (Testing)

For the best estimate in this case the IM simulation was run using as input the 1975 EF data adjusted for the absence of certification (by adding the difference between average emissions in case 1 and case 2 to

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[1]See tables 6 and 7 for further information concerning the simulation run.

each data item), and further adjusted for the average effects of SEA (see sections 3.1.4 and 3.1.8).[1] No NO_x benefit from IM was assumed. Evaporative benefits used the reduction computed for case 7a (standards plus IM) and applied it to the case 4 result (standards plus SEA).

The low estimate applied half the first year percentage emission reductions computed from the simulation to precontrol emission levels, adjusted for the effect of SEA. The low evaporative estimate applied the percentage reduction achieved in the best estimate to the case 4 low results. All high estimates assumed that cars meet the FTP standards at 50,000 miles in the field.

3.1.13 Case 17: Standards Plus Selective Enforcement Audit Plus Recall

The best estimate in this case again used 1975 EF data adjusted for the absence of certification and for the direct benefit of SEA (see sections 3.1.4 and 3.1.8). The benefit of recall to those vehicles in this data base which matched classes identified in [MSED, 1977] was then computed. The net emission rates including this benefit provided the case 17 best estimate. Evaporative emissions were assumed to equal the case 1 level minus a reduction due to SEA. (Recall is assumed to have no direct effect on these emissions, since there are no evaporative recalls on the MSED list.)

Low estimates were developed by subtracting average effects due to SEA failures (see section 3.1.4) and recall (see section 3.1.7) from the precontrol emission levels. High estimates assumed that all vehicles meet FTP standards on all pollutants at 50,000 miles in the field.

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[1]See tables 6 and 7 for further information concerning the simulation run.

3.1.14 Case 18: Standards Plus Selective Enforcement Audit Plus Inspection And Maintenance (Testing) Plus Recall

For case 18, the best estimate again used 1975 EF data adjusted for the absence of certification and for the average direct benefit of SEA. These data served as input to the IM simulation as modified to include the effects of recall.[1] Recalls were again assumed to affect those vehicles in this data base corresponding to the classes identified in [MSED, 1977]. No NO_x benefit from IM was assumed. Evaporative benefits used the reduction computed for case 7a (standards plus IM) and applied it to the case 4 result (standards plus SEA).

The low estimate for HC and CO applied half the first year percentage reductions computed from the simulation to precontrol emission levels, adjusted for the effect of SEA. The low evaporative estimate applied the percentage reduction achieved in the best estimate to the case 4 low evaporative estimate. All high estimates assumed that cars meet the FTP standards at 50,000 miles in the field.

3.1.15 Case 19: Standards Plus Certification Plus Inspection and Maintenance (Testing)

The best estimate for this case applied the percentage benefits of IM predicted by [EPA, 1977] to the results of case 2 (standards plus certification). The best estimate for evaporative emissions applied the percent reduction computed for case 7a to the best case 2 estimate.

The low exhaust estimate applied half the first year percentage reductions from [EPA, 1977] to the case 2 estimates. The low evaporative

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[1]See tables 6 and 7 for further information concerning the simulation run.

estimate again applied the case 4 reduction to the low case 2 estimate. All high estimates assumed that cars meet the FTP standards at 50,000 miles in the field.

3.2 Cost Estimates

Development of cost estimates for the 21 cases evaluated in this study involved developing best, high, and low cost estimates for each compliance technique separately. These costs were then added for the combination of compliance techniques present in a given case. Note that the high and low cost estimates for a given technique are not necessarily the greatest and least costs possible for that technique, but rather represent the costs most likely to accrue given the high or low benefit accrues. The following paragraphs describe the estimates used for government and total costs for each compliance technique. A summary of these cost estimates appears in table 8.

3.2.1 Standards

For all best and high effectiveness estimates, promulgation of emission standards was assumed to result in the installation of emission controls. Therefore, the cost associated with the existence of standards was assumed to be the manufacturer design and production costs required to install these controls. Based on recent EPA estimates, an average cost of $170 per vehicle was assumed to be incurred for this purpose [EPA, undated]. In cases in which the low effectiveness estimate assumed that no such controls would be installed, this cost was not assessed. In all cases, government costs were assumed to equal zero.

