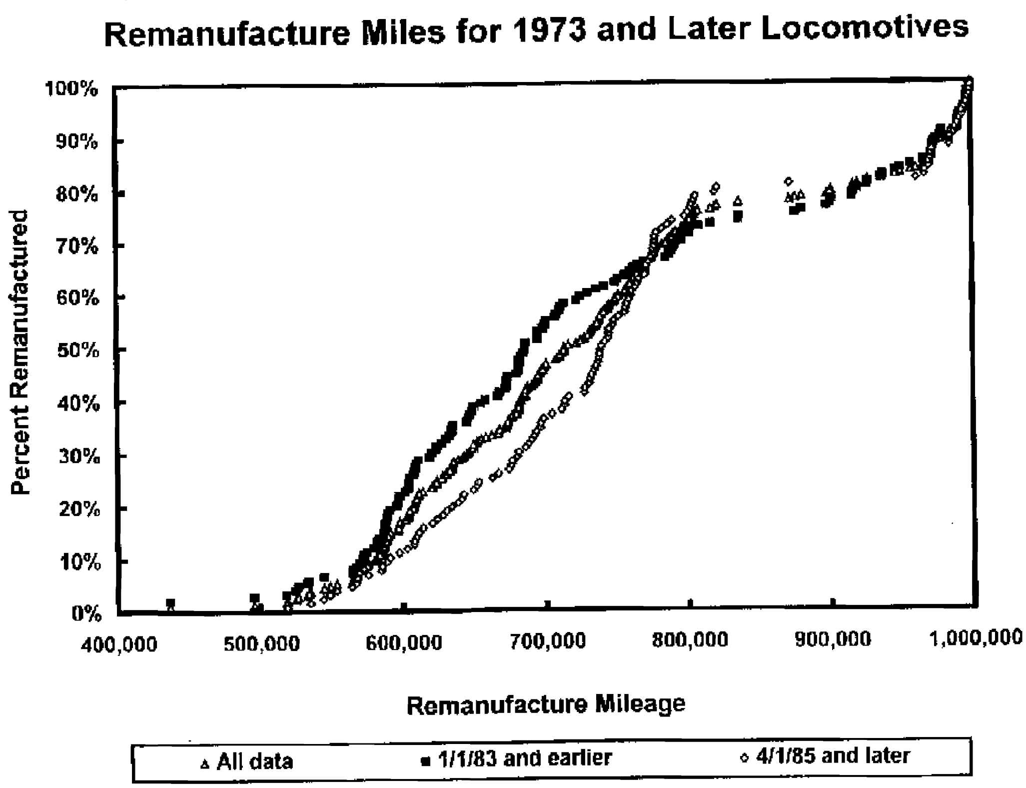
APPENDICES

APPENDIX A

Locomotive Remanufacture Mileage Data From AAR, June 1996
(Data for Santa Fe Railway)



APPENDIX B

Locomotive Emission Data by Throttle Notch

(Note: this appendix not available in electronic version.)

APPENDIX C

Calculation of Baseline Locomotive Emission Rates

This appendix contains a numerical description of how EPA developed its baseline emission factors. The cycle-weighted emission factors listed here were calculated from the notch data in Appendix B using the respective line-haul or switch duty-cycle. Cycle-weighted horsepower (i.e., the average power used over the cycle) was also calculated. The emission factors were weighted by the product of number of locomotives in the fleet and the average power:

$$EF_{AVG} = \frac{\sum (No.)(HP)(EF)}{\sum (No.)(HP)}$$

These weighted average emission factors were multiplied by deterioration factors to be more representative of in-use emissions. The line-haul emissions were determined for two locomotive categories (pre-1991 and 1991-1995) because of the limits of the data set. The emission factors for these two categories were weighted together in the same manner as the individual emission factors.

Weighted Average Line-Haul Emissions

Model	Number in 1990 Fleet	Cycle-Wtd Power (hp)	HC g/bhp-hr	CO g/bhp-hr	NOx g/bhp-hr	PM g/bhp-hr
EMD 16-645E3	1562	853	0.48	1.85	13.64	0.29
EMD 20-645E3	723	1023	0.49	1.18	13.46	0.30
EMD 16-645E3B	2693	835	0.47	1.40	13.12	0.29
EMD 16-645F3	232	988	0.49	1.33	15.54	0.30
EMD 12-645F3B	6	769	0.35	1.17	11.52	0.25
EMD 16-645F3B	400	1073	0.33	0.63	15.23	0.25
EMD 12-710G3	2	807	0.36	0.90	10.55	0.25
EMD 16-710G3	537	1084	0.38	0.52	11.55	0.26
EMD 12-710G3A	17	846	0.15	1.09	10.75	0.25
EMD 16-710G3A	250	1086	0.21	2.30	11.04	0.25
GE 12 - 2500	843	686	0.48	2.12	10.32	0.26
GE 12 - 3000	145	819	0.45	1.73	10.56	0.24
GE 12 -3300	0	860	0.32	1.68	10.75	0.24
GE 16 - 3000	801	839	0.73	2.44	11.35	0.41
GE 16- 3600	451	1001	0.62	1.67	11.29	0.36
GE 16 - 4100	1029	1127	0.58	1.44	11.23	0.34
Weighted Average			0.49	1.53	12.53	0.30
Deterioration Factors			1.15	1.00	1.00	1.15
1990 and Earlier In-Use			0.57	1.53	12.53	0.35
GE	3000	1200	0.30	0.90	13.50	0.20
EMD	1500	1200	0.30	0.80	14.00	0.30
Weighted Average			0.30	0.87	13.67	0.23
Deterioration Factors			1.15	1.00	1.00	1.15
1991-1995 In-Use			0.35	0.87	13.70	0.27
Estimated In-Use Emission Factors for Entire 1995 Line-Haul Fleet:					HC	0.48
					CO	1.28
					NOx	13.0
					PM	0.32

Weighted Average Switch Emissions

Model	Number in 1990 Fleet	Cycle-Wtd Power (hp)	HC g/bhp-hr	CO g/bhp-hr	NOx g/bhp-hr	PM g/bhp-hr
EMD 16-567C	1279	159	1.25	2.13	17.27	0.40
EMD 12-645E	1216	160	0.76	1.71	17.39	0.38
EMD 16-645E	1763	212	0.74	1.72	17.55	0.38
Weighted Average			0.88	1.83	17.44	0.38
Deterioration Factors			1.15	1.00	1.00	1.15
In-Use Baseline			1.01	1.83	17.44	0.44
Estimated In-Use Emission Factors for Entire 1995 Line-Haul Fleet:					HC	1.01
					CO	1.83
					NOx	17.4
					PM	0.44

APPENDIX D

Locomotive Smoke Emissions

Table 25 (page D-2): SwRI Report for EPA, Emission Measurements - Locomotives, SwRI 5374-024

Table 12 (page D-3) Association of American Railroads, Locomotive Exhaust Emission Field Tests, AAR Report R-885

Table 28 (page D-4) Association of American Railroads, Locomotive Exhaust Emission Field Tests, AAR Report R-877

TABLE 25. SMOKE OPACITY TEST RESULTS

Unit	Date	Fuel	Smokemeter Position	Steady-State Smoke, % Opacity										
				LI	DB	Idle	N1	N2	N3	N4	N5	N6	N7	N8
AT&SF601	2/9/95	EM-1880-F	Perpendicular	5	4	5	5	5	5	6	5	5	5	5
	2/10/95		Diagonal	6	4	5	4	4	4	5	4	4	5	9
BN 9457	4/10/95	EM-1902-F	Perpendicular		2	2	2	3	2	2	2	1	0	0
	4/11/95		Diagonal		0	0	0	0	0	0	1	0	0	1
	4/12/95	EM-1880-F	Diagonal		0	0	0	1	0	0	0	0	--*	--*
	4/13/95		Perpendicular		1	1	2	2	2	2	2	2	1	2
SP502	5/3/95	EM-1880-F	Perpendicular		11	14	9	9	17	14	12	11	10	9
	5/4/95		Diagonal		9	12	5	7	15	12	8	5	3	2
	5/5/95	EM-1902-F	Perpendicular		11	13	7	8	17	13	10	7	4	3
	5/6/95		Diagonal		9	12	5	4	14	11	8	4	1	0
AT&SF202	5/23/95	EM-1902-F	Perpendicular		2	2	2	3	4	3	4	4	3	3
	5/24/95		Diagonal		2	2	3	4	3	2	2	1	1	1
	5/24/95	EM-1880-F	Diagonal		1	2	2	3	3	2	3	3	2	2
	5/25/95		Perpendicular		3	3	4	4	4	3	3	3	3	3
NS 8842	5/29/95	EM-1902-F	Perpendicular	10	5	6	5	4	5	7	7	9	--*	--*
	5/30/95		Diagonal	8	4	4	4	4	6	7	6	7	8	10
	5/31/95	EM-1880-F	Diagonal	9	4	5	4	3	2	2	2	1	0	1
	6/1/95		Perpendicular	10	4	5	4	4	3	4	4	3	3	3

