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Report No. SR2004-06-01

Revised Inventory Guidance For Locomotive Emissions

prepared for:

Southeastern States Air Resource Managers, Inc.

June 2004

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1. INTRODUCTION

This document illustrates how a state or local agency can calculate emissions from locomotives within an inventory area. Railroad locomotives used in the United States are primarily of two types: electric and diesel-electric. Electric locomotives are powered by electricity generated at stationary power plants and distributed by either a third rail or overhead catenary system. Emissions produced from the generation of this electricity are attributed to the power plants generating the electricity. Such emissions are not part of this inventory.

Diesel-electric locomotives, on the other hand, use a diesel engine and an alternator or generator to produce the electricity required to power its traction motors. Emissions produced by these diesel engines are of interest in emission inventory development. Emissions for hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NOx), sulfur dioxide (SO_2), and particulate matter (PM) from this source are covered here. This document is a revision of the previous guidance for determining emission factors from locomotives.[1] The main difference between this document and previous guidance is the use of revised emission factors to account for locomotive emission standards that are phased in between 2000 and 2005. In addition, estimated adjustment factors to system-wide fuel use have been included in this revision.

Other sources of emissions from railroad operations include the small gasoline and diesel engines used on refrigerated and heated rail cars. These engines are thermostatically controlled, working independently of train motive power, and fall in the category of off-highway equipment, which are addressed as a separate offroad source category. Railroads can be separated into three classes based on size: Class I, Class II, and Class III.[2] Class I railroads represent the largest railroad systems in the country. Because of their size, Class I railroads operate over a large geographic area. Also, they carry most of the interstate freight and carry most of the passenger service. They are required to keep detailed records of their operations and to report yearly to the Surface

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[1] U. S. Environmental Protection Agency, "Procedures for Emission Inventory Preparation Volume IV Mobile Sources," Office of Mobile Sources, EPA420-R-92-009, Chapter 6, December 1992.

[2] According to the Surface Transportation Board, Class I railroads are defined as railroads earning adjusted annual operating revenues for three consecutive years of $250,000,000 or more. Railroads with less than $250,000,000 revenues are classified as either Class II ($20,000,000 to $250,000,000 revenues) or Class III (less than $20,000,000 in revenues).

Transportation Board (STB).[1] Information on the size of the Class I railroads, expressed in terms of their ton miles of freight and the amount of fuel used, is shown in Table B-1. Table B-2 shows the states in which the individual Class I railroads operate.

Class II and III railroads represent the remainder of the rail transportation system and generally operate within smaller, localized areas. These smaller railroads are not subject to the same reporting requirements, and their recordkeeping may be less extensive. Also, their fleet of locomotives tends to be older, with the Class I railroads buying almost all of the new locomotives. The AAR maintains a listing, by state, of each railroad operating in the state. This includes all Class II and Class III railroads. This information is currently available at http://www.aar.org/AboutTheIndustry/StateInformation.asp.

Locomotives within each of the classes can perform two different types of operations: line-haul and yard (or switch). Line-haul locomotives, which perform the line-haul operations, generally travel between distant locations, such as from one city to another. Yard locomotives, which perform yard operations, are primarily responsible for moving railcars within a particular railway yard.

Following this introduction, Section 2 provides an overview of the recommended methodology, and Section 3 describes the recommended methods for calculating the emissions from various types of rail service based on generic or national operating characteristics. Information on converting from total hydrocarbons to other organic gases is provided in Appendix A, a sample inventory calculation is provided in Appendix B, and contact information is provided in Appendix C.

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[1] The Class I railroads operating in the United States are The Burlington Northern Santa Fe Railway (BNSF), CSX Transportation (CSXT), Grand Trunk Corporation (GTC), Kansas City Southern Railway (KCS), Norfolk Southern Consolidated Subsidiary Railways (NS), Soo Line Railroad (SOO), and Union Pacific Railroad (UP). Grand Trunk Corporation, which is a subsidiary of Canadian National, includes the Illinois Central and other railroads. The Soo Line is a subsidiary of Canadian Pacific Railway.

2. OVERVIEW OF RECOMMENDED INVENTORY METHODOLOGY

Four steps are necessary in order to assess locomotive emissions within an inventory area:

1. Railroad operations are separated into three distinct categories: (1) Class I - line-haul, (2) Class II and Class III line-haul, and (3) yard.

2. Separate information is obtained for each railroad operating in the inventory area.

3. Emissions for each pollutant are calculated for each railroad operating in the area. Each railroad may have two kinds of emissions: line-haul and yard. (Some small railroads that only operate in a rail yard will not have line-haul emissions.)

4. The total locomotive emissions in the inventory area are the sum of the line-haul and the yard emissions for each railroad operating in the inventory area.[1]

The methods described here are based on annual inventories and annual data. Developing inventories for shorter time periods is straightforward because railroad traffic is relatively constant throughout the year and, therefore, less than annual calculations can be done by simple apportionment. The recommended methods described in Section 3 are based on a national locomotive fleet mix and average fuel consumption figures, with possible adjustments for local conditions of grade and train type.

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[1] The agency preparing the inventory can choose to sum both yard and line-haul emissions first, getting a total emissions number for each railroad. Alternatively, the agency can sum all the line-haul and all the yard emissions separately to get a measure of how much the two kinds of operations contributes to overall emissions in the area.

3. RECOMMENDED METHODS

The recommended methods for each of the three categories, as follows: Class I line-haul, Class II and Class III line-haul, and yard, are discussed separately below.

