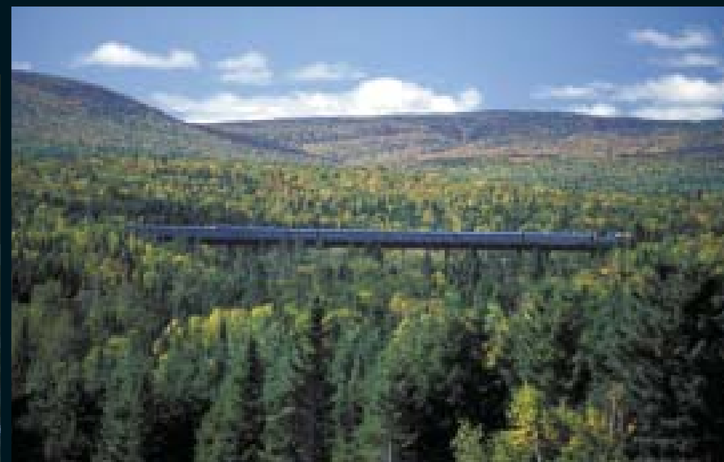
EPS 2/TS/17
December 2003

Transportation Systems Division
Air Pollution Prevention Directorate
Environment Canada

Environmental Protection Series

# Locomotive Emissions Monitoring Program 2002



Environment Canada
Environnement Canada

Canada

RAC

Environmental Protection Series

## Sample Number

| EPS | 3 / | HA / | 1 |
|---|---|---|---|
| Environmental Protection Series | Report Category | Subject Area Code | Report Number with the qualifer EPS 3/HA |

## Categories

1 Regulations/Guidelines/Codes of Practice
2 Problem Assessment and Control Options
3 Research and Technology
4 Literature Reviews
5 Surveys
6 Social, Economic and Environmental Impact Assessments
7 Surveillance
8 Policy Proposals and Statements
9 Manuals

## Subjects

AG Agriculture
AN Anaerobic Technology
AP Airborne Pollutants
AT Aquatic Toxicity
BT Biotechnology
CC Commercial Chemicals
CE Consumers and the Environment
CI Chemical Industries
FA Federal Activities
FP Food Processing
HA Hazardous Wastes
IC Inorganic Chemicals
MA Marine Pollutants
MM Mining and Ore Processing
NR Northern and Rural Regions
PF Paper and Fibres
PG Power Generation
PN Petroleum and Natural Gas
RA Refrigeration and Air Conditioning
RM Reference Methods
SF Surface Finishing
SP Oil and Chemical Spills
SRM Standard Reference Methods
TS Transportation Systems
TX Textiles
UP Urban Pollution
WP Wood Protection/Preservation

# Locomotive Emissions Monitoring Program 2002


## National Library of Canada cataloguing in publication data

**Locomotive Emissions Monitoring Program 2002**

(Environmental protections series: EPS 2/TS/17)
Text in English and French on inverted pages.
Title on added t.p.: Programme de surveillance des émissions des locomotives 2002.
"RAC, The Railway Association of Canada"

ISBN 0-662-36167-9
Catalogue Number EN49-1/2-17



1. Locomotives – Environmental aspects – Canada – Periodicals.
2. Air – Pollution – Canada – Measurement – Periodicals.
3. Environmental monitoring – Canada – Periodicals.
I. Canada, Environment Canada.
II. Railway Association of Canada.
III. Series: Information report (Canada. Environment Canada); EPS 2/TS/17.
IV. Title

T885.5N5L62 2004 385'.36'0971


## Readers' Comments

Comments on the contents of this report may be addressed to:


Transportation Systems Branch
Air Pollution Prevention Directorate
Environment Canada
Otawa, Ontario
K1A 0H3


## Review Notice

This report has been reviewed by members of the Transportation Systems Branch, Environment Canada, and approved for publication. Approval does not necessarily signify that the contents reflect the views and policies of Environment Canada. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

This report has been prepared by the Railway Association of Canada in partnership with Environment Canada for the Transportation System Branch, Air Pollution Prevention Directorate, Environment Canada.