TABLE 8: SUMMARY OF COSTS USED IN THE ANALYSIS
(MILLIONS OF DOLLARS)

COMPLIANCE TECHNIQUE	BEST ESTIMATE		LOW ESTIMATE		HIGH ESTIMATE	
	GOV'T. COSTS	OTHER COSTS	GOV'T. COSTS	OTHER COSTS	GOV'T. COSTS	OTHER COSTS
Standards	0	1700	0	1700 or 0[1]	0	1700
Certification or Certification with Parameter Adjustment	3.26	60	3.26	50	3.26	70
Selective Enforcement Audit	.70	19.1	.70	16.6	.70	21.6
Inspection and Maintenance (All Versions)	0	400	0	400	0	400
Recall	.52	24.41 or 42.71[2]	.52	24.41 or 42.71[2]	.52	24.41 or 42.71[2]

ssumed to be 1700 when in presence of certification or certification with parameter djustment, and 0 otherwise.

ssumed to be 24.41 for a response rate of 40 percent and 42.71 for a response rate of 0 percent.

3.2.2 Certification

The costs of certification (and certification with parameter adjustment) included government and manufacturer costs associated with the operation of the certification process. These costs were based on estimates provided by [Auerbach, 1977]. Certification process cost to the government was estimated at $3.26 million, while manufacturer costs were assumed to range between $50 million and $70 million. The $50 million estimate was used with low effectiveness estimates, the $70 million estimate was used with high estimates, and their average was used as the best estimate of manufacturer costs.

3.2.3 Selective Enforcement Audit

Costs of SEA were based on [Train, 1976], which states that "The SEA program is estimated to cost about $0.7 million per year for the government, about $1.6 million per year for company testing, and about $15-20 million per year for modifications to automobiles." For the latter range of estimates, the $15 million figure was used with low effectiveness estimates, the $20 million figure was used with high effectiveness estimates, and their average was used as a best estimate. It should be pointed out that these costs are not completely consistent with the assumptions of this analysis, since the $15-20 million estimate apparently is based on the assumption that vehicle design changes will be implemented to eliminate all SEA test failures. (The current analysis assumes that test failures actually occur.) However, these costs were used here because they represent EPA's current best estimate of the cost of SEA.

3.2.4 Inspection and Maintenance

Costs for all versions of inspection and maintenance were based on [Walsh, 1976]. These estimates indicate that the average cost of an inspection is approximately $5 per car. Because an average car will be subject to eight annual inspections during its 100,000-mile life, a total lifetime cost of $40 per car was assumed. The estimates in [Walsh, 1976] also indicate that vehicle repair costs after an IM failure will be approximately equal to the fuel economy savings resulting from the repair. Therefore, no repair costs or fuel economy savings were explicitly included in these estimates. No federal government costs were assumed to be incurred for IM. Note that these estimates were used on the assumption that differences in costs of idle mode testing, loaded mode testing, and parameter inspection are negligible.

3.2.5 Recall

The costs of recall were assumed to include:

(1) government costs for operating a recall program one year[1] (assumed to equal $200,000),

(2) government testing costs (assumed to equal $1000 per car tested, where 20 cars are assumed to be tested for each recall action considered), and

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[1]This estimate assumes that the cost of one year's operation of the program reasonably approximates that portion of program costs associated with recalls of vehicles for a single model year.

(3) manufacturer costs to fix recalled cars (assumed to equal $12 per car fixed).

Note that high effectiveness estimates assume that no recall actions are found to be necessary. Therefore, the manufacturer cost for repairing recalled cars is zero. However, this repair cost is still assessed as an approximation of the additional cost to manufacturers of building the cars in such a way that the recalls become unnecessary.