Class I Line-Haul Locomotives

For Class I line-haul locomotives, emissions are calculated by multiplying the amount of fuel consumed in the inventory area by the appropriate emission factors for each species. The following calculation is performed for each railroad and each species of interest. The results for each railroad are then summed to obtain the total Class I railroad emissions in the inventory area. The basic equation, with conversion factors, is given below.

$$\begin{bmatrix} \text{Railroad} \\ \text{Line Haul Emissions} \\ \text{Tons / year} \end{bmatrix} = \begin{bmatrix} \text{Annual Railroad} \\ \text{fuel use} \\ \text{gallons / year} \end{bmatrix} \bullet \begin{bmatrix} \text{Emission Factor} \\ \text{pounds per} \\ \text{thousand gallons} \end{bmatrix} \bullet \frac{1\ \text{ton}}{2000\ \text{lb}} \bullet \frac{\text{thousand gallons}}{1000\ \text{gallons}}$$

The two conversion factors can be combined to give the working equation shown below.

$$\begin{bmatrix} \text{Railroad} \\ \text{Line Haul Emissions} \\ \text{Tons / year} \end{bmatrix} = \frac{\begin{bmatrix} \text{Annual Railroad} \\ \text{fuel use} \\ \text{gallons / year} \end{bmatrix} \bullet \begin{bmatrix} \text{Emission Factor} \\ \text{pounds per} \\ \text{thousand gallons} \end{bmatrix}}{2{,}000{,}000} \qquad [1]$$

<u>Class I Line-Haul Locomotives Fuel Consumption</u> - If Class I line-haul locomotives traveled only within the inventory area, fuel consumption could be determined directly from the amount of fuel dispensed into the units. However, these line-haul locomotives travel predominantly interstate. Hence, they do not necessarily burn the fuel in the same location where the fuel was pumped, making it impossible to determine fuel consumption in the area of interest from information on fuel dispensed.

In order to determine fuel consumption in the inventory area, it is necessary to allocate the total amount of fuel consumed for individual Class I railroads to the inventory area. This is done by dividing the traffic density (expressed in Gross Ton Miles, or GTM) for each Class I railroad track segment within the inventory area by the system-wide fuel consumption index (expressed in Gross Ton Miles per gallon or GTM/gal) for that railroad.[1] This process is repeated for each railroad.

$$\begin{bmatrix} \textit{Annual Railroad} \\ \textit{fuel use} \\ \textit{gallons / year} \end{bmatrix} = \frac{\begin{bmatrix} \textit{Railroad Traffic in Inventory} \\ \textit{Area (gross ton miles)} \end{bmatrix}}{\begin{bmatrix} \textit{Railroad Fuel Consumption Index} \\ \textit{(gross ton miles per gallon)} \end{bmatrix}} \qquad [2]$$

In any given area, there will be only a few active Class I railroads, and the railroad company staff should be able to perform this step and provide the amount of fuel consumed within the inventory area on request. In addition, this guidance includes a detailed explanation of how this step is performed based on published data and information that is available from the Surface Transportation Board for each railroad. (See the contact information in Appendix C for details on obtaining this information.) The inventory area traffic measure and the fuel consumption index are described separately below.

<u>Traffic Density</u> - For every track segment within a state, each Class I railroad maintains information on traffic density (GTM), length (miles), direction, and geographic location. Therefore, it is possible to calculate the traffic density for an inventory area by summing the traffic densities for each track segment or portion thereof within the inventory area. This information can be obtained, for each area, either directly from the individual railroads or from the Association of American Railroads in Washington, D.C. (See specific contact information for the AAR in Appendix C.) The information should contain enough detail so that track segments or portions thereof can be assigned to the inventory area. However, if the agency is unable to perform this task, it may become necessary to obtain assistance from the Class I railroad in order to determine where the inventory area boundary intersects the track segment. (See contact information for Class I railroads in Appendix C.)

The gross ton mile information may be supplied in one of two ways: (1) without the weight of the locomotives included, or (2) with the weight of the locomotives included. This distinction is important when calculating the fuel consumption index.[2]

[1] Some railroads may use other measures for these data. For example, UP reports data as a burn rate in gallons of fuel per thousand ton miles. For UP, the fuel consumption index used in this report would be computed by dividing 1000 by the burn rate reported by UP.

[2] There are three items whose weight can be included in the measure of ton-miles: the freight, the railcars, and the locomotives. If the freight only is included, the measure is called net ton miles. The term gross ton miles is used for both the freight plus the railcars and the sum of all three (freight, railcars and locomotives). Thus, it is necessary to have different calculations of the fuel index, in gross ton miles per gallon, if the weight of the locomotives is or is not included in this measure for a particular railroad.

Fuel Consumption Index - The fuel consumption index (GTM/gal), for each Class I railroad within an inventory area, should be calculated by dividing the system-wide gross ton miles (GTM) by the system-wide fuel consumption (gal). This is shown in the following formula:

$$\begin{bmatrix} Railroad\ Fuel\ Consumption\ Index \\ (gross\ ton\ miles\ per\ gallon) \end{bmatrix} = \frac{\begin{bmatrix} Railroad\ Systemwide \\ Gross\ Ton\ Miles \end{bmatrix}}{\begin{bmatrix} Railroad\ Systemwide\ Fuel \\ Consumption\ (gallons) \end{bmatrix}} \qquad [3]$$

Each Class I railroad is required to report these statistics each year to the STB in an annual report entitled "R-1." Data in the R-1 report can be used to compute the fuel consumption index. (See Appendix C for information on obtaining the necessary schedules from the R-1 reports.) The approach used for this calculation depends on the way in which the traffic data are presented for the inventory area. The information on schedules 750 and 755 can be used, as described below and outlined in Table 1, to obtain the data necessary to compute the fuel consumption index, depending on the measure of gross ton miles, for each Class I railroad in the inventory area. A sample calculation is provided in Appendix B.

