United States
Environmental Protection
Agency

Air and Radiation

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Office of Mobile Sources

Technical Highlights

Emission Factors for Locomotives

The Environmental Protection Agency (EPA) has established emission standards for oxides of nitrogen (NOx), hydrocarbons (HC), carbon monoxide (CO), particulate matter (PM) and smoke for newly manufactured and remanufactured diesel-powered locomotives and locomotive engines, which have previously been unregulated. Three separate sets of emission standards have been adopted, with applicability of the standards dependent on the date a locomotive is first manufactured. The first set of standards (Tier 0) apply to locomotives and locomotive engines originally manufactured from 1973 through 2001. The second set of standards (Tier 1) apply to locomotives and locomotive engines originally manufactured from 2002 through 2004. The final set of standards (Tier 2) apply to locomotives and locomotive engines originally manufactured in 2005 and later. To analyze the environmental benefits expected from these new standards, EPA had to calculate emission factors for locomotives.

Estimated Baseline Freight Locomotive Emission Rates

In support of the rulemaking finalizing the locomotive emission standards, EPA has estimated average emission rates, given in grams per brake horsepower-hour (g/bhp-hr), for current uncontrolled locomotives. These estimates are shown in Table 1. It is important to note that there is significant variability in in-use emission rates. Table 2 shows the range of emission rates that have been reported for NOx and PM.

Table 1 - Estimated Baseline In-Use Emission Rates (g/bhp-hr)				
	HC	CO	NOx	PM
Line-Haul*	0.48	1.28	13.0	0.32
Switch**	1.01	1.83	17.4	0.44

* Line-haul locomotives over the line-haul duty-cycle
** Switch locomotives over the switch duty-cycle

Table 2 - Range of NOx and PM Emission Rates (g/bhp-hr)			
Line-Haul Cycle		Switch Cycle	
NOx	PM	NOx	PM
10.3-18.2	0.22-0.41	9.2-33.1	0.22-0.86

Conversion to Gram per Gallon Emission Factors

It is often useful to express emission rates as grams of pollutant emitted per gallon of fuel consumed (g/gal). This can be done by multiplying the emission rates in Table 1 by a conversion factor. EPA has estimated the appropriate conversion factor to be 20.8 bhp-hr/gal. These converted emission factors are shown in Table 3.

Table 3 - Converted Emission Factors (g/gal)				
	HC	CO	NOx	PM
Line-Haul	10	26.6	270	6.7
Switch	21	38.1	362	9.2

Projected Future Emission Factors

With the new national emission standards for both newly manufactured and remanufactured locomotives originally built after 1972, future locomotive emission rates are projected to be much lower than the baseline rates shown above. EPA's estimates of future emission rates for

Tier 0-Tier 2 locomotives are shown in Tables 4-6, respectively. Table 9 gives the expected fleet average emission factors for all locomotives, which reflects the penetration of the Tier 0-Tier 2 locomotives into the fleet over time.

Table 4 - Estimated Controlled Emission Rates for Locomotives Manufactured in 1973-2001 (Tier 0)

	HC		CO		NOx		PM	
	g/bhp-hr	g/gal	g/bhp-hr	g/gal	g/bhp-hr	g/gal	g/bhp-hr	g/gal
Line-Haul	0.48	10	1.28	26.6	8.6	178	0.32	6.7
Switch	1.01	21	1.83	38.1	12.6	262	0.44	9.2

Table 5 - Estimated Controlled Emission Rates for Locomotives Manufactured in 2002-2004 (Tier 1)

	HC		CO		NOx		PM	
	g/bhp-hr	g/gal	g/bhp-hr	g/gal	g/bhp-hr	g/gal	g/bhp-hr	g/gal
Line-Haul	0.47	9.8	1.28	26.6	6.7	139	0.32	6.7
Switch	1.01	21	1.83	38.1	9.9	202	0.44	9.2

Table 6 - Estimated Controlled Emission Rates for Locomotives Manufactured after 2004 (Tier 2)

	HC		CO		NOx		PM	
	g/bhp-hr	g/gal	g/bhp-hr	g/gal	g/bhp-hr	g/gal	g/bhp-hr	g/gal
Line-Haul	0.26	5.4	1.28	26.6	5.0	103	0.17	3.6
Switch	0.52	11	1.83	38.1	7.3	152	0.21	4.3

Emission Inventory Estimation

Total emissions can be calculated by multiplying the emission factors (in g/gal) by the fuel consumption rates (in million-gal/yr) to give annual emission rates (in metric tons per year). This metric estimate can be converted to standard tons (or short tons) per year, by multiplying it by 1.1.

In the United States, the great majority of fuel consumed by locomotives each year is used in line-haul freight service. Smaller amounts are also used in switching and passenger service. EPA's estimates of these fuel volumes are shown in Table 7. EPA's estimates of annual emission rates calculated from these fuel consumption rates are shown in Table 8.