2002

# Executive Summary

This report contains the Railway Association of Canada's (RAC) Locomotive Emissions Monitoring (LEM) filing for 2002 under the terms of the Memorandum of Understanding (MOU) between Environment Canada and the RAC, signed in 1995 and covering the period 1990–2005.

Data is collected by the RAC for this LEM through a questionnaire sent annually to each railway according to a RAC LEM Protocol. The LEM data reported by the RAC include locomotive inventory, annual traffic volumes and annual diesel fuel consumption for mainline, branch line, yard switching and passenger service. Included in this document are the annual emissions of oxides of nitrogen, carbon dioxide, hydrocarbons, oxides of sulphur, particulate matter, and carbon monoxide. The report also details measures being undertaken to reduce fuel consumption and emissions.

The railways also calculate and report on their fuel consumption and emissions in three designated Tropospheric Ozone Management Areas (TOMA): the Lower Fraser Valley in British Columbia, the Windsor–Quebec City Corridor, and the Saint John area in New Brunswick. The data for winter and summer operations is also segregated.

Litres of fuel per 1000 revenue tonne-kilometers (RTK) increased to 6.08 in 2002 from 5.96 in 2001 and are down from 7.83 in 1990, a decrease of 22.3 percent. Canada's freight railways handled 320.7 billion RTK of traffic in 2002 compared to 321.7 billion RTK in 2001 and consumed slightly more fuel. Overall rail fuel consumption increased to 2,051 million litres (L) in 2002 from 2,017 million L in 2001. Traffic growth, measured in gross tonne-kilometers (GTK), has increased an average of 2.2 percent per year since 1990. This is significantly higher than the 1.2 percent predicted when the MOU was originally signed in 1995.

Intermodal carloads increased from 637,443 in 2001 to 690,933 in 2002, an increase of 8.4 percent from 2001. Intermodal tonnage increased from 22.59 million tonnes in 2001 to 26.14 million tonnes in 2002, an increase of 15.7 percent from 2001. Overall intermodal tonnage has grown 104.3 percent since 1990 and container on freight car (COFC) tonnage has increased 175.3 percent since 1990. The growth of COFC in intermodal traffic is the result of the success of Canadian railways in developing strategic partnerships with shippers and trucking companies for the transportation of goods.

Intercity passenger traffic increased to 4.22 million passengers in 2002 from 4.11 million passengers in 2001, an increase of 2.7 percent. Intercity train efficiency, expressed as the average passenger kilometers per train kilometer, has increased by 10.7 percent since 1990. Commuter rail traffic increased from 47.97 million passengers in 2001 to 49.25 million passengers in 2002, also an increase of 2.7 percent and up from 4,022 million passengers in 1990, an increase of 20.1 percent. Since 1997 commuter rail passengers have increased by 20.1 percent. Overall intercity and commuter rail fuel consumption increased by 2.9 percent from 2001.

The Emissions Factor (EF) for the oxides of nitrogen ($NO_x$) for freight locomotives that was introduced in 2001 was used again in 2002. The RAC calculates the EF annually to ensure the values being used in the calculations accurately reflect the emissions profile of the current fleet of locomotives. Canadian railways will continue to purchase locomotives meeting U.S EPA emissions compliance requirements, and will continue to upgrade locomotives, at overhaul, to U.S. EPA Tier 0; hence, the EF of the locomotive fleet is expected to decrease.

Kilotonnes of $NO_x$ per 1000 RTK are 17.1 percent lower than in 1990, decreasing from 0.43 in 1990 to 0.36 in 2002 despite an increase of 28.2 percent in RTK. Total rail $NO_x$ emissions in 2002 for the rail sector, calculated using the new factor, were 120.21 kilotonnes (kt), slightly above the value of 118.36 kt reported in 2001, and are above the voluntary cap of 115 kt. Similarly, $CO_2$ emissions, measured as kilotonnes per 1000 RTK, have decreased 23.2 percent since 1990 from 21.21 in 1990 to 16.30 in 2002. Total carbon dioxide emissions for the rail sector were 5,548 kt in 2002, up from 5,462 kt in 2001. $CO_2$ emissions have declined by 7.4 percent since the peak year 1997, and by 0.6 percent since 1990.