Table 1
R-1 Report Data For Fuel Consumption Index Calculation

Ton-mile measure	Source of Data
If weight of locomotives is included	
Fuel consumption	Schedule 750, Line 1
Gross ton miles with locomotives	Schedule 755, Line 104
If weight of locomotives is not included	
Ton-miles with locomotives	Schedule 755, Line 98
Ton-miles without locomotives	Subtract Schedule 755 Line 98 from Schedule 755 Line, 104

The appropriate measure of ton-miles is then divided into the fuel consumption to get the fuel consumption index. Expressed as an equation, this index is computed as follows if the weight of locomotives is included in the inventory gross ton miles reported by the railroad.

$$\begin{bmatrix} Railroad\ Fuel\ Consumption\ Index \\ Including\ Locomotives \\ (gross\ ton\ miles\ per\ gallon) \end{bmatrix} = \frac{\begin{bmatrix} Schedule\ 755 \\ Line\ 104 \end{bmatrix}}{\begin{bmatrix} Schedule\ 750 \\ Line\ 1 \end{bmatrix}} \quad [4]$$

The following equation is used if the weight of locomotives is not included.

$$\begin{bmatrix} Railroad\ Fuel\ Consumption\ Index \\ \textbf{NOT}\ Including\ Locomotives \\ (gross\ ton\ miles\ per\ gallon) \end{bmatrix} = \frac{\begin{bmatrix} Schedule\ 755 \\ Line\ 104 \end{bmatrix} - \begin{bmatrix} Schedule\ 755 \\ Line\ 98 \end{bmatrix}}{\begin{bmatrix} Schedule\ 750 \\ Line\ 1 \end{bmatrix}} \quad [5]$$

An example of the R-1 schedules and the corresponding calculation is shown in Appendix B.

<u>Adjusted Fuel Consumption Index</u> - The actual fuel use in a local inventory area may be different from the system-wide average. There are two adjustment factors—one for grade and one for train type—that can be used to adjust the fuel consumption index computed above to account for these factors in a local area.

The correction for grade operation is based on two factors: the severity of the grade and the amount of operation on the grade. Although the final correction factor is quantitative, the inputs for determining the grade severity and the fraction of operation on the grade are qualitative, with some numerical guidance for the amount of operation on grade. Each of these factors has three levels, where the lowest level has no correction. (The correction factor is one.)

Grade severity is a measure of the steepness of the grade and has three levels. The user should select one of the levels from the list below.

0 No significant grades in region or some grades that are generally slight.
1 Grades are significant part of operations in region.
2 Grade in region is exemplified by Cascade Range, Rocky Mountains, or Sierra Nevada.

The amount of operation on grade is also a qualitative measure with some guidance numbers attached. The user should select one of the operation levels from the list below.

0 No significant operation on grades or some small fraction of operation on grades.

1 A small but important part of operation in the region is on grades. This might correspond to about 15% the ton-miles being on grade.
2 Significant operation on grades in the region. This might correspond to about 30% of the operation being on grades in the region.

The determination of the grade severity and the amount of operation on grades should be done in consultation with the railroads. If the railroad cannot provide this estimate, the planning agency may make its own individual estimate, based on any information available about railroad grades and amounts of operation on the grades. If there is no clear evidence for determining the amount and significance of grade operations, this factor should not be applied.

Once the severity and amount of grade operation is determined, by selecting an index for 0 to 2 for both severity and amount of operation, the grade correction factor can be found from Table 2. The system-wide fuel consumption index should be multiplied by the factor shown in Table 2.

Table 2
Adjustment Factors for Operation on Grade

Grade Severity	Grade Operation Fraction Index In Row Below		
	Operation = 0	Operation =1	Operation = 2
Severity = 0	1	1	1
Severity = 1	1	0.93	0.85
Severity = 2	1	0.85	0.7

The second correction factor deals with the fraction of ton-miles in the region that are operated by bulk freight, typically coal trains. These trains have a much greater amount of ton-miles per gallon. If the fraction of bulk freight were the same throughout the rail system, no correction for the nature of regional freight would be necessary. However, the fraction of bulk freight in a given region could be greater or less than the system-wide average. Such a variation in the fraction of bulk freight would cause an increase or decrease, respectively, in the ton-miles per gallon for the region as compared to the system-wide average.

Table 3 provides a correction factor that can be used to account for differences in the fraction of ton-miles attributed to bulk freight in a local region. This table provides five different descriptions to characterize differences between the bulk freight fraction in a region and the system-wide bulk freight fraction.

<u>Class I Line-Haul Emission Factors</u> - Because of changing emission standards for locomotives, the fleet average emission factors will be a function of calendar year. The emission factors to be used for line-haul locomotives, in a particular inventory year are shown in Table 4.

Table 3 Correction Factors For Regional Differences In The Fraction Of Ton Miles Attributed To Bulk Freight	
Correction Factor	Description of region
0.9	The region has almost no bulk freight.
0.95	The region's fraction of bulk freight is well below the system average.
1.0	The region's fraction of bulk freight is about the same as the system average.
1.06	The region's fraction of bulk freight is well above the system average.
1.13	The region has exceptionally large fractions of bulk freight as compared to the system average.