4.0 RESULTS

Effectiveness and cost results for all cases evaluated appear in tables 9 through 29.[1] In generating some of the low and high estimates appearing in these tables, effectiveness values were sometimes adjusted to maintain internal consistency among the assumptions used to generate the estimates.[2] These adjustments were necessary because assumptions and procedures used to compute preliminary values for some of the low and high estimates were found to be inconsistent when the calculations were actually made. For example, the assumption initially used to compute the high estimate for cases 7 and 8 (standards plus IM) was that vehicles would meet the FTP standards in the field. However, the high estimate for NO_x emissions in case 1 (standards alone) was an emission rate which was below the FTP standards for vehicles in the field. Since it seemed unreasonable that an upper bound on the effectiveness of standards plus IM would be less than an upper bound on the effectiveness of standards alone, the case 7 and 8 high estimate for NO_x was adjusted to equal the case 1 high estimate.

The following points may assist in interpreting and estimating the validity of the effectiveness values appearing in the tables:

(1) All effectiveness estimates were based on available data. Because certification is the compliance technique which has been in effect longest (and therefore has the most data accumulated on it), estimates of the effectiveness of certification are probably the most accurate.

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[1]These tables are located at the end of section 4.0.

[2]Note that these adjustments were required for low and high estimates only. None of the best estimates was changed. All adjusted values are marked with asterisks in the tables.

(2) Deterrent effects for cases which have never actually been implemented are based on assumptions which are believed to be reasonable, but for which supporting data were not always available. This is especially true of effectiveness estimates associated with the promulgation of standards in the absence of a certification program.

(3) Because of the limited amount of SHED data available and the lack of a meaningful evaporative emission standard actually in existence for 1975 vehicles, results for evaporative emissions are necessarily based on limited data and several "reasonable" assumptions. These results should, therefore, be interpreted carefully.

(4) The results for case 6 (standards plus diagnostic IM) are based on results for a very small number of vehicles and, therefore, should be interpreted with caution.

(5) The results for all cases involving IM testing are sensitive to the specific combinations of HC, CO, and NO_x cutpoints used to achieve the required first-year failure rates. Other cutpoints could result in the same initial failure rate but a somewhat different effectiveness estimate.

(6) Results for cases involving the loaded-mode IM test (cases 7b and 8b) show little additional benefit over the corresponding idle-mode cases (cases 7a and 8a, respectively). This is apparently because all these cases assume IM is implemented in the absence of a certification process, so the resulting in-use emissions are quite high before application of IM. As a result, the greater precision of the loaded-mode test is, in a sense, "wasted" on vehicles which are likely to fail any reasonable test used on them.

(7) Note that certification with parameter adjustment (e.g., case 3) appears to produce an increase in NO_x emissions concomitant with the reduction in HC and CO emissions realized over either case 1 or case 2.

Tables 30 and 31[1] present cost effectiveness estimates for all cases in units of either government dollars or total dollars spent per ton of pollutant removed. These results were computed for a given case by allocating costs equally among the four pollutants and dividing the result by the effectiveness values. Values in these tables can be misleading because they result from a somewhat arbitrary allocation of costs among pollutants,[2] and because they mask the actual magnitude of effectiveness that can be achieved and costs required to implement a given case. Therefore, cases with low cost effectiveness are not necessarily the most desirable cases in the context of budget constraints and/or specific pollution reduction goals.[3] Furthermore, these values cannot be used directly to estimate the marginal cost effectiveness of adding a new compliance technique to an existing compliance assurance program.

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[1]These tables are located at the end of section 4.0.

[2]Although any such allocation is likely to seem arbitrary, it might be possible to allocate costs in proportion to the relative effectiveness of a given case at reducing the emissions of each pollutant, or in proportion to subjective estimates of the relative degree to which each pollutant is a "target" of the compliance techniques used in a given case.

[3]For example, promulgation of standards alone (case 1) produces a reduction in emissions at essentially no cost to the government. It therefore has a cost effectiveness of zero and appears highly desirable from a cost effectiveness standpoint. However, it is generally considered to be an unacceptable alternative because it does not result in a sufficient reduction in vehicle emissions.