Table 7 - 1996 Locomotive Fuel Consumption by Service Category (million gal/year)

National Freight Line-Haul	3,331
National Freight Switching	270
Local and Regional Freight	215
Passenger	133

Table 8 - Estimated 1996 Nationwide Locomotive Emission Rates (thousand short tons per year)

HC	CO	NOx	PM
47	119	1,202	30

For More Information

For further information on emission factors for locomotives, please write to:

U.S. Environmental Protection Agency
Engine Programs and Compliance Division
2565 Plymouth Road
Ann Arbor, MI 48105

Additional documents on locomotive emission standards are available electronically from the EPA Internet server at:

http://www.epa.gov/OMSWWW/locomotv.htm

or by calling (734) 668-4333.

Table 9 - Fleet Average Emission Factors For All Locomotives								
	(g/bhp-hr)				(g/gal)			
Year	HC	CO	NOx	PM	HC	CO	NOx	PM
1999	0.52	1.32	13.30	0.33	10.7	27.4	276.7	6.8
2000	0.52	1.32	13.16	0.33	10.7	27.4	273.8	6.8
2001	0.52	1.32	12.74	0.33	10.7	27.4	265.0	6.8
2002	0.52	1.32	11.96	0.33	10.7	27.4	248.8	6.8
2003	0.52	1.32	11.22	0.33	10.7	27.4	233.3	6.8
2004	0.51	1.32	10.49	0.33	10.7	27.4	218.1	6.8
2005	0.50	1.32	9.60	0.32	10.4	27.4	199.8	6.6
2006	0.48	1.32	8.92	0.31	10.1	27.4	185.6	6.4
2007	0.47	1.32	8.51	0.30	9.8	27.4	177.0	6.2
2008	0.46	1.32	8.29	0.29	9.6	27.4	172.5	6.0
2009	0.45	1.32	8.09	0.28	9.4	27.4	168.3	5.9
2010	0.44	1.32	7.84	0.28	9.1	27.4	163.0	5.7
2011	0.44	1.32	7.74	0.27	9.1	27.4	161.1	5.7
2012	0.43	1.32	7.62	0.27	8.9	27.4	158.5	5.6
2013	0.42	1.32	7.50	0.26	8.8	27.4	155.9	5.5
2014	0.42	1.32	7.37	0.26	8.7	27.4	153.4	5.4
2015	0.41	1.32	7.26	0.25	8.5	27.4	151.0	5.3
2016	0.40	1.32	7.14	0.25	8.4	27.4	148.5	5.2
2017	0.40	1.32	7.04	0.25	8.3	27.4	146.5	5.1
2018	0.39	1.32	6.94	0.24	8.2	27.4	144.4	5.1
2019	0.39	1.32	6.84	0.24	8.1	27.4	142.4	5.0
2020	0.38	1.32	6.75	0.24	7.9	27.4	140.3	4.9
2021	0.38	1.32	6.65	0.23	7.8	27.4	138.3	4.8
2022	0.37	1.32	6.56	0.23	7.7	27.4	136.4	4.7
2023	0.37	1.32	6.46	0.22	7.6	27.4	134.4	4.7
2024	0.36	1.32	6.37	0.22	7.5	27.4	132.5	4.6
2025	0.36	1.32	6.29	0.22	7.4	27.4	130.7	4.5
2026	0.35	1.32	6.20	0.21	7.3	27.4	129.0	4.4
2027	0.35	1.32	6.12	0.21	7.2	27.4	127.2	4.4
2028	0.34	1.32	6.04	0.21	7.1	27.4	125.6	4.3
2029	0.34	1.32	5.96	0.20	7.0	27.4	124.0	4.2
2030	0.33	1.32	5.88	0.20	6.9	27.4	122.3	4.2
2031	0.33	1.32	5.80	0.20	6.8	27.4	120.7	4.1
2032	0.32	1.32	5.73	0.19	6.7	27.4	119.2	4.0
2033	0.32	1.32	5.66	0.19	6.6	27.4	117.6	4.0
2034	0.31	1.32	5.58	0.19	6.5	27.4	116.1	3.9
2035	0.31	1.32	5.54	0.19	6.4	27.4	115.3	3.9
2036	0.31	1.32	5.52	0.19	6.4	27.4	114.9	3.9
2037	0.31	1.32	5.49	0.18	6.3	27.4	114.3	3.8
2038	0.30	1.32	5.47	0.18	6.3	27.4	113.7	3.8
2039	0.30	1.32	5.44	0.18	6.2	27.4	113.2	3.7
2040	0.30	1.32	5.41	0.18	6.2	27.4	112.6	3.7