Table 4 Class I Line-haul emission factors				
Inventory Year	Factors (pounds per thousand gallons)			
	HC	CO	NOx	PM
2002	14.62	79.96	531.5	10.33
2003	15.73	76.62	505.7	11.00
2004	16.65	73.87	484.0	11.55
2005	17.42	71.59	465.5	12.01
2006	17.62	69.65	446.1	12.07
2007	17.74	68.04	429.2	12.08
2008	17.80	66.70	414.4	12.05
2009	17.80	65.57	401.2	12.00
2010	17.77	64.61	389.5	11.93
2011	17.71	63.81	379.0	11.85
2012	17.62	63.13	369.6	11.75
2013	17.51	62.55	361.1	11.64
2014	17.39	62.05	353.3	11.53
2015	17.26	61.62	346.2	11.41

The emission factor for SO_2 depends on the sulfur content of the fuel. There are no requirements for the sulfur content of fuel burned in locomotive engines. Railroads purchase fuel that meets the specifications for nonroad diesel fuel. The average sulfur content of nonroad diesel fuel is 2700 parts per million sulfur by weight (ppmw S); however, some suppliers will provide diesel fuels with lower sulfur contents. Starting in 2007, fuels burned in locomotive and marine diesel engines will have to meet a standard of 500 ppmw sulfur. This is the current EPA requirement for highway diesel fuel. Such fuel has an average sulfur content of 370 ppmw sulfur. Table 5 gives the projected emission factors for SO_2, and the sulfur content of the fuel on which these emission factors are based.

Table 5
SO_2 Emission Factors (lbs/1000 Gallons) and Fuel Sulfur Content (ppmw S) Used For These Factors

Year	Factor	ppmw S
2002	36.00	2500
2003	34.56	2400
2004	33.12	2300
2005	31.68	2200
2006	30.24	2100
2007	20.16	1400
2008	5.33	370
2009	5.33	370
2010	5.33	370
2011	5.33	370
2012	5.33	370
2013	5.33	370
2014	5.33	370
2015	5.33	370

The sulfur content for 2007 is an average for the year in which the new standard is phased in. If an inventory is prepared on other than an annual basis, the figure should be adjusted for sulfur content.

The emission factors in Table 5 can be used directly. However, if the railroad whose inventory is being prepared is able to supply an average sulfur content of its fuel use in the area, the emission factor may be adjusted as follows.

$$\begin{bmatrix} SO_2\ Emission \\ Factor\ Used\ for \\ Inventory\ Calculations \end{bmatrix} = \begin{bmatrix} SO_2\ Emission \\ Factor \\ from\ table\ 3 \end{bmatrix} \frac{\begin{bmatrix} Fuel\ Sulfur\ Content \\ from\ Railroad \end{bmatrix}}{\begin{bmatrix} Fuel\ Sulfur\ Content \\ from\ table\ 3 \end{bmatrix}} \qquad [6]$$

If the railroad supplies the fuel sulfur content in another set of units, a unit conversion to ppmw is required before applying equation [6].

Class II and Class III Line-Haul Locomotives

Similar to the recommended method for Class I line-haul locomotives, emissions from Class II and III line-haul locomotives are calculated by multiplying the amount of fuel consumed in the inventory area by the appropriate emission factors, using equation [7]. However, the method used for determining the fuel consumption is different for these locomotives.

$$\begin{bmatrix} Inventory\ Area \\ Railroad\ Emissions \\ Tons/year \end{bmatrix} = \frac{\begin{bmatrix} Annual\ Railroad \\ fuel\ use \\ gallons/year \end{bmatrix} \bullet \begin{bmatrix} Emission\ Factor \\ pounds\ per \\ thousand\ gallons \end{bmatrix}}{2{,}000{,}000} \qquad [7]$$

Class II and Class III Line-haul Locomotives Fuel Consumption - Since Class II and III railroad companies are not required to file R-1 reports, annual fuel consumption should be obtained directly through interviews or letters with each Class II and III railroad operating within the inventory area. This approach is sufficient because, unlike Class I line-haul operations, most Class II and III line-haul travel is predominantly within a relatively small geographic area. Therefore, in most instances, it is unnecessary to apportion system fuel use to an inventory area, because the fuel is consumed by the locomotives within the inventory area.

For the small number of Class II and III railroads operating outside the inventory area, however, EPA recommends simply allocating the fuel consumption by track length or track density (GTM). Each Class II and III railroad can supply both track length and track density information. So, the percentage of fuel consumed is based on the percentage of track length or track density within the inventory area. If, for example, 30 percent of the track length, for a particular railroad, runs within the inventory area, then, in order to apportion the total fuel consumed in the inventory area, multiply the total fuel consumption for the railroad by 0.30.

Class II and Class III Line-Haul Locomotive Emission Factors - Class II and Class III railroads usually purchase their locomotives as used locomotives from Class I railroads. They generally do not purchase new line-haul locomotives, which are required to meet the standards for such locomotives in 2002 and later. In addition, they do not engage in a significant amount of locomotive rebuilding. The emission factors for these locomotives will therefore be significantly different from those of Class I railroads in future years. The emission factors for Class II and Class III line-haul locomotives have been developed by assuming that these railroads will have some small fraction of rebuilt locomotives. This may come from either rebuilds by the Class II or Class III railroads or from purchases of locomotives that were previously rebuilt by Class I railroads.

Table 6 shows the emission factors for line-haul operations for Class II and Class III locomotives. This table contains the data that were placed in two tables for Class I locomotives. All the emission factors are shown as well as the fuel sulfur content on which the SO_2 emission factor is based.