TABLE 9: RESULTS FOR CASE 1 - STANDARDS ONLY

ESTIMATE	EFFECTIVENESS (MILLIONS OF TONS OF POLLUTANT SAVED)				COST (MILLIONS OF DOLLARS)	
	HC	CO	NO_x	EVAP.	GOV'T.	TOTAL
BEST	5.32	46.25	0.07	1.73	0	1700
LOW	0	0	0	0	0	0
HIGH	6.40	70.76	1.22	3.09	0	1700

TABLE 10: RESULTS FOR CASE 2 - STANDARDS PLUS CERTIFICATION

ESTIMATE	EFFECTIVENESS (MILLIONS OF TONS OF POLLUTANT SAVED)				COST (MILLIONS OF DOLLARS)	
	HC	CO	NO_x	EVAP.	GOV'T.	TOTAL
BEST	5.94	62.17	0.50	3.09	3.26	1763.26
LOW	5.48	53.58	-.23	1.73	3.26	1753.26
HIGH	6.40	70.76	1.22	3.09	3.26	1773.26

TABLE 11: RESULTS FOR CASE 3 - STANDARDS PLUS CERTIFICATION WITH PARAMETER ADJUSTMENT

ESTIMATE	EFFECTIVENESS (MILLIONS OF TONS OF POLLUTANT SAVED)				COST (MILLIONS OF DOLLARS)	
	HC	CO	NO_x	EVAP.	GOV'T.	TOTAL
BEST	6.29	75.97	-.03	3.09	3.26	1763.26
LOW	5.88	69.23	-.63	1.73	3.26	1753.26
HIGH	6.70	82.72	.56	3.09	3.26	1773.26

TABLE 12: RESULTS FOR CASE 4 - STANDARDS PLUS SELECTIVE ENFORCEMENT AUDIT (100% REJECTION RATE)

ESTIMATE	EFFECTIVENESS (MILLIONS OF TONS OF POLLUTANT SAVED)				COST (MILLIONS OF DOLLARS)	
	HC	CO	NO_x	EVAP.	GOV'T.	TOTAL
BEST	5.74	58.16	0.09	1.86	.70	1719.80
LOW	1.78	20.80	0.08	0.54	.70	1717.30
HIGH	6.49	76.09	1.24	3.13	.70	1722.30

TABLE 13: RESULTS FOR CASE 5 - STANDARDS PLUS SELECTIVE ENFORCEMENT AUDIT (75% REJECTION RATE)

ESTIMATE	EFFECTIVENESS (MILLIONS OF TONS OF POLLUTANT SAVED)				COST (MILLIONS OF DOLLARS)	
	HC	CO	NO_x	EVAP.	GOV'T.	TOTAL
BEST	5.72	57.50	0.08	1.83	.70	1719.80
LOW	1.47	17.69	0.06	0.41	.70	1717.30
HIGH	6.48	75.71	1.24	3.13	.70	1722.30

TABLE 14: RESULTS FOR CASE 6 - STANDARDS PLUS INSPECTION AND MAINTENANCE (DIAGNOSTIC)

ESTIMATE	EFFECTIVENESS (MILLIONS OF TONS OF POLLUTANT SAVED)				COST (MILLIONS OF DOLLARS)	
	HC	CO	NO_x	EVAP.	GOV'T.	TOTAL
BEST	6.74	68.01	0.19	1.73	0	2100
LOW	0	0	0	0	0	400
HIGH	6.83	70.76	1.22*	3.09	0	2100

*Adjusted for consistency.

TABLE 15: RESULTS FOR CASE 7a - STANDARDS PLUS IDLE INSPECTION AND MAINTENANCE (30% FAILURE RATE)

ESTIMATE	EFFECTIVENESS (MILLIONS OF TONS OF POLLUTANT SAVED)				COST (MILLIONS OF DOLLARS)	
	HC	CO	NO_x	EVAP.	GOV'T.	TOTAL
BEST	6.19	62.03	0.07	1.80	0	2100
LOW	0.87	20.57	0	0.12	0	400
HIGH	6.66	79.04	1.22*	3.09*	0	2100

*Adjusted for consistency.