Unit	Date	Fuel	Smokemeter Position	Transient Smoke Maximum % Opacity During Throttle Notch Change										
				LI	DB	Idle	N1	N2	N3	N4	N5	N6	N7	N8
AT&SF601	2/9/95	EM-1880-F	Perpendicular	12	12	15	22	36	13	19	17	10	9	8
	2/10/95		Diagonal	13	13	11	32	40	13	16	17	10	10	12
BN 9457	4/10/95	EM-1902-F	Perpendicular		7	3	5	6	9	8	8	11	4	2
	4/11/95		Diagonal		1	0	1	1	0	3	2	2	1	2
	4/12/95	EM-1880-F	Diagonal		3	1	2	3	3	3	1	8	--*	--*
	4/13/95		Perpendicular		5	2	3	4	4	4	4	8	4	2
SP502	5/3/95	EM-1880-F	Perpendicular		60	87	55	55	59	44	17	39	21	24
	5/4/95		Diagonal		56	86	62	58	58	41	13	24	5	5
	5/5/95	EM-1902-F	Perpendicular		26	71	56	60	58	40	16	19	7	6
	5/6/95		Diagonal		43	76	61	56	60	41	14	14	4	3
AT&SF202	5/23/95	EM-1902-F	Perpendicular		2	7	4	5	5	4	6	8	4	6
	5/24/95		Diagonal		3	7	5	5	4	3	5	6	3	3
	5/24/95	EM-1880-F	Diagonal		2	7	4	5	5	4	6	6	4	4
	5/25/95		Perpendicular		3	7	5	6	5	4	5	6	5	5
NS 8842	5/29/95	EM-1902-F	Perpendicular	18	5	14	21	36	12	14	15	12	--*	--*
	5/30/95		Diagonal	14	8	6	21	61*	11	12	13	10	11	17
	5/31/95	EM-1880-F	Diagonal	17	9	13	22	21	8	7	6	4	3	7
	6/1/95		Perpendicular	16	10	10	23	33	13	11	10	7	5	6

*bulb failure
**heavy rain

TABLE 12. STEADY-STATE SMOKE TEST RESULTS

Locomotive Model	Standard Timing	4°Retarded Timing	Increase in Maximum Opacity
	Maximum Steady State Smoke[a] (% Opacity)		(% Opacity)
EMD SD40-2 (E3B)			
UP 3808	30	3	O
UP 3953	9	15	6
UP 3938	12	21	9
UP 3959	8	12	4
UP 3228	5	6	1
GE C40-8			
UP 9108	17	34	17
UP 9113	25	33	8
UP 9126	35	55	20
UP 9133	28	51	23
EMD SD40-2 (E3)			
SP 8270	9	11	2
SP 7315	21	40	19
SP 8303	12	17	5
SP 7323	<5	<5	0

Note: a - Maximum steady-state smoke opacity in any notch during "UP" smoke test.

TABLE 28. STEADY-STATE SMOKE TEST SUMMARY

Locomotive Unit Number	Model	Standard Timing	4° Retarded Timing	Increase in Maximum Opacity
		Maximum Steady-State Smoke (% Opacity)[a]		(% Opacity)
SP 2706[b]	EMD MP15AC	7	8	1
SP 2754[b]	EMD MP15AC	6	8	2
SP 2742[b]	EMD MP15AC	8	16	8
SP 2720[b]	EMD MP15AC	11	15	4
SP 2739[b]	EMD MP15AC	10	23	13
Amtrak 514[c]	GE DASH8-B32	10	10	0
Amtrak 229[c]	EMD F40PH	11	11	0
Amtrak 806[c]	GE AMD-103	9	14	5
CSX 8704	EMD SD60	10	12	2
SP 6344	EMD GP35	35	35	0
UP20	Republic RD20	<5	30	30
CSX 8709	EMD SD60	8	16	8
AT&SF 601	GE DASH9-44CW	5	11	6
SP 6344[d]	EMD GP35	34	49	15

Note: a - Maximum steady-state smoke opacity in any notch during "UP" smoke cycle.
b - Highest reading from either of the two exhaust stacks.
c - Non-HEP
d - Repeat testing of SP 6344.

APPENDIX E

Compliance Margins for On-Highway
Heavy-Duty Diesel Engines

In complying with engine emission standards, engine manufacturers typically strive to produce engines that emit at levels below the applicable standards. This compliance margin (i.e., the difference between the level of the standard and the engine's certification level or FEL) is used by the manufacturers to assure that factors such as testing, production variability or unexpected deterioration will not result in noncompliance. Since engines typically operate at emission levels below the standards, it is important to consider the engine's actual emissions, rather than the levels of the standards, when quantifying the emission benefits of regulations.

An analysis of actual compliance margins from on-highway heavy-duty diesel engine (HDDE) certification results was performed in order to estimate the actual locomotive emission levels that will result from the federal locomotive emission standards. HDDEs were chosen because they are similar in many ways to locomotive engines, and it is expected that locomotive engine manufacturers will use compliance strategies similar to those currently used for on-highway heavy-duty diesel engines.

The 1993 through 1995 model years were chosen for the analysis of compliance margins. The 1993 to 1994 transition represents a change in the particulate standard for HDDEs (from 0.25 to 0.10 g/bhp-hr) and could be seen as indicating what might happen in the case of previously unregulated locomotives coming under new emission standards. For the 1995 model year, the analysis was limited to those engine families which had been certified as of January 30, 1995. Although a few more 1995 HDDEs were certified, those included in this analysis represent the majority of 1995 HDDEs.

When determining what compliance margin to use for a given engine family, HDDE manufacturers take many factors into account. One of the most important factors is the expected potential for deterioration of critical emission control components. Until recently, HDDE manufacturers have met the applicable standards with modifications to the engine itself. However, due to the increasing stringency of the HDDE particulate standard there has been increasing use of oxidation catalysts on HDDEs. Given that exhaust aftertreatment technologies typically have higher rates of deterioration compared to engine technologies, it is likely that manufacturers would utilize different compliance strategies for engines with catalysts compared to engines without catalysts. For this reason only HDDEs which did not utilize exhaust aftertreatment were considered in the analysis of HDDE compliance margins.

In addition to excluding HDDEs with exhaust aftertreatment from the compliance margin analysis, engines certified to the urban bus standards were also excluded. Given that urban bus engines are required to meet more stringent particulate standards than other HDDEs, they cannot be directly compared to other HDDEs and must be analyzed separately. Additionally, only two manufacturers currently certify urban bus engine families, and the total number of urban bus engine families is very small in relation to all HDDE families. In the emissions averaging, banking and trading program (ABT) urban bus engines constitute a separate class and cannot be averaged with other HDDEs. The situation of few engine families and an exclusive ABT class leads to manufacturers using unique compliance strategies for this class of HDDEs such as using a trap oxidizer on one family for particulate emissions well below the standard and using these credits to offset production of another family which emits well above the standard. These strategies lead to very few urban bus engine families with widely varying emissions which are not representative of HDDEs as a whole. Thus, urban bus engines are also excluded from this analysis.

The results of the analysis are summarized in Table E-1. NOx and particulate matter (PM) compliance margins were analyzed separately. Additionally, for each model year the engines were sorted according to HDDE subclass (light, medium and heavy) and according to whether the engine was certified to the applicable standards for NOx and PM or whether they were certified to a family emission limit (FEL) above or below the standard under the ABT program. The purpose of this sorting was to determine whether there are trends which should lead to the exclusion of particular groups of engines, as was done with aftertreatment-equipped and urban bus engines. As can be seen from Table E-1, neither the change in PM standards from the 1993 to the 1994 model year, nor the sorting according HDDE subclass and FEL yields any strong trends which would lead to excluding any of these groups from the analysis. In addition to analysis by model year, the average of all three model years is included in Table E-1.

Table E-1									
NOx and Particulate Compliance Margins of Heavy-Duty Diesel Engines[1,2]									
	1993		1994		1995		Average		
	NOx	PM	NOx	PM	NOx	PM	NOx	PM	Avg NOx+PM
NOx FEL<std	7.7	19.7	9.0	29.3	5.8	35.9	7.5	28.3	17.9
NOx FEL=std	7.7	19.3	8.2	17.1	8.5	20.1	8.1	18.8	13.1
NOx FEL>std	9.8	11.9	8.9	18.0	8.2	14.6	9.0	14.8	11.9
PM FEL<std	8.1	19.0	NA	NA	NA	NA	NA	NA	NA
PM FEL=std	7.5	19.1	6.1	18.5	8.8	23.5	7.5	20.4	14.0
PM FEL>std	7.3	17.7	9.4	18.3	7.4	20.9	8.0	19.0	13.5
Class=L	11.9	19.2	12.6	22.0	9.4	21.6	11.3	20.9	16.1
Class=M	6.8	16.1	9.1	12.0	10.1	16.1	8.7	14.7	11.7
Class=H	7.6	20.9	6.9	21.0	7.0	24.9	7.2	22.3	14.8
Total	7.8	18.9	8.3	18.4	8.1	22.0	8.1	19.8	14.0

1. Compliance margins expressed as a percentage of applicable family emission limit. Urban bus engines and engines utilizing exhaust aftertreatment excluded.