Table 6
Class II and Class III Line-Haul Emission Factors

Inventory Year	Emission Factors (pounds per thousand gallons)					Fuel S ppmw
	HC	CO	NOx	PM	SO_2	
2002	14.28	78.11	519.2	10.10	36.00	2500
2003	14.35	77.89	517.8	10.14	34.56	2400
2004	14.43	77.67	516.4	10.18	33.12	2300
2005	14.50	77.45	514.9	10.22	31.68	2200
2006	14.57	77.23	513.5	10.26	30.24	2100
2007	14.64	77.00	512.1	10.31	20.16	1400
2008	14.71	76.78	510.6	10.35	5.33	370
2009	14.79	76.56	509.2	10.39	5.33	370
2010	14.86	76.34	507.8	10.43	5.33	370
2011	14.93	76.11	506.3	10.48	5.33	370
2012	15.00	75.89	504.9	10.52	5.33	370
2013	15.08	75.67	503.5	10.56	5.33	370
2014	15.15	75.45	502.0	10.60	5.33	370
2015	15.22	75.23	500.6	10.64	5.33	370

Yard Operations

There are two possible methods for determining the locomotive emissions from yard operations. These methods are the same for all classes of railroads. The first method can be applied if the railroad can supply the total amount of fuel used for yard operations. In this case the fuel use, in thousand gallons per year, can be multiplied by the yard emission factors in Table 7 to determine the total emissions, using the equation below.

$$\begin{bmatrix} \textit{Inventory Area} \\ \textit{Yard Emissions} \\ \textit{Tons / year} \end{bmatrix} = \frac{\begin{bmatrix} \textit{Annual Railroad} \\ \textit{fuel use for yard operations} \\ \textit{gallons / year} \end{bmatrix} \bullet \begin{bmatrix} \textit{Yard Emission Factor} \\ \textit{pounds per} \\ \textit{thousand gallons} \end{bmatrix}}{2{,}000{,}000} \qquad [8]$$

The SO_2 emission factors for yard operations shown in Table 7 is seen to be the same as that for line-haul operations. This is because all the sulfur in the fuel is assumed to be converted to SO_2 during combustion. If the railroad can supply data on the actual average sulfur content of the fuel used, the emission factors for SO_2 can be adjusted in the same manner as recommended for line-haul locomotives, using equation [6].

Table 7
Yard Emission Factors For All Railroad Classes

Inventory Year	Emission Factors (pounds per thousand gallons)					Fuel S ppmw
	HC	CO	NOx	PM	SO_2	
2002	38.22	69.25	658.41	16.65	36.00	2500
2003	38.26	69.32	653.15	16.66	34.56	2400
2004	38.30	69.39	647.91	16.67	33.12	2300
2005	38.33	69.46	642.70	16.69	31.68	2200
2006	38.37	69.53	637.51	16.70	30.24	2100
2007	38.17	69.58	631.07	16.59	20.16	1400
2008	37.96	69.64	624.65	16.49	5.33	370
2009	37.76	69.70	618.27	16.39	5.33	370
2010	37.56	69.76	611.91	16.28	5.33	370
2011	37.36	69.82	605.58	16.18	5.33	370
2012	37.16	69.88	599.28	16.08	5.33	370
2013	36.96	69.94	593.02	15.98	5.33	370
2014	36.76	69.99	586.78	15.88	5.33	370
2015	36.57	70.05	580.57	15.78	5.33	370

If the fuel used in yard locomotives is not available, the yard emissions may be determined from equation [9] by determining the number of locomotives used in yard operations and using the data on annual emissions per yard locomotive from Table 8.

$$\begin{bmatrix} \text{Yard Emissions for} \\ \text{All Classes (tons / year)} \end{bmatrix} = \begin{bmatrix} \text{Number of} \\ \text{Yard Locomotives} \end{bmatrix} \begin{bmatrix} \text{Annual Emissions per Yard} \\ \text{Locomotive (tons / year)} \end{bmatrix} \qquad [9]$$

Equation [9] gives the annual emissions for one rail yard. The emissions for all rail yards are computed in a similar manner and summed to give the total yard emissions. (Alternatively, the emissions for one rail yard can be combined with the line-haul emissions of the railroad operating the yard to get the total emissions for each railroad.) Since yard locomotives operate within the boundaries of a railway yard, it is possible to determine the number of locomotives operating within an inventory area through interviews with the railway yard managers, who keep accurate records of yard locomotive operations. If this first approach proves unproductive, the number of yard locomotives can be determined by actually counting the units operating in each railway yard during a day. This is sufficient because the number of yard locomotives in operation each day remains relatively constant throughout the year. Switch yard engines are sent to railroad maintenance facilities according to regular schedules. When a particular yard locomotive is away getting maintenance or repair, the yard will replace the unit with another of approximately the same horsepower.

Table 8
Annual Emissions per Yard Locomotive

Inventory Year	Emissions In Tons Per Year Per Yard Locomotive					Fuel S ppmw
	HC	CO	NOx	PM	SO_2	
2002	1.08	2.52	23.54	0.51	1.48	2500
2003	1.09	2.53	23.41	0.52	1.43	2400
2004	1.10	2.55	23.29	0.52	1.37	2300
2005	1.12	2.56	23.17	0.53	1.31	2200
2006	1.13	2.57	23.04	0.53	1.25	2100
2007	1.14	2.58	22.87	0.53	0.83	1400
2008	1.14	2.59	22.69	0.53	0.22	370
2009	1.14	2.60	22.52	0.53	0.22	370
2010	1.15	2.61	22.34	0.53	0.22	370
2011	1.15	2.62	22.17	0.53	0.22	370
2012	1.15	2.63	22.00	0.53	0.22	370
2013	1.16	2.64	21.83	0.53	0.22	370
2014	1.16	2.65	21.66	0.53	0.22	370
2015	1.16	2.66	21.49	0.53	0.22	370

The emission levels in Table 8 were calculated as follows. In the previous guidance,[1] EPA estimated that the average yard engine consumes 82,490 gallons of fuel per year.[2]

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[1] U. S. Environmental Protection Agency, "Procedures for Emission Inventory Preparation Volume IV Mobile Sources," Office of Mobile Sources, EPA420-R-92-009, Chapter 6, December 1992.