TABLE 16: RESULTS FOR CASE 7b - STANDARDS PLUS LOADE
LOADED INSPECTION AND MAINTENANCE (30%
FAILURE RATE)

ESTIMATE	EFFECTIVENESS (MILLIONS OF TONS OF POLLUTANT SAVED)				COST (MILLIONS OF DOLLARS)	
	HC	CO	NO_x	EVAP.	GOV'T.	TOTAL
BEST	6.22	61.04	0.10	1.80	0	2100
LOW	0.87	20.57	0	0.12	0	400
HIGH	6.66	79.04	1.22*	3.09*	0	2100

*Adjusted for consistency.

TABLE 17: RESULTS FOR CASE 8a - STANDARDS PLUS IDLE INSPECTION AND MAINTENANCE (50% FAILURE RATE)

ESTIMATE	EFFECTIVENESS (MILLIONS OF TONS OF POLLUTANT SAVED)				COST (MILLIONS OF DOLLARS)	
	HC	CO	NO_x	EVAP.	GOV'T.	TOTAL
BEST	6.46	65.97	0.07	1.80	0	2100
LOW	0.87	20.57	0	0.12	0	400
HIGH	6.66	79.04	1.22*	3.09*	0	2100

*Adjusted for consistency.

TABLE 18: RESULTS FOR CASE 8b - STANDARDS PLUS LOADED INSPECTION AND MAINTENANCE (50% FAILURE RATE)

ESTIMATE	EFFECTIVENESS (MILLIONS OF TONS OF POLLUTANT SAVED)				COST (MILLIONS OF DOLLARS)	
	HC	CO	NO_x	EVAP.	GOV'T.	TOTAL
BEST	6.46	65.48	0.21	1.80	0	2100
LOW	0.87	20.57	0	0.12	0	400
HIGH	6.66	79.04	1.22*	3.09*	0	2100

*Adjusted for consistency.

TABLE: 19: RESULTS FOR CASE 9 - STANDARDS PLUS RECALL (40% RESPONSE RATE)

ESTIMATE	EFFECTIVENESS (MILLIONS OF TONS OF POLLUTANT SAVED)				COST (MILLIONS OF DOLLARS)	
	HC	CO	NO_x	EVAP.	GOV'T.	TOTAL
BEST	5.40	47.45	0.13	1.73	.52	1724.93
LOW	1.14	11.67	0.06	0	.52	24.93
HIGH	6.66	79.04	1.22*	3.09*	.52	1724.93

*Adjusted for consistency.

TABLE 20: RESULTS FOR CASE 10 - STANDARDS PLUS RECALL (70% RESPONSE RATE)

ESTIMATE	EFFECTIVENESS (MILLIONS OF TONS OF POLLUTANT SAVED)				COST (MILLIONS OF DOLLARS)	
	HC	CO	NO_x	EVAP.	GOV'T.	TOTAL
BEST	5.45	49.15	0.19	1.73	.52	1743.23
LOW	1.61	14.16	0.10	0	.52	43.23
HIGH	6.66	79.04	1.22*	3.09*	.52	1743.23

*Adjusted for consistency

TABLE 21: RESULTS FOR CASE 11 - STANDARDS PLUS CERTIFICATION WITH PARAMETER ADJUSTMENT PLUS SELECTIVE ENFORCEMENT AUDIT

ESTIMATE	EFFECTIVENESS (MILLIONS OF TONS OF POLLUTANT SAVED)				COST (MILLIONS OF DOLLARS)	
	HC	CO	NO_x	EVAP.	GOV'T.	TOTAL
BEST	6.32	77.51	-.03	3.09	3.96	1783.06
LOW	5.91	70.77	-.62	1.73	3.96	1770.56
HIGH	6.79	88.05	1.24*	3.13*	3.96	1795.56

*Adjusted for consistency.