2. The NOx standard is 5.0 g/bhp-hr for all three model years. The PM standard is 0.25 g/bhp-hr for the 1993 model year and 0.10 g/bhp-hr for the 1994 and 1995 model years.

APPENDIX F

Supplementary Cost-Effectiveness Data

Year-by-Year Costs and Benefits

Tables F-1 and F-2 contain year-by-year costs and benefits for the locomotive standards rulemaking described in Section 7.3. (Note: Benefits are consistent with the uncorrected benefits of Chapter 6.) Table F-1 shows the costs and benefits in undiscounted form, while Table F-2 shows the year-by-year results discounted at an interest rate of 7 percent. (Note: Discounted benefits were calculated upon request by the Office of Management and Budget; they were not used by EPA during this rulemaking.) Summing the annual discounted costs yields a 41-year fleet wide cost of $1.2 billion and emission reductions of 5.3 million tons of NOx, 84,000 tons of HC, and 58,000 tons of PM. The resulting 41-year annualized fleetwide costs and emission reductions are $89 million per year and 390,000 tons of NOx, 6,000 tons of HC, and 4,000 tons of PM, respectively. A copy of the spreadsheet prepared for this 41-year cost and benefit analysis has been placed in the Public Docket for this rulemaking.

Marginal Cost Effectiveness

Tables F-3A through F-4B show the marginal cost effectiveness calculations described in Section 7.3. Tables F-3A and F-4A are based on the costs contained in the base case cost scenario shown in Table 7-4, while Tables F-3B and F-4B represent the same calculations made using the high range costs contained in Table 7-5. Tables F-3A through F-4B are shown in a format similar to the format of Tables 7-4 and 7-5. The format is similar in that economic information is shown separately for the same three sets of locomotives: 1) those originally manufactured 1973-2001; 2) those originally manufactured 2001-2004; and 3) those originally manufactured 2005-2040. Tables F-3A and F-3B show the how the cost effectiveness would have changed if the Tier 2 standards had not been finalized, so that newly manufactured locomotives would have continued to be certified to the Tier 1 after 2004. Tables F-4A and F-4B show the how the cost effectiveness would have changed if neither the Tier 1 nor the Tier 2 standards had been finalized, so that newly manufactured locomotives would have continued to be certified to the Tier 0 after 2001; the total costs from these tables are the marginal Tier 0 costs. Marginal costs for Tier 1 are calculated by subtracting the total costs of Table F-4A (F-4B) from the total costs of Table F-3A (F-3B). Marginal costs for Tier 2 are calculated by subtracting the total costs of Table F-3A (F-3B) from the total costs of Table 7-4 (7-5).

TABLE F-1				
UNDISCOUNTED COSTS AND BENEFITS OF RULEMAKING				
		BENEFITS - Metric Tons		
YEAR	COST	HC	NOx	PM
2000	$14,752,491	0	11211	0
2001	$48,065,475	0	45880	0
2002	$109,864,672	44	110000	0
2003	$116,983,557	87	171261	1
2004	$124,777,069	127	231215	1
2005	$68,250,344	1433	303684	928
2006	$76,457,368	2614	359785	1765
2007	$81,976,166	3687	393564	2525
2008	$86,155,991	4611	411517	3178
2009	$90,346,096	5440	427815	3764
2010	$88,538,250	6277	448821	4354
2011	$80,012,843	6663	456429	4622
2012	$81,482,532	7185	466628	4986
2013	$82,962,502	7703	476765	5346
2014	$84,452,752	8216	486832	5703
2015	$85,953,282	8696	496414	6036
2016	$87,464,092	9171	505915	6365
2017	$88,535,431	9640	514137	6690
2018	$89,617,050	10104	522277	7011
2019	$90,708,949	10562	530336	7327
2020	$91,811,127	11016	538314	7640
2021	$92,923,586	11463	546211	7948
2022	$94,046,325	11906	554026	8252
2023	$95,179,344	12343	561759	8553
2024	$96,255,180	12774	569231	8849
2025	$97,206,371	13200	576263	9141
2026	$98,163,345	13621	583200	9428
2027	$99,124,829	14036	590030	9712
2028	$74,766,683	14444	596578	9992
2029	$77,040,784	14847	603033	10267
2030	$79,240,704	15257	609532	10544
2031	$80,258,167	15641	615772	10801
2032	$82,314,167	16019	621924	11054
2033	$84,370,167	16393	627988	11303
2034	$86,426,167	16762	633965	11549
2035	$88,482,167	16967	637232	11678
2036	$90,538,167	17092	638943	11750
2037	$92,594,167	17346	641226	11918
2038	$94,650,167	17593	643455	12080
2039	$96,706,167	17833	645631	12236
2040	$98,762,167	18065	647756	12387

TABLE F-2				
DISCOUNTED COSTS AND BENEFITS OF RULEMAKING				
		BENEFITS - Metric Tons		
YEAR	COST	HC	NOx	PM
2000	$14,752,491	0	11211	0
2001	$44,921,005	0	42878	0
2002	$95,960,060	39	96078	0
2003	$95,493,429	71	139800	1
2004	$95,191,828	97	176393	1
2005	$48,661,552	1021	216522	662
2006	$50,946,773	1742	239740	1176
2007	$51,050,636	2296	245092	1572
2008	$50,143,571	2683	239506	1850
2009	$49,142,290	2959	232703	2048
2010	$45,008,357	3191	228158	2213
2011	$38,013,525	3166	216846	2196
2012	$36,179,219	3190	207188	2214
2013	$34,426,489	3196	197840	2218
2014	$32,752,233	3186	188802	2212
2015	$31,153,425	3152	179923	2188
2016	$29,627,114	3106	171371	2156
2017	$28,028,050	3052	162763	2118
2018	$26,514,451	2989	154523	2074
2019	$25,081,780	2921	146642	2026
2020	$23,725,740	2847	139111	1974
2021	$22,442,262	2769	131917	1920
2022	$21,227,494	2687	125051	1863
2023	$20,077,786	2604	118501	1804
2024	$18,976,383	2518	112222	1744
2025	$17,910,194	2432	106176	1684
2026	$16,903,286	2345	100424	1624
2027	$15,952,195	2259	94954	1563
2028	$11,245,075	2172	89727	1503
2029	$10,829,070	2087	84764	1443
2030	$10,409,623	2004	80072	1385
2031	$9,853,536	1920	75600	1326
2032	$9,444,820	1838	71360	1268
2033	$9,047,409	1758	67342	1212
2034	$8,661,574	1680	63536	1157
2035	$8,287,500	1589	59685	1094
2036	$7,925,300	1496	55930	1028
2037	$7,575,021	1419	52458	975
2038	$7,236,654	1345	49197	924
2039	$6,910,140	1274	46134	874
2040	$6,595,375	1206	43257	827

TABLE F-3A - MARGINAL COST-EFFECTIVENESS ANALYSIS (BASE CASE ANALYSIS WITHOUT TIER 2 STANDARDS)	
CATEGORY	TOTAL COSTS
TIER 0 LOCOMOTIVES (Model Years 1973-2001)	
INCREMENTAL COSTS:	
Initial Manufacture	$470,446,480
Fuel consumption	$435,742,226
Maintenance	$217,159,792
TOTAL	$1,123,348,498
NPV	$584,926,672
TIER 1 LOCOMOTIVES (Model Years 2002-2004)	
INCREMENTAL COSTS:	
Initial Manufacture	$102,890,062
Fuel consumption	$79,754,324
Maintenance	$32,013,080
TOTAL	$214,657,466
NPV	$132,572,277
TIER 1 LOCOMOTIVES (Model Years 2005-2040)	
INCREMENTAL COSTS:	
Initial Manufacture	$644,639,666
Fuel consumption	$593,307,704
Maintenance	$78,433,920
TOTAL	$1,316,381,289
NPV	$435,028,487
TOTAL COSTS	$2,654,387,253
NPV	$1,152,527,435
TOTAL NOx BENEFIT (Tons-M)	16,981,126
COST EFFECTIVENESS ($/Ton)	$156
NPV	$68

TABLE F-4A - MARGINAL COST-EFFECTIVENESS ANALYSIS (BASE CASE ANALYSIS WITHOUT TIER 1 OR TIER 2 STANDARDS)	
CATEGORY	TOTAL COSTS
TIER 0 LOCOMOTIVES (Model Years 1973-2001)	
INCREMENTAL COSTS:	
Initial Manufacture	$470,446,480
Fuel consumption	$435,742,226
Maintenance	$217,159,792
TOTAL	$1,123,348,498
NPV	$584,926,672
TIER 0 LOCOMOTIVES (Model Years 2002-2004)	
INCREMENTAL COSTS:	
Initial Manufacture	$42,648,927
Fuel consumption	$79,754,324
Maintenance	$12,392,160
TOTAL	$134,795,412
NPV	$73,219,144
TIER 0 LOCOMOTIVES (Model Years 2005-2040)	
INCREMENTAL COSTS:	
Initial Manufacture	$492,535,877
Fuel consumption	$593,307,704
Maintenance	$78,433,920
TOTAL	$1,164,277,501
NPV	$374,170,736
TOTAL COSTS	$2,422,421,411
NPV	$1,032,316,552
TOTAL NOx BENEFIT (Tons-M)	12,809,089
COST EFFECTIVENESS ($/Ton)	$189
NPV	$81