[2] The following text is taken from the previous EPA guidance: "EPA estimated that, based on a reasonable activity or duty cycle and typical fuel consumption rates, the average yard engine consumes 228 gallons of fuel per day. Since yard locomotives can be assumed to operate 365 days a year (this assumes that when a yard engine is taken in for repairs it is replaced during that period), the average yard engine consumes 82,490 (226 X 365) gallons of fuel per year."

The annual emissions per yard locomotive in Table 8 were determined by multiplying this fuel consumption estimate by each emission factor in Table 7.

As in the previous calculations, a more accurate estimate of SO_2 emissions can be obtained if the actual fuel sulfur content used by the railroad is known. If this fuel sulfur content is known, the emissions per yard locomotive shown in Table 8 can be adjusted as follows.

$$\begin{bmatrix} Tons\ of\ SO_2\ per\ Yard \\ Locomotive\ Used\ for \\ Inventory\ Calculations \end{bmatrix} = \begin{bmatrix} Tons\ of\ SO_2\ per \\ Yard\ Locomotive \\ from\ table\ 8 \end{bmatrix} \frac{\begin{bmatrix} Fuel\ Sulfur\ Content \\ from\ Railroad \end{bmatrix}}{\begin{bmatrix} Fuel\ Sulfur\ Content \\ from\ table\ 8 \end{bmatrix}} \quad [10]$$

###

Appendix A

Converting from Total Hydrocarbons (THC) to Other Measures of Organic Gases

The emission factors used for locomotive engines are based on flame-ionization measurements of total hydrocarbons. These can be converted to other measures used for organic emissions that are used for inventories and regulatory compliance using the factors in Table A-1. These factors are taken from an EPA report giving conversion factors for nonroad engines. The report acknowledges that the database for the conversion factor is "sparse" with only three on-highway engines from the 1970s and 1980s being used to develop these factors.[1]

Table A-1
Conversion Factors for Organic Gas Measures

(Multiply total hydrocarbons, THC, by the conversion factors shown to get the other hydrocarbon measures)

Hydrocarbon measure	Abbreviation	Conversion Factor
Non-methane organic gases	NMOG	1.054
Volatile organic compounds	VOC	1.053
Total organic gases	TOG	1.070
Non-methane hydrocarbons	NMHC	0.984

[1] U.S. Environmental Projection Agency, "Conversion Factors for Hydrocarbon Emission Components," Office of Transportation and Air Quality, EPA420-P-03-002, May 2003.

Appendix B

Sample Calculations

The data from Class I railroad R-1 reports and the fuel index calculations required for inventory calculations are shown in Table B-1. Copies of example R-1 report sections employed in the CSXT calculations are provided after the table, with highlighting added to note the rows containing data used in the calculations shown in Table B-1. These calculations would not be required if the railroad supplied the fuel index in gross ton miles per gallon. The data in Table B-1 show the calculation of the fuel index in two ways, including and not including locomotives. The actual calculation would be done only one way to give a measure that is consistent with the gross-ton mile data supplied by the railroad. Note that the ton-mile data are recorded in the R-1 report as thousands of ton-miles. These data must be multiplied by 1,000 before dividing by the fuel use.

A sample calculation of the annual fuel consumption from an actual emission inventory[1] is quoted below. (Although UP is cited in the third sentence, the data being discussed here are from BNSF; UP data are discussed in a later quote.)

> Class I line haul locomotives carry mainly interstate freight and most of the passenger service. Emissions were calculated by multiplying the amount of fuel consumed by these locomotives in the inventory area by the appropriate emission factors (EPA, 1992, Table 8-1). UP provided 1999 Gross Tons (GT) and a Fuel Consumption Index (FCI) for all trains scheduled to operate in the nonattainment area of Maricopa County (Appendix 4-3). The following calculations show how the line haul locomotive emissions were obtained.
>
> BNSF provided a Fuel Consumption Index (FCI) of 734 GTM/gal. (GTM = Gross Ton Miles)
>
> 1999 Gallons of Diesel per Line Segment =[GT x Length of segment (miles)] / FCI
>
> $$\begin{bmatrix} 1999\ \textit{Gallons of} \\ \textit{Diesel per} \\ \textit{Line Segment} \end{bmatrix} = \frac{[37{,}570{,}000\ \textit{gross tons}][49.0\ \textit{miles}]}{\begin{bmatrix} 734\ \textit{gross ton} \\ \textit{miles per gallon} \end{bmatrix}} = \frac{2{,}508{,}079\ \textit{gallons}}{\textit{year}}$$

[1] Maricopa County Environmental Services Division, "1999 Periodic Ozone Emissions Inventory for the Maricopa County Nonattainment Area," Phoenix, AZ, November 2001.

Table B-1
Railroad Data from Surface Transportation Board R-1 Schedules for 2002

Title, units and column letter used in formulas	Fuel Use, Gallons (A)	Thousands of Total Ton Miles (B)	Thousands of Locomotive Ton Miles (C)	Thousands of Ton miles with-out Locomotives (D)	Ton-miles per gallon with locomotives (E)	Ton-miles per gallon without locomotives (F)
Data Source or calculation formula	R-1 Schedule 750, line 1	R-1 Schedule 755, line 104	R-1 Schedule 755, line 98	(B) – (C)	$1000\frac{(B)}{(A)}$	$1000\frac{(D)}{(A)}$
Burlington Northern Santa Fe (BNSF)	1,091,248,247	958,862,994	82,638,883	876,224,111	878.7	803.0
CSX Transportation (CSXT)	514,107,567	469,392,729	32,779,315	436,613,414	913.0	849.3
Grand Trunk Central (GTC)	108,013,647	104,578,305	6,286,640	98,291,665	968.2	910.0
Kansas City Southern (KCS)	51,256,604	37,563,933	3,358,570	34,205,363	732.9	667.3
Norfolk Southern (NS)	433,678,710	373,281,203	30,492,974	342,788,229	860.7	790.4
SOO Line (SOO)	42,198,000	45,426,616	3,002,702	42,423,914	1076.5	1005.4
Union Pacific (UP)	1,176,963,998	1,085,700,525	86,966,458	998,734,067	922.5	848.6