TABLE 22: RESULTS FOR CASE 12 - STANDARDS PLUS CERTIFICATION WITH PARAMETER ADJUSTMENT PLUS INSPECTION AND MAINTENANCE

ESTIMATE	EFFECTIVENESS (MILLIONS OF TONS OF POLLUTANT SAVED)				COST (MILLIONS OF DOLLARS)	
	HC	CO	NO_x	EVAP.	GOV'T.	TOTAL
BEST	7.12	81.85	-.03	3.09	3.26	2163.26
LOW	6.05	70.28	-.63	1.80	3.26	2153.26
HIGH	7.12*	82.72*	.56*	3.09*	3.26	2173.26

*Adjusted for consistency.

TABLE 23: RESULTS FOR CASE 13 - STANDARDS PLUS CERTIFICATION WITH PARAMETER ADJUSTMENT PLUS SELECTIVE ENFORCEMENT AUDIT PLUS RECALL

ESTIMATE	EFFECTIVENESS (MILLIONS OF TONS OF POLLUTANT SAVED)				COST (MILLIONS OF DOLLARS)	
	HC	CO	NO_x	EVAP.	GOV'T.	TOTAL
BEST	6.53	78.03	0.38	3.09	4.48	1826.29
LOW	6.20	72.45	-0.14	1.73	4.48	1813.79
HIGH	6.79*	88.05*	1.24*	3.13*	4.48	1838.79

*Adjusted for consistency.

TABLE 24: RESULTS FOR CASE 14 - STANDARDS PLUS CERTIFICATION WITH PARAMETER ADJUSTMENT PLUS SELECTIVE ENFORCEMENT AUDIT PLUS INSPECTION AND MAINTENANCE (30% FAILURE RATE) PLUS RECALL

ESTIMATE	EFFECTIVENESS (MILLIONS OF TONS OF POLLUTANT SAVED)				COST (MILLIONS OF DOLLARS)	
	HC	CO	NO_x	EVAP.	GOV'T.	TOTAL
BEST	7.16	83.83	0.38	3.09	4.48	2226.29
LOW	6.20*	72.45*	-0.14	1.80	4.48	2213.79
HIGH	7.16*	88.05*	1.24*	3.13*	4.48	2238.79

*Adjusted for consistency.

TABLE 25: RESULTS FOR CASE 15 - STANDARDS PLUS SELECTIVE ENFORCEMENT AUDIT PLUS INSPECTION AND MAINTENANCE

ESTIMATE	EFFECTIVENESS (MILLIONS OF TONS OF POLLUTANT SAVED)				COST (MILLIONS OF DOLLARS)	
	HC	CO	NO_x	EVAP.	GOV'T.	TOTAL
BEST	6.72	72.75	0.09	1.89	0.70	2119.80
LOW	2.20	29.40	0.08	0.60	0.70	417.30
HIGH	6.72*	79.04	1.24 *	3.09 *	0.70	2122.30

*Adjusted for consistency

TABLE 26: RESULTS FOR CASE 16 - STANDARDS PLUS CERTIFICATION WITH PARAMETER ADJUSTMENT PLUS SELECTIVE ENFORCEMENT AUDIT PLUS INSPECTION AND MAINTENANCE (50% FAILURE RATE) PLUS RECALL

ESTIMATE	EFFECTIVENESS (MILLIONS OF TONS OF POLLUTANT SAVED)				COST (MILLIONS OF DOLLARS)	
	HC	CO	NO_x	EVAP.	GOV'T.	TOTAL
BEST	7.22	84.01	0.38	3.09	4.48	2226.29
LOW	6.20	72.63	-0.14	1.80	4.48	2213.79
HIGH	7.22	88.05	1.24*	3.13*	4.48	2238.79

*Adjusted for consistency.

TABLE 27: RESULTS FOR CASE 17 - STANDARDS PLUS SELECTIVE ENFORCEMENT AUDIT PLUS RECALL

ESTIMATE	EFFECTIVENESS (MILLIONS OF TONS OF POLLUTANT SAVED)				COST (MILLIONS OF DOLLARS)	
	HC	CO	NO_X	EVAP.	GOV'T.	TOTAL
BEST	5.90	62.31	0.23	1.86	1.22	1763.03
LOW	2.67	26.72	0.18	0.54	1.22	60.53
HIGH	6.66	79.04	1.24*	3.09*	1.22	1765.53

*Adjusted for consistency.