TABLE F-3B - MARGINAL COST-EFFECTIVENESS ANALYSIS (HIGH RANGE ANALYSIS WITHOUT TIER 2 STANDARDS)	
CATEGORY	TOTAL COSTS
TIER 0 LOCOMOTIVES (Model Years 1973-2001)	
INCREMENTAL COSTS:	
Initial Manufacture	$502,544,778
Fuel consumption	$871,484,452
Maintenance	$217,159,792
TOTAL	$1,591,189,022
NPV	$782,324,482
TIER 1 LOCOMOTIVES (Model Years 2002-2004)	
INCREMENTAL COSTS:	
Initial Manufacture	$134,317,119
Fuel consumption	$159,508,649
Maintenance	$32,013,080
TOTAL	$325,838,848
NPV	$191,771,133
TIER 1 LOCOMOTIVES (Model Years 2005-2040)	
INCREMENTAL COSTS:	
Initial Manufacture	$664,026,920
Fuel consumption	$1,186,615,407
Maintenance	$78,433,920
TOTAL	$1,929,076,247
NPV	$600,514,176
TOTAL COSTS	$3,846,104,116
NPV	$1,574,609,791
TOTAL NOx BENEFIT (Tons-M)	16,981,126
COST EFFECTIVENESS ($/Ton)	$226
NPV	$93

TABLE F-4B - MARGINAL COST-EFFECTIVENESS ANALYSIS (HIGH RANGE ANALYSIS WITHOUT TIER 1 OR TIER 2 STANDARDS)	
CATEGORY	TOTAL COSTS
TIER 0 LOCOMOTIVES (Model Years 1973-2001)	
INCREMENTAL COSTS:	
Initial Manufacture	$470,446,480
Fuel consumption	$871,484,452
Maintenance	$217,159,792
TOTAL	$1,559,090,724
NPV	$759,309,513
TIER 0 LOCOMOTIVES (Model Years 2002-2004)	
INCREMENTAL COSTS:	
Initial Manufacture	$45,900,000
Fuel consumption	$159,508,649
Maintenance	$12,392,160
TOTAL	$217,800,809
NPV	$107,770,438
TIER 0 LOCOMOTIVES (Model Years 2005-2040)	
INCREMENTAL COSTS:	
Initial Manufacture	$530,081,249
Fuel consumption	$1,186,615,407
Maintenance	$78,433,920
TOTAL	$1,795,130,576
NPV	$546,921,611
TOTAL COSTS	$3,572,022,108
NPV	$1,414,001,562
TOTAL NOx BENEFIT (Tons-M)	12,809,089
COST EFFECTIVENESS ($/Ton)	$279
NPV	$110

APPENDIX G

Results of SwRI Testing for EPA

From "Emission Measurements - Locomotives"
SwRI 5374-024, August 1995

TABLE 23. AVERAGE DUTY-CYCLE WEIGHTED EXHAUST EMISSIONS USING LOW-SULFUR CERTIFICATION DIESEL FUEL

Locomotive	Duty Cycle	g/hp-hr[a]					
		HC	CO	NOx	PM #1[a]	PM #2[b]	PM #3[c]
AT&SF No. 601 GE DASH 9-44CW	EPA Freight	0.21	1.10	10.84	NA	0.07	0.08
	EPA Switcher	0.40	1.63	12.23	NA	0.13	0.15
	AAR 3-Mode	0.18	1.28	10.80	0.05	0.06	0.07
BN No. 9457 EMD SD70MAC	EPA Freight	0.31	0.60	13.28	NA	0.22	0.24
	EPA Switcher	0.44	0.68	13.62	NA	0.22	0.24
	AAR 3-Mode	0.28	0.57	13.01	0.23	0.21	0.23
SP No. 502 MK 5000C	EPA Freight	0.51	1.07	15.46	NA	0.16	0.19
	EPA Switcher	0.81	1.62	20.88	NA	0.39	0.45
	AAR 3-Mode	0.43	0.99	14.59	0.11	0.11	0.13
AT&SF No. 202 EMD SD75M	EPA Freight	0.28	0.94	13.23	NA	0.24	0.30
	EPA Switcher	0.43	0.88	15.19	NA	0.25	0.31
	AAR 3-Mode	0.28	0.87	13.05	0.23	0.24	0.30
NS No. 8842 GE DASH 9-40C	EPA Freight	0.29	0.85	14.07	NA	0.11	0.15
	EPA Switcher	0.52	1.33	14.88	NA	0.21	0.28
	AAR 3-Mode	0.27	0.87	14.38	0.11	0.11	0.14

Notes: a - PM sampling system #1 - 30 cm/s face velocity and 30-minute maximum sampling time.
b - PM sampling system #2 - 70 cm/s face velocity and 15-minute maximum sampling time.
c - PM sampling system #3 - 70 cm/s face velocity and 5-minute maximum sampling time.

TABLE 24. AVERAGE DUTY-CYCLE WEIGHTED EXHAUST EMISSIONS USING HIGH-SULFUR DIESEL FUEL

Locomotive	Duty Cycle	g/hp-hr[a]					
		HC	CO	NOx	PM #1[a]	PM #2[b]	PM #3[c]
AT&SF No. 601 GE DASH 9-44CW	EPA Freight	***	***	***	***	***	***
	EPA Switcher	***	***	***	***	***	***
	AAR 3-Mode	***	***	***	***	***	***
BN No. 9457 EMD SD70MAC	EPA Freight	0.28	0.64	14.19	NA	0.29	0.30
	EPA Switcher	0.38	0.78	14.80	NA	0.29	0.30
	AAR 3-Mode	0.25	0.63	13.72	0.28	0.28	0.30
SP No. 502 MK 5000C	EPA Freight	0.54	1.09	15.86	NA	0.24	0.27
	EPA Switcher	0.90	1.66	21.33	NA	0.46	0.55
	AAR 3-Mode	0.45	1.00	14.96	0.18	0.19	0.22
AT&SF No. 202 EMD SD75M	EPA Freight	0.33	0.88	13.79	NA	0.29	0.35
	EPA Switcher	0.52	0.86	15.75	NA	0.32	0.39
	AAR 3-Mode	0.31	0.79	13.48	0.28	0.29	0.34
NS No. 8842 GE DASH 9-40C	EPA Freight	0.34	0.89	15.01	NA	0.19	0.22
	EPA Switcher	0.58	1.38	15.80	NA	0.27	0.33
	AAR 3-Mode	0.32	0.92	15.32	0.18	0.19	0.21

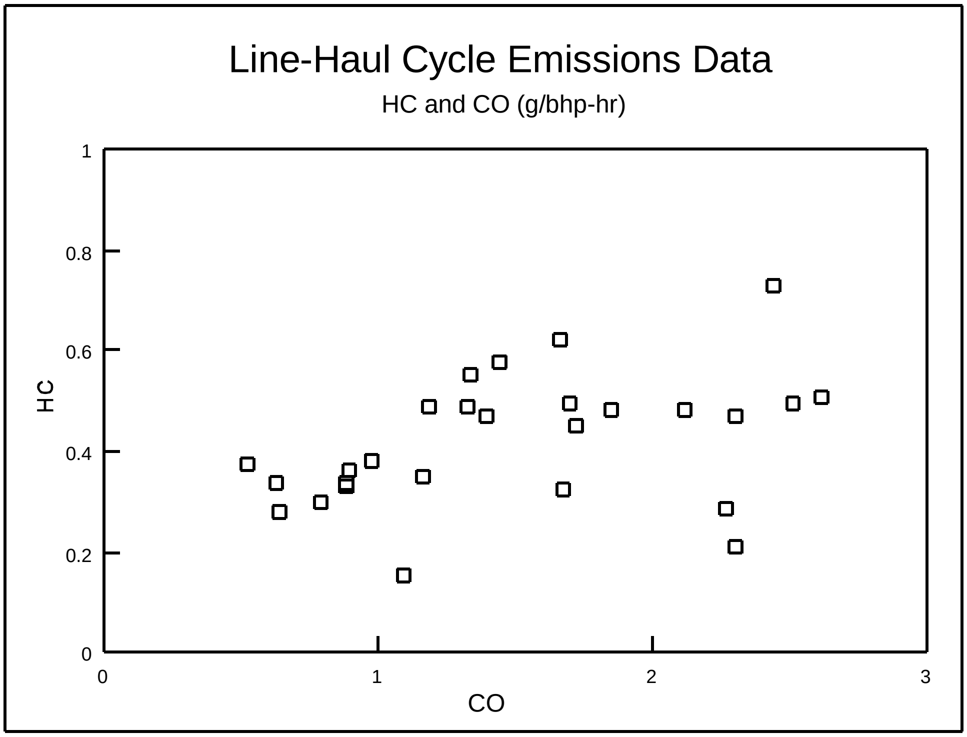
Notes: a - PM sampling system #1 - 30 cm/s face velocity and 30-minute maximum sampling time.
b - PM sampling system #2 - 70 cm/s face velocity and 15-minute maximum sampling time.
c - PM sampling system #3 - 70 cm/s face velocity and 5-minute maximum sampling time.
*** - No tests were conducted on AT&SF No. 601 using high-sulfur fuel.