Table B-2
States in Which Class I Railroads Operate

Railroad	Burlington Northern Santa Fe	CSX Transportation	Grand Trunk Corporation	Kansas City Southern	Norfolk Southern	SOO Line	Union Pacific
Abbreviation	BNSF	CSXT	GTC	KCS	NS	SOO	UP
States in which railroads operate	Alabama, Arizona, Arkansas, California, Colorado, Idaho, Illinois, Iowa, Kansas, Louisiana, Minnesota, Mississippi, Missouri, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Tennessee, Texas, Utah, Washington, Wisconsin, Wyoming	Alabama, Connecticut, Delaware, District of Columbia, Florida, Georgia, Illinois, Indiana, Kentucky, Louisiana, Maryland, Massachusetts, Michigan, Mississippi, Missouri, New Jersey, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia, West Virginia	Alabama, Illinois, Indiana, Iowa, Kentucky, Louisiana, Michigan, Minnesota, Mississippi, Ohio, Tennessee, Wisconsin	Alabama, Arkansas, Illinois, Kansas, Louisiana, Mississippi, Missouri, Oklahoma, Tennessee, Texas	Alabama, Delaware, District of Columbia, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Michigan, Mississippi, Missouri, New Jersey, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia, West Virginia	Illinois, Indiana, Kentucky, Michigan, Minnesota, South Dakota, Wisconsin	Arizona, Arkansas, California, Colorado, Idaho, Illinois, Indiana, Iowa, Kansas, Louisiana, Minnesota, Missouri, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, Tennessee, Texas, Utah, Washington, Wisconsin, Wyoming

726. SUMMARY OF TRACK REPLACEMENTS

1. Furnish the requested information concerning the summary of track replacements.
2. In columns (d), (e), (g) and (j) give the percentage of replacements to units of property in each track category at year end.

Line No.	Track category	Ties				Rail		Ballast	Track surfacing		Line No.
		Number of ties replaced		Percent replaced							
		Crossties	Switch and Bridge ties (board feet)	Crossties	Switch and Bridge ties (board feet)	Miles of rail replaced (rail-miles)	Percent replaced	Cubic yards of ballast placed	Miles surfaced	Percent surfaced	
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	
1	A	1,479,813	3,033,099	4.3	3.6 *	683.82	2.89	1,001,200	3,818	32.3	1
2	B	803,150	713,891	3.8	1.1 *	127.43	0.86	396,200	1,511	20.5	2
3	C	203,046	327,677	2.6	0.9 *	18.28	0.30	83,600	319	10.6	3
4	D	153,643	149,315	1.6	0.7 *	34.75	0.50	157,100	599	17.1	4
5	E	228,387	1,685,306	1.1	2.0 *	63.68	0.40	31,900	243	3.0	5
6	TOTAL	2,868,039	5,909,288	3.1	1.8 *	927.95	1.37	1,670,000	6,490	19.2	6
7	F										7
8	Potential abandonments										8

* Estimate

750. CONSUMPTION OF DIESEL FUEL

(Dollars in Thousands

Line No.	LOCOMOTIVES		Line No.
	Kind of locomotive service	Diesel Diesel oil (gallons)	
	(a)	(b)	
1	Freight	514,107,567	1
2	Passenger		2
3	Yard switching	56,172,596	3
4	TOTAL	570,280,163	4
5	COST OF FUEL $(000)	$ 448,824	5
6	Work Train	1,159,000	6