TABLE 28: RESULTS FOR CASE 18 - STANDARDS PLUS SELECTIVE ENFORCEMENT AUDIT PLUS INSPECTION AND MAINTENANCE PLUS RECALL

ESTIMATE	EFFECTIVENESS (MILLIONS OF TONS OF POLLUTANT SAVED)				COST (MILLIONS OF DOLLARS)	
	HC	CO	NO_x	EVAP.	GOV'T.	TOTAL
BEST	6.72	73.12	0.23	1.89	1.22	2163.03
LOW	2.67	29.40	0.18	0.60	1.22	460.53
HIGH	6.72*	79.04	1.24*	3.13*	1.22	2165.53

*Adjusted for consistency.

TABLE 29: RESULTS FOR CASE 19 - STANDARDS PLUS CERTIFICATION PLUS INSPECTION AND MAINTENANCE

ESTIMATE	EFFECTIVENESS (MILLIONS OF TONS OF POLLUTANT SAVED)				COST (MILLIONS OF DOLLARS)	
	HC	CO	NO_x	EVAP.	GOV'T.	TOTAL
BEST	6.53	77.06	0.50	3.11	3.26	2163.26
LOW	5.61	59.55	-.23	1.79	3.26	2153.26
HIGH	6.66	79.04	1.22*	3.11*	3.26	2173.26

*Adjusted for consistency.

TABLE 30: COST EFFECTIVENESS - FEDERAL GOVERNMENT DOLLARS SPENT PER TON OF POLLUTANT REMOVED (BEST ESTIMATES)

CASE	HC	CO	NO_x	EVAP.
1	0	0	0	0
2	0.137	0.013	1.630	0.264
3	0.130	0.011	∞[1]	0.264
4	0.030	0.003	1.944	0.094
5	0.031	0.003	2.188	0.096
6	0	0	0	0
7a	0	0	0	0
7b	0	0	0	0
8a	0	0	0	0
8b	0	0	0	0
9	0.024	0.003	1.000	0.075
10	0.024	0.003	0.684	0.075
11	0.157	0.013	∞[1]	0.320
12	0.114	0.010	∞[1]	0.264
13	0.172	0.014	2.947	0.362
14	0.156	0.013	0.339	0.362
15	0.026	0.002	1.944	0.093
16	0.155	0.013	2.947	0.362
17	0.052	0.005	1.326	0.164
18	0.045	0.004	1.326	0.161
19	0.125	0.011	1.630	0.262

[1] NO_x effectiveness for this case is negative.

TABLE 31: COST EFFECTIVENESS - TOTAL DOLLARS SPENT PER TON OF POLLUTANT REMOVED (BEST ESTIMATES)

CASE	HC	CO	NO_x	EVAP.
1	79.89	9.19	6071.43	245.66
2	74.21	7.09	881.63	142.66
3	70.08	5.80	∞[1]	142.66
4	74.90	7.39	4777.22	231.16
5	75.17	7.48	109.37	234.95
6	77.89	7.72	2763.16	303.47
7a	84.81	8.46	7500.00	291.67
7b	84.41	8.60	5250.00	291.67
8a	81.27	7.96	7500.00	291.67
8b	81.27	8.02	2500.00	291.67
9	79.86	9.09	3317.17	249.27
10	79.97	8.87	2293.72	251.91
11	70.53	5.75	∞[1]	144.26
12	75.96	6.61	∞[1]	175.02
13	69.92	5.85	1201.51	147.76
14	77.73	6.64	1464.66	180.12
15	78.86	7.29	5888.33	280.40
16	77.09	6.63	1464.66	180.12
17	74.71	7.07	1916.34	236.97
18	80.47	7.40	2351.12	286.12
19	82.82	7.02	1081.63	173.90

[1]NO_x effectiveness for this case is negative.

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