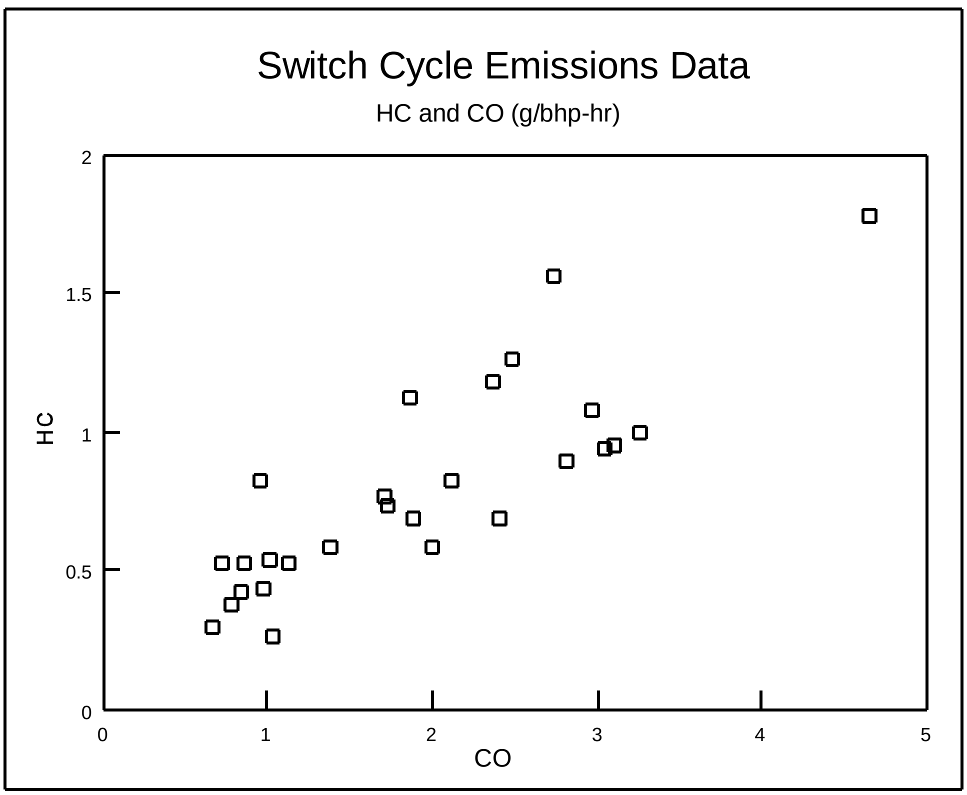
APPENDIX H

Graphical HC and CO Data:

Numerical Data are in Appendices B and C
NOx and PM Data are in Chapter 4

(Note: Not all of the data presented here or in Figures 4-2 and 4-3 were used in the baseline emission analysis; and thus, not all the data in this appendix are shown in Appendices B and C.)


Line-Haul Cycle Emissions Data
HC and CO (g/bhp-hr)
HC
CO
0
0.2
0.4
0.6
0.8
1
0
1
2
3


Switch Cycle Emissions Data
HC and CO (g/bhp-hr)
HC
CO
0
0.5
1
1.5
2
0
1
2
3
4
5

APPENDIX I

Environmental Analysis

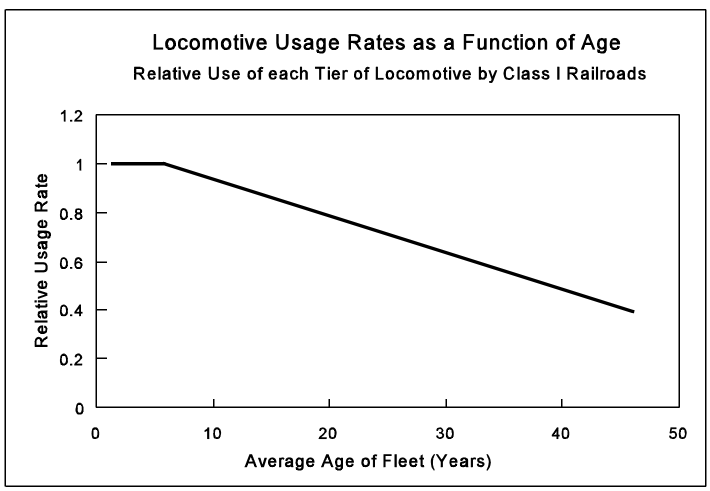
This appendix contains the original uncorrected environmental analysis. See Chapter 6 for details, and Appendix O for corrected tables.

(Note: complete appendix not available in electronic version.)

The figure below shows the relationship between relative usage rate and average fleet age assumed by EPA for Class I line-haul locomotives. It is based on the following assumptions:

(1) That each individual newly manufactured locomotive is used to the maximum extent possible for the first 10 years of its service life. This means that this maximum usage rate (hours of use per year) applies to new Tier 1 or Tier 2 fleets for the first 10 years of production, which corresponds to an average fleet age of up to 5.5 years.

(2) That after this point, the relative usage rate decreases linearly with average fleet age such that the usage rate for a fleet with an average age of 40 years would be 50 percent of the usage rate of a newly manufactured locomotive.



This table shows the projected marginal NOx benefits of the Tier 0, Tier 1, and Tier 2 standards in the columns labeled "Tier 0", "Tier 1", and "Tier 2", respectively. The column labeled "All Tiers" shows the total projected NOx benefits of the entire program (as finalized) consistent with Chapter 6. The column labeled "Tiers 0&1" shows the total projected NOx benefits of the program without the Tier 2 standards (i.e., assuming that the Tier 1 standards continue to apply to newly manufactured locomotives after 2004). The marginal benefits of the Tier 1 and Tier 2 standards are calculated from the first three columns.

Marginal NOx :Benefit Analysis
(Metric Tons)

Year	All Tiers	Tiers 0 &1	Tier 0	Tier 1	Tier 2
1999	0	0	0	0	0
2000	11211	11211	10906	305	0
2001	45880	45880	44631	1249	0
2002	110000	110000	100363	9637	0
2003	171261	171261	153538	17723	0
2004	231215	231215	205959	25256	0
2005	303684	293785	257207	36578	9899
2006	359785	340943	294403	46540	18842
2007	393564	366605	311455	55149	26959
2008	411517	377574	315551	62022	33943
2009	427815	387614	319427	68187	40201
2010	448821	402324	327526	74798	46497
2011	456429	407066	329417	77650	49363
2012	466628	413384	331666	81718	53244
2013	476765	419673	333928	85745	57092
2014	486832	425928	336200	89728	60904
2015	496414	431954	338485	93469	64460
2016	505915	437943	340781	97162	67972
2017	514137	442697	341923	100773	71440
2018	522277	447413	343077	104336	74864
2019	530336	452092	344242	107849	78244
2020	538314	456734	345419	111314	81580
2021	546211	461338	346608	114730	84872
2022	554026	465905	347809	118097	88120
2023	561759	470435	349021	121414	91324
2024	569231	474748	350069	124678	94484
2025	576263	478663	350780	127883	97599
2026	583200	482530	351491	131039	100670
2027	590030	486333	352202	134131	103697
2028	596578	489899	352912	136986	106680
2029	603033	493415	353623	139792	109618
2030	609532	496961	354334	142627	112571
2031	615772	500460	355044	145415	115312
2032	621924	503912	355755	148157	118012
2033	627988	507318	356466	150852	120670
2034	633965	510678	357177	153502	123287
2035	637232	512575	357887	154688	124657
2036	638943	513527	358361	155166	125416
2037	641226	514018	358361	155656	127208
2038	643455	514520	358361	156159	128935
2039	645631	515035	358361	156674	130596
2040	647756	515563	358361	157202	132193
Total	20052552	16981126	12809089	4172037	3071426

APPENDIX J

Terms and Abbreviations Used in the Rulemaking

Terms Used in the Rulemaking

Aftercooling - (see "charge air cooling")

Baseline - relating to uncontrolled locomotives.

Charge air cooling - an engine technology (for turbocharged or supercharged engines) that reduces NOx emissions by lowering combustion temperatures. Can also improve power output.

Class I railroads - the largest railroads in the U.S., based on annual revenue, as defined by the U.S. Surface Transportation Board in 49 CFR Chapter X. Class I railroads comprise about 90 percent of the railroad industry.

Class II and III railroads - small railroads, as defined by the U.S. Surface Transportation Board in 49 CFR Chapter X.

Commuter railroad - a passenger railroad that operates within a single metropolitan area, using diesel-powered locomotives.