755. RAILROAD OPERATING STATISTICS - Concluded

Line No.	Check Check	Item Description (a)	Freight Train (b)	Passenger Train (c)	Line No.
		6. Gross Ton-Miles (thousands) (K)			
98		6-01 Road Locomotives	32,779,315		98
		6-02 Freight Trains, Crs., Cnts., and Caboose			
99		6-020 Unit Trains	136,490,550	XXXXXX	99
100		6-021 Way Trains	18,863,166	XXXXXX	100
101		6-022 Through Trains	279,125,210	XXXXXX	101
102		6-03 Passenger-Trains, Crs., Cnts., and Caboose			102
103		6-04 Non-Revenue	2,134,488	XXXXXX	103
104		6-05 TOTAL (lines 98-103)	469,392,729		104
		7. Tons of Freight (thousands)			
105		7-01 Revenue	442,092	XXXXXX	105
106		7-02 Non-Revenue	1,410	XXXXXX	106
107		7-03 TOTAL (lines 105,106)	443,502	XXXXXX	107
		8. Ton-Miles of Freight (thousands) (L)			
108		8-01 Revenue-Road Service	228,175,827	XXXXXX	108
109		8-02 Revenue-Lake Transfer Service		XXXXXX	109
110		8-03 TOTAL (lines 108,109)	228,175,827	XXXXXX	110
111		8-04 Non-Revenue-Road Service	227,215	XXXXXX	111
112		8-05 Non-Revenue-Lake Transfer Service		XXXXXX	112
113		8-06 TOTAL (lines 111,112)	227,215	XXXXXX	113
114		8-07 TOTAL-Revenue & Non-Revenue (lines 110,113)	228,403,042	XXXXXX	114
		9. Train Hours (M)			
115		9-01 Road Service	4,555,196	XXXXXX	115
116		9-02 Train Switching	886,903	XXXXXX	116
117		10. TOTAL YARD-SWITCHING HOURS (N)	2,412,994	XXXXXX	117
		11. Train-Miles Work Trains (O)			
118		11-01 Locomotives	331,208	XXXXXX	118
119		11-02 Motorcars		XXXXXX	119
		12. Number of Loaded Freight Cars (P)			
120		12-01 Unit Trains	2,132,277	XXXXXX	120
121		12-02 Way Trains	8,281,712	XXXXXX	121
122		12-03 Through Trains	8,593,712	XXXXXX	122
123		13. TOFC/COFC-No. of Rev. Trlrs & Cntnrs Lded & Unlded (Q)		XXXXXX	123
124		14. Multi-level Cars-No. of Motor Vehicles Lded & Unlded	4,705,354	XXXXXX	124
125		15. TOFC/COFC-No. of Rev. Trailers Picked Up & Delivered		XXXXXX	125
		16. Revenue Tons-Marine Terminal (S)			
126		16-01 Marine Terminals-Coal	6,756,700	XXXXXX	126
127		16-02 Marine Terminals-Ore	26,211	XXXXXX	127
128		16-03 Marine Terminals-Other		XXXXXX	128
129		16-04 TOTAL (lines 126-128)	6,782,911	XXXXXX	129
		17. Number of Foreign Per Diem Cars on Line (T)			
130		17-01 Serviceable	28,862	XXXXXX	130
131		17-02 Unserviceable	98	XXXXXX	131
132		17-03 Surplus		XXXXXX	132
133		17-04 TOTAL (lines 130-132)	28,960	XXXXXX	133

The inventory document then computes the line-haul emissions for BNSF by multiplying this annual fuel use by the emission factors. It then cites the data used for UP, the other railroad operating in the nonattainment area.

> The Union Pacific Railway Company (UP) determined fuel consumption and calculated emissions following the same method as described above. Traffic density data and fuel consumption index were provided by UP (Appendix 4-4). The 1999 fuel consumption as reported by UP for line haul locomotives in Maricopa County is calculated as follows:

$$\begin{bmatrix} 1999\ \textit{Gallons of} \\ \textit{Diesel per} \\ \textit{Line Segment} \end{bmatrix} = \frac{[68{,}380{,}000\ \textit{gross tons}][413\ \textit{miles}]}{\begin{bmatrix} 722\ \textit{gross ton} \\ \textit{miles per gallon} \end{bmatrix}} = \frac{39{,}114{,}875\ \textit{gallons}}{\textit{year}}$$

The inventory document then computes the line-haul emissions for UP by multiplying the annual fuel use just computed by the emission factors. There were no Class II or Class III locomotives operating in the nonattainment area, so the only calculation remaining is for yard locomotives.

> UP verified that four yard locomotives operated in 1999. BNSF verified that twelve yard locomotives operated in 1999. Therefore, the total number of yard locomotives in Maricopa County is sixteen. Emission calculations for these sixteen yard locomotives are shown below. Emissions (lb/year) = (number of yard/switch locomotives) x (emission factor, lbs/yard locomotive)

The final emissions calculations for this inventory are shown in the table below.

Locomotive Type	**VOC tons/yr**	**NO_x tons/yr**	**CO tons/yr**
Line haul, Class I	375.8	10,262.2	1,302.8
Line haul, Classes II and III	0.0	0.0	0.0
Yard operations	28.6	332.9	59.0
Totals:	**404.4**	**10,595.1**	**1,361.8**

Appendix C

Contact Information

Association of American Railroads
Mr. Mike Rush
202.639.2503
mrush@www.aar.org

Surface Transportation Board
R-1 Report Schedules 750 and 755
Ms. Arlene Jeffcoat, Records Officer
202.565.1702
Fax 202.565.9016
Although the STB maintains some portions of the R-1 forms available for download, the items required for the computation of the fuel index were not available on-line at the time this guidance was written. To get the necessary schedules (750 and 755) send a FAX, like the sample FAX on the next page to the STB requesting schedules 750 and 755 for each Class I railroad in your region.

Class I railroads

Burlington Northern Santa Fe (BNSF)
No contact information provided

CSX Transportation (CSXT)
No contact information provided

Grand Trunk Corporation (GTC)
No contact information provided

Kansas City Southern (KCS)
No contact information provided

Norfolk Southern (NS)
Environmental Department
Norfolk Southern Corporation
110 Franklin Road, S.E.
Roanoke, VA 24042-0013
540,981,5185
540,981,4651 (fax)
Attn: Gibson Barbee, P.E.
gvbarbee@nscorp.com

Soo Line (SOO)
Canadian Pacific Railway
Environmental Services
Attn: Grete Bridgewater
Tel: 403-319-6142

Union Pacific (UP)
No contact information provided

FAX

Date: ________________

To: Arlene Jeffcoat — Fax Phone: 202.565.9016

From: ___________________ — Fax Phone: ____________

Subject: Request for R-1 schedules

Number of pages including this one: 1

Please send me copies of Schedules 750 and 755 from the R-1 forms for the following Class I railroads for calendar year _____.

____Burlington Northern Santa Fe

____CSX Transportation

____Grand Trunk Corporation

____Kansas City Southern

____Norfolk Southern

____Soo Line

____Union Pacific

Please mail these to the following address:

____

____

____

____

I understand that you will bill me at a cost of one dollar ($1) per page for these schedules. Please send the bill to address shown above.

Please give me a call at ______________ if you have any questions about this request.