Compliance margin - the degree to which a locomotive's emissions are below the applicable standard. Compliance margins are expressed as percent of the standard, so that a ten percent compliance margin for the Tier 0 NOx standard (9.5 g/bhp-hr) would be 0.95 g/bhp-hr.

Consist - a series of two or more locomotives pulling the same train. Railroads use more than one locomotive in a consist when they need more power to pull the train than can be supplied by a single locomotive. The total amount of power need is determined by the total weight of the train and the steepest grade that it must climb.

Diesel-electric locomotive - the standard type of locomotive in the U.S.,it is a locomotive that uses a diesel engine to power electrical traction motors connected to the wheels.

Duty-cycle - a description of the amount of time a typical locomotive spends in each throttle notch, expressed as percent of total time in use.

Dynamic brake - a means of slowing a train by using the traction motors as generators, effectively converting the momentum of the train to electrical energy which is dissipated as heat.

Emission inventory - an emission total for a given pollutant and a given class of source, usually expressed as tons of emissions per year.

Four-stroke - relating to a type of engine that uses four piston strokes per combustion event.

Freshly manufactured - newly manufactured (and not yet remanufactured).

Grams per brake horsepower hour - the ratio of the mass of emissions from an engine to the amount of power produced by the engine at the same time. Use of the word "brake" in this context indicates that the power includes power supplied to accessories, in addition to the power available for propulsion. One gram per brake horsepower-hour is equal 0.7457 grams per kilowatt-hour.

Hotel power - electrical power supplied by the engine for use in passenger cars.

Injection timing - the time at which fuel is injected into the engine for combustion. Retarding the timing of a diesel engine (i.e., delaying the point at which the fuel is injected into the cylinder) reduces NOx emissions, but can increase PM emissions, smoke, and fuel consumption. Advancing the timing (i.e, injecting the fuel earlier) can have the opposite effects.

Insular railroad - an industrial facility that uses locomotives to move rail cars short distances on its own property. Locomotives used in this way usually have very low power ratings, and use very little fuel each year.

Line-haul - relating to the movement of trains across reasonably long distances. Most railroad operations are line-haul operations.

Local railroad - a railroad that operates within a very limited geographic range. Local railroad is roughly equivalent to Class III railroad.

Lugging - reducing the speed of an engine by increasing the engine load.

Megawatt-hour - unit of work equivalent to the total work perform in one hour at a constant power rate of one megawatt. One megawatt-hour is equal to 1341 horsepower-hours.

Net present value - an economic term used to account for the time value of money.

Notch - (see "throttle notch")

Particulates or particulate matter - very small solid particles emitted by engines and other sources. Particulates are formed by incomplete combustion, and are often related to visible smoke. Particulates from diesel engines are typically a few microns in diameter, or smaller.

Power assembly - a cylinder of an engine and related components that are detachable from the engine as a single system.

Rated horsepower - the maximum power out of a locomotive engine.

Regional railroad - a railroad that operates within a moderate geographic range. Regional railroad is roughly equivalent to Class II railroad.

Remanufacture - to thoroughly overhaul (or remanufacture) an engine, such that it is functionally equivalent to its original condition (or better).

Roots-blower - a mechanical blower that is used to force air into an engine for combustion. A roots-blower operates at much lower pressures than turbochargers and superchargers.

Service life - the entire period during which a locomotive is in service, from the time it is manufactured, until it is scrapped. The service life of a locomotive is typically about 40 years.

Switch - relating to movement of railroad cars over short distances, usually within a switch yard. Most switch locomotives have rated power of less than 2000 horsepower.

Throttle notch - a discrete power setting of a locomotive throttle. Most locomotives have eight throttle notches for propulsion, plus notches for dynamic brake and idle.

Train - a series of rail cars and locomotives. Individual locomotives are not trains.

Truck - the part of a locomotive that contains the traction motors, axles and wheels. (Note: the term truck is also used in this document to refer to large highway vehicles.)

Turbocharger - a turbine device that uses energy from exhaust gases to compress intake air.

Two-stroke - relating to a type of engine that uses two piston strokes per combustion event.

Upgrade - the process of converting an uncontrolled locomotive that was built before 1973 (and therefore not subject to these regulations) into a locomotive that complies with the Tier 0 standards. Upgrading is optional.

Useful life - the period (expressed as MW-hrs of work performed by the engine) during which a locomotive is designed to be properly functioning with respect to power out, reliability and fuel consumption. These regulations require that locomotives also comply with emission standards during this period. A typical useful life period is about six years.

Yard - (see "switch")

Abbreviations Used in the Rulemaking

AAR - Association of American Railroads

ABT - averaging, banking and trading

ASLRA - American Short Line Railroad Association

ATSF - Atchison, Topeka, and Santa Fe Railway

BN - Burlington Northern Railroad

BNSF - Burlington Northern Santa Fe Railway (formerly BN and ATSF)

CFR - Code of Federal Regulations

CSX - CSX Transportation

DOE - U.S. Department of Energy

EF&EE - Engine, Fuel, and Emission Engineering, Inc.

EGR - exhaust gas recirculation

EMA - Engine Manufacturers Association

EMD (or EMD-GM) - Electro-Motive Division of General Motors

EPA - Environmental Protection Agency

FPI - first price increase

FRA - Federal Railroad Administration

FTP - Federal Test Procedure

GE or GETS - General Electric Transportation Systems

g/bhp-hr - grams per brake horsepower hour

HC - hydrocarbons

HFID - heated flame ionization detector

HP - horsepower

kW - kilowatt

MW-hr - megawatt-hour

OEM - original equipment manufacturer

NDIR - nondispersive infrared detector

NOx - oxides of nitrogen

NPV - net present value

PLT - production line testing

PM - particulate matter

PM-10 - particulate matter in the size range of 0 to 10 microns

RSD - Regulatory Support Document

SAE - Society of Automotive Engineers

SCR - selective catalytic reduction

SF - (see ATSF)

SOx - oxides of sulfur

STB - Surface Transportation Board

SwRI - Southwest Research Institute

UP - Union Pacific Railroad

VGT - variable geometry turbocharger

APPENDIX K

Calculation of Weighting Factors for ABT Credits

The ABT program requires that locomotives certified to an FEL other than the applicable standard be recertified to that FEL at all subsequent remanufactures. The result of this requirement is that credit calculations are based on the total emissions of that locomotive for its remaining service life. Thus, in order to allow ABT credits generated by remanufactured locomotives to be used by freshly manufactured locomotives (and vice versa), it is necessary to prorate emission credits. For simplicity, the prorating factors are assumed to be a function of locomotive age. These factors, which are shown in the table, are the estimated fraction of the service life that is remaining for a locomotive.

These factors were calculated assuming that a typical locomotive remains in service for 40 years, and is remanufactured 6 times. This means that a typical locomotive will experience 7 useful lives during its service life. Due to the fact that a locomotive's usage rate (MW-hrs per year) typically declines with age, the remanufacturing interval in terms of years is expected to change with locomotive age. For this analysis, developed an assumed remanufacture schedule, based on a typical locomotive. During the first 12 years, a locomotive is assumed to be remanufactured every 4 years (after 4, 8, and 12 years). During the next 12 years, a locomotive is assumed to be remanufactured every 6 years (at 18 and 24 years). A locomotive is assumed to be remanufactured once more at 32 years, and scrapped at 40 years. Each one of these points represents 1/7 of the locomotive's service life. For example, at 12 years, which is assumed to be the point at which the locomotive needs to be remanufactured for the third time, a locomotive is assumed to have expended 3/7 of its service life and have 4/7 (0.571) of its service life remaining. Any locomotive that is 32 or more years old is assumed to be in its final useful life, and is therefore assumed to have 1/7 (0.143) of its service life remaining at the point of its remanufacture.

Determination of Fractional Service Life Remaining (F) for ABT Calculations			
Age	F	Age	F
1	0.964	17	0.452
2	0.929	18	0.429
3	0.893	19	0.405
4	0.857	20	0.381
5	0.821	21	0.357
6	0.786	22	0.333
7	0.750	23	0.310
8	0.714	24	0.286
9	0.679	25	0.268
10	0.643	26	0.250
11	0.607	27	0.232
12	0.571	28	0.214
13	0.548	29	0.196
14	0.524	30	0.179
15	0.500	31	0.161
16	0.476	32	0.143

APPENDIX L

Exclusion of Pre-1973 Locomotives

Locomotives originally manufactured prior to 1973 are excluded from the regulations, unless these units undergo certain modifications resulting in post-1972 configurations. EPA is not including pre-1973 locomotives in the regulations for the following reasons: First, the number of locomotives in these subgroups is small and utilization of individual locomotives is generally low. As a result, contributions to the national emission inventory are low. Second, technologies for reducing emissions from these "old" units either do not exist in a form that could be applied to the locomotives, or the cost of applying available technology would greatly exceed the value of the locomotive.

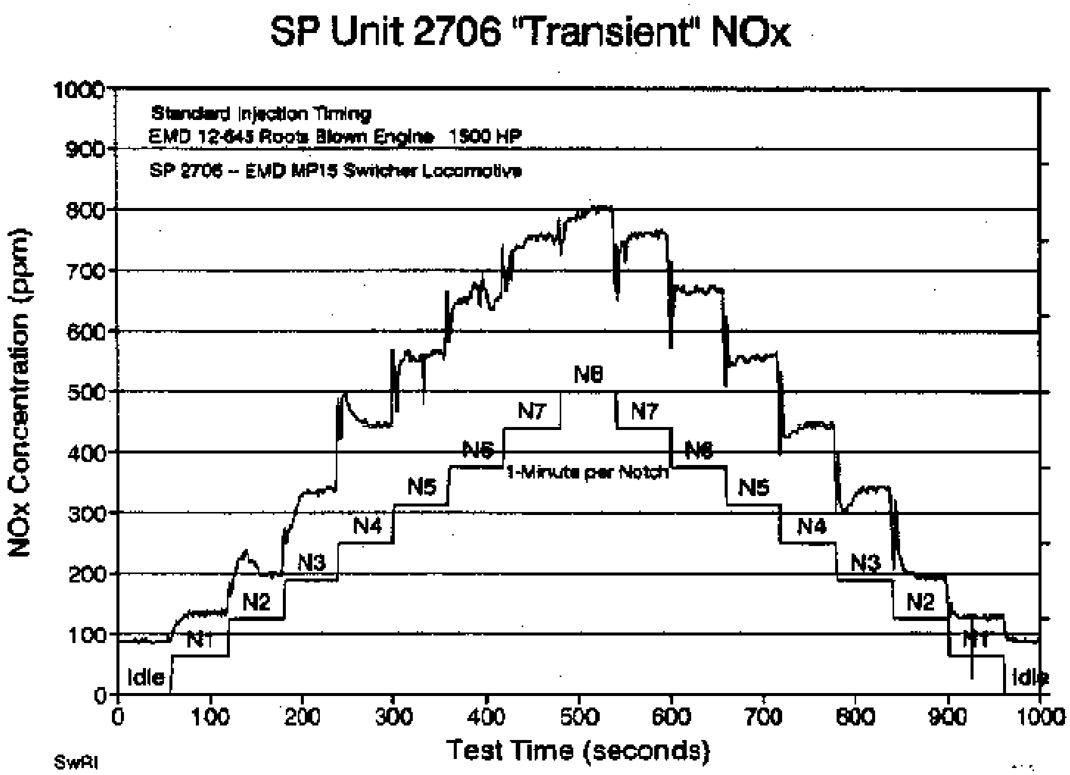
In developing a description for "old" locomotives which would not be included in the final rule, EPA sought to identify points either in engine design or in the sourcing of components which could lead to substantial technical problems or high costs in achieving compliance. However, to achieve the greatest benefit from the regulations, EPA sought to identify a date which would allow for the inclusion of a significant portion of the national locomotive fleet at the time that standards became effective. To avoid the potential for establishing unequal burdens between railroads as a function of the original manufacturer of the locomotives in their fleets, EPA decided to use a single dividing line for all locomotives. As a result of reviews of dates at which either design changes or the sourcing for major parts occurred, EPA identified the following: EMD introduced its 645 series of engines in 1966, and continued this series into the 1980s. GE changed design and sourcing for turbochargers, fuel injection pumps, and fuel injectors at the start of 1973. In mid-1983 GE again changed sourcing for fuel injection pumps, and in mid 1986 again changed sourcing for fuel injectors. The results of the review lead EPA to select January 1, 1973 as the date of original manufacture for separation between included and excluded locomotives. Since this date precedes the effective date of the standards by 27 years, a significant fraction of the existing fleet of locomotives will be included in the regulation. Pre-1973 engines still in operation by the year 2000 will be almost exclusively used by Class II and III railroads or for switching operations. They will therefore have relatively low usage and emissions rates when expressed as grams per year. Since benefits from emission control could be low, expressed as an annual mass of emissions, and the costs of control high, exclusion of these locomotives from the regulation appears to be appropriate.

APPENDIX M

NOx Concentrations as a Function of Test Sequence

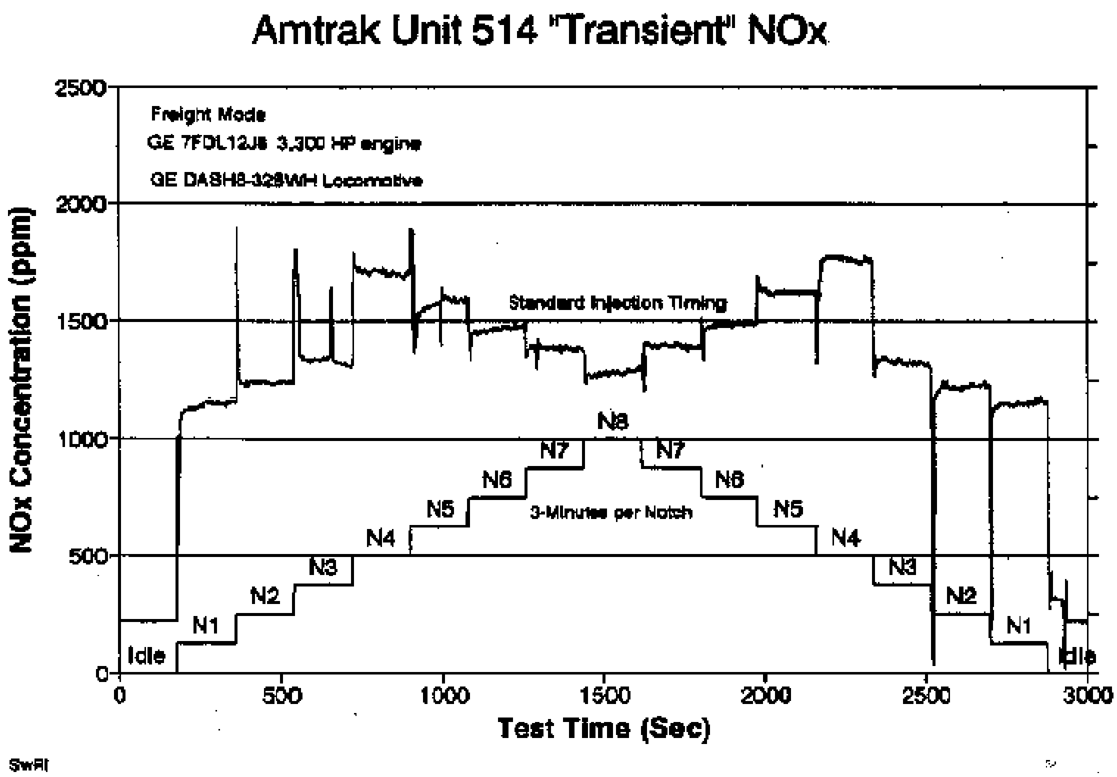
This appendix contains continuous traces of NOx emissions provided by AAR, for locomotives manufactured by both GE and EMD, measured under different test sequences. Starting with the engine at idle, NOx concentration in the exhaust was measured continuously as engine power was increased to full power and returned to idle.

Figure M-1



SP Unit 2706 "Transient" NOx
Standard Injection Timing
EMD 12-645 Roots Blown Engine 1500 HP
SP 2706 -- EMD MP15 Switcher Locomotive
NOx Concentration (ppm)
Test Time (seconds)
1-Minute per Notch
Idle
N1
N2
N3
N4
N5
N6
N7
N8
SwRI

Figure M-2



Amtrak Unit 514 "Transient" NOx
Freight Mode
GE 7FDL12J8 3,300 HP engine
GE DASH8-32BWH Locomotive
Standard Injection Timing
3-Minutes per Notch
Idle
N1
N2
N3
N4
N5
N6
N7
N8
N7
N6
N5
N4
N3
N2
N1
Idle
NOx Concentration (ppm)
2500
2000
1500
1000
500
0
0
500
1000
1500
2000
2500
3000
Test Time (Sec)
SwRI

Figure M-3

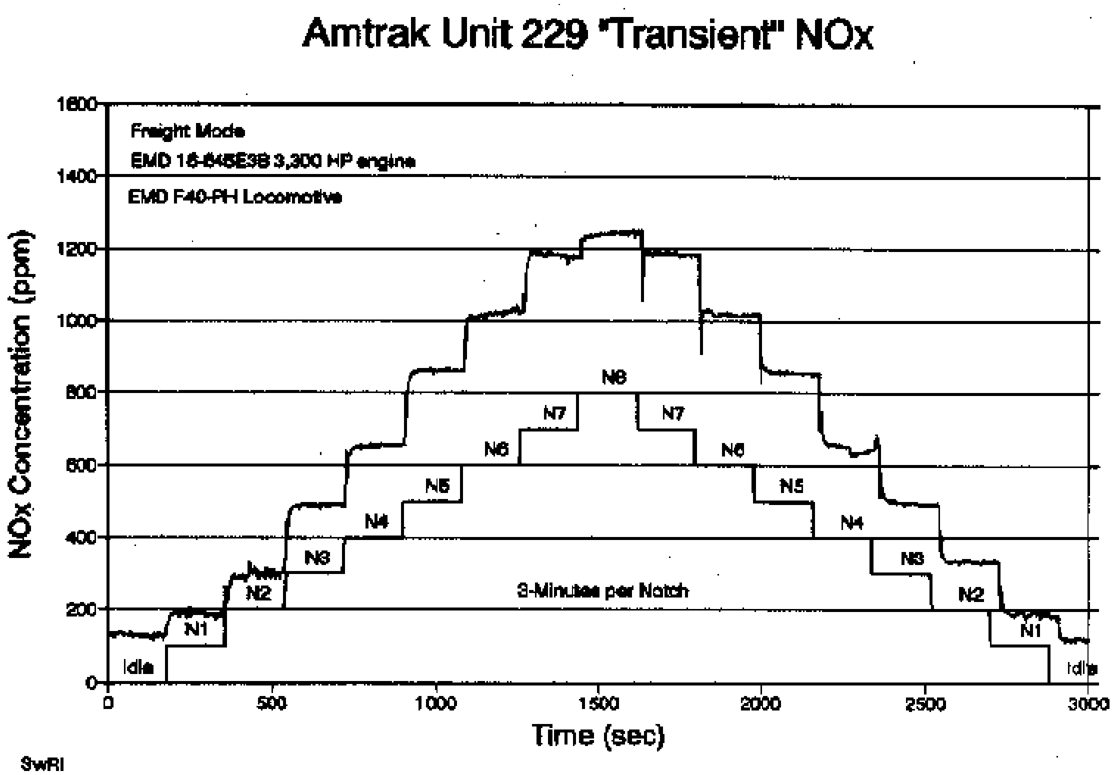
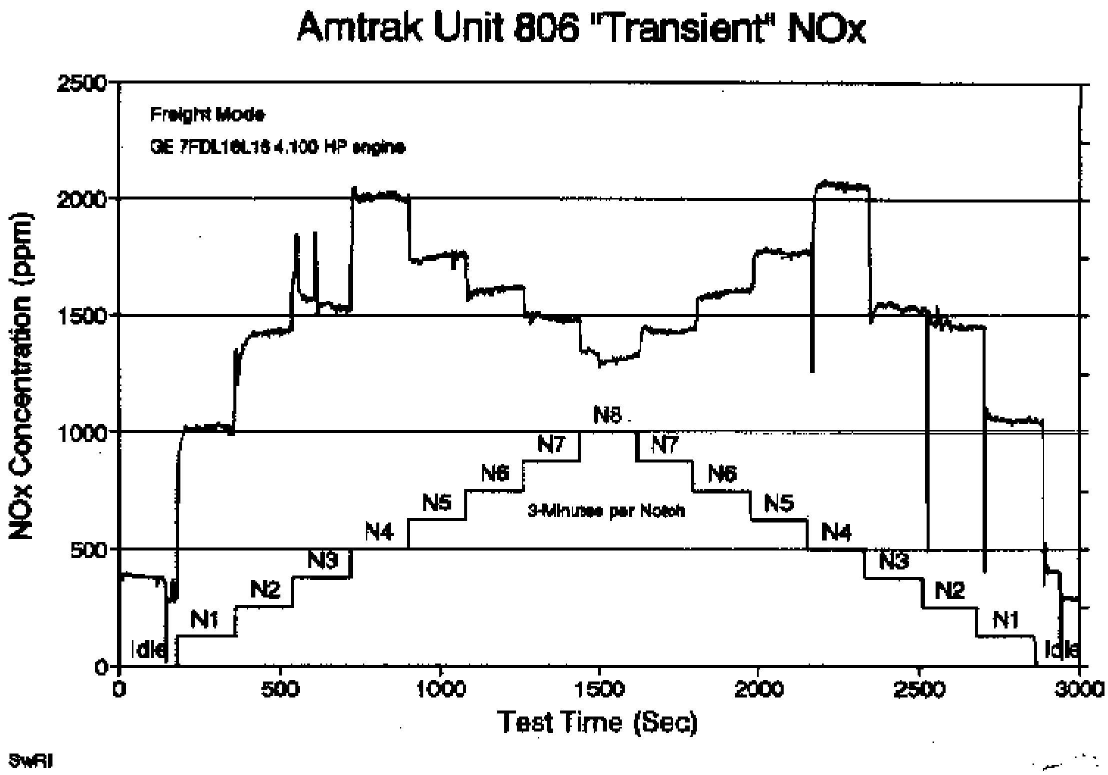

Amtrak Unit 229 "Transient" NOx
Freight Mode
EMD 16-645E3B 3,300 HP engine
EMD F40-PH Locomotive
NOx Concentration (ppm)
Time (sec)
3-Minutes per Notch
Idle
N1
N2
N3
N4
N5
N6
N7
N8
SwRI

Figure M-4



Amtrak Unit 806 "Transient" NOx
Freight Mode
GE 7FDL16L15 4,100 HP engine
NOx Concentration (ppm)
Test Time (Sec)
3-Minutes per Notch
Idle
N1
N2
N3
N4
N5
N6
N7
N8
0
500
1000
1500
2000
2500
3000
SwRI

APPENDIX N

1995 Emissions Inventory Data

TABLE N-1					
Pollutant	Emissions* (Thousand Metric Tons per Year)			Percent of Total	Percent of Mobile Source
	Total	Mobile Source	Locomotives		
HC	20786	7596	42	0.20%	0.56%
CO	83726	67496	108	0.13%	0.16%
NOx	19799	9637	1093	5.52%	11.34%
PM-10	38760	634	27	0.07%	4.25%

* Total and Mobile Source emissions from 1996 "National Air Pollutant Emission Trends, 1900-1995" EPA-454/R-96-007; Locomotive emissions from this document.

APPENDIX O

Corrections to Environmental Analysis

(Note: this appendix is not entirely available in electronic version.)

This appendix contains corrections to the environmental impacts analysis. The corrections are described below, followed by corrected versions of the "Passenger Locomotives", "Class I Line-Haul Locomotives", "All Locomotives", and "Fleet Average Emission Factors" tables of Appendix I. These corrections have a minimal effect on the projection of total benefits, and are presented here only for the purpose of completeness. The tables found in Chapter 6 and Appendix I are unchanged from the December 1997 version of this document.

Correction #1 - Delay of Tier 0 standards for passenger locomotives

The original passenger table showed the Tier 0 standards taking effect in 2002, instead of 2007 as was specified in the regulations. This correction has an effect on emission projections only for years 2002-2010.

Correction #2 - Line-haul remanufacturing and retirement schedule

The original Class I line-haul table was not consistent with the description of the assumptions made in the text regarding the remanufacturing and retirement of locomotives. The table on the next page shows the correct schedule in greater detail than was presented in the December 1997 version of this document.

Summary of Corrected Remanufacturing and Retirement Schedule During the Period 2000-2010						
Year	Uncontrolled Locomotives Remanufactured into Tier 0 Configuration	Uncontrolled Locomotives that are Retired from Service	Newly Manufactured Uncontrolled Locomotives	Newly Manufactured Tier 0 Locomotives	Total Number of Uncontrolled Locomotives	Total Number of Tier 0 Locomotives
1999					16500	0
2000	500	100	300	100	16200	600
2001	1600	100	100	300	14600	2500
2002	2250	400			11950	4750
2003	2250	400			9300	7000
2004	2550	400			6350	9550
2005	2350	400			3600	11900
2006	1750	400			1450	13650
2007	650	400			400	14300
2008		300			100	14300
2009		100			0	14300
2010					0	14300

Notes: This table accounts for the projection of 300 pre-1973 locomotives being remanufactured into Tier 0 configurations by adding 50 locomotives to the second column for years 2002-2007.

This table properly accounts for the new production of uncontrolled locomotives in 2000 and 2001, and their first remanufacture into complying configurations in 2004 and 2005.

This table accounts for all 3000 existing locomotives that are projected to be retired from service: 100 pre-1973 locomotives per year during 2000-2009 (as part of a normal retirement schedule); 300 later locomotives per year during 2002-2007; and 200 later locomotives in 2008.

APPENDIX P

Conversion of Emission Rates to g/kW-hr

The emission standards and rates presented in this document, which are expressed in g/bhp-hr, can be converted to g/kW-hr by multiplying them by 1.341. The converted baseline emission rates and emission standards for the line-haul and switch cycles are shown below.

Baseline Emission Factors and Standards Expressed as g/kW-hr				
Line-Haul				
	HC	CO	NOx	PM
Baseline	0.644	1.716	17.433	0.429
Tier 0	1.341	6.705	12.740	0.805
Tier 1	0.738	2.950	9.923	0.603
Tier 2	0.402	2.012	7.376	0.268
Switch				
	HC	CO	NOx	PM
Baseline	1.354	2.454	23.333	0.590
Tier 0	2.816	10.728	18.774	0.966
Tier 1	1.609	3.353	14.751	0.724
Tier 2	0.805	3.218	10.862	0.322