Canada's railways continue to invest in new locomotives, lower weight aluminum freight cars and high capacity freight cars. They have also introduced automatic stop/start devices and low idle settings on locomotives. Operational advantages such as the co-production agreement between CN and CP in the Fraser canyon also reduce fuel consumption.

In conclusion, Canada's railways have reduced fuel consumption by 0.5 percent since 1990 while increasing RTK by 28.2 percent, demonstrating a steady improvement in the area of fuel efficiency and reducing atmospheric emissions per unit of tonnage hauled.

# Glossary of Terms

**Terminology of Diesel Locomotive Emissions and Related Technology**

**Duty Cycle**: The duty cycle for a locomotive refers to the percentage of time the locomotive is operated at different power settings. Locomotives have eight power settings or "notches" plus low idle, idle and dynamic braking settings.

**Dynamic Braking**: A term characterizing a train-operating mode in which the traction motors of a locomotive are controlled to function as generators and, hence, retard the motion of the train. Dynamic braking requires an application of engine power equivalent to Notch 1 or 2 throttle setting. Dynamic braking reduces fuel consumption and, hence, exhaust emissions by eliminating braking under power (to keep the train stretched out).

**Emissions Factors**: The emissions factors of a locomotive are the average mass of a product which is emitted in the combustion of a specified amount of fuel. They are calculations based on data from test measurements of specific emissions, its operational duty cycle and the specific fuel consumption of its engine. In this report the units are grams of a specific pollutant per litre of diesel fuel consumed (g/L).

**Gross Tonne-Kilometers (GTK)**: refer to the product of the tonnes carried and the distance traveled; the tonnes carried are the total weight of the train including both loaded and empty cars but excluding the contribution of the weight of the locomotives pulling the train.

**Intermodal Service**: The movement of trailers or containers by rail and at least one other mode of transportation. Import and export containers generally are shipped via marine and rail. Domestic intermodal service usually involves truck and rail. It includes both container on flat car (COFC) and trailer on flat car (TOFC) movements.

**Locomotive Prime Mover**: The medium-speed diesel engine provides the predominant motive power for locomotives in operation on Canadian railways. It has found its niche as a result of its fuel efficiency, ruggedness, reliability and installation flexibility. Combustion takes place in a diesel engine by compressing air and then injecting diesel fuel near top dead centre where auto-ignition occurs (compression ignition).

**Low-idle and Engine Shut-down Options**: Outfitting locomotive engines with a low-idle option and, when in standby use, outfitting them with mechanisms for automatic engine shutdown and restart (to avoid water coolant freezing) leads to reduced overall locomotive fuel consumption and emissions.

**Products of Combustion**: The products of combustion include carbon dioxide, water vapour, partially combusted fuel (hydrocarbons and particulate matter), carbon monoxide, and the oxides of nitrogen and sulphur. The high temperatures typical of combustion in the cylinder of a diesel engine cause oxygen and nitrogen from the intake air to combine as oxides of nitrogen ($NO_x$). $NO_x$ is an invisible, toxic gas and a precursor to low level ozone development and can form fine aerosol particles of salts that contribute to acidic precipitation (commonly known as acid rain, snow or fog). If the combustion temperature is decreased to reduce $NO_x$, the amount of non-combusted fuel that may be emitted as particulate matter (PM) or gaseous hydrocarbons (HC) tends to increase. HC reacts with $NO_x$ and other pollutants to form ground-level ozone (smog). Pollutants referred to in this report are:

**CO (Carbon Monoxide)**: This toxic gas is a by-product of the combustion of fossil fuels. Relative to other prime movers, it is low in diesel engines.

**$CO_2$ (Carbon Dioxide)**: This gas is by far the largest by-product of combustion emitted from engines and is the principal greenhouse gas which, because of its accumulation in the atmosphere, is considered to be the principal contributor to global warming. $CO_2$ and water vapour are normal by-products of the combustion of fossil fuels. One way to reduce $CO_2$ emissions is to reduce fuel consumption.

**HC (Hydrocarbons)**: These are the result of incomplete combustion of diesel fuel and small amounts of lubricating oil that are not oxidized during the combustion process. HC emissions result from partial combustion caused by short combustion time and low combustion temperatures, which can occur during excessive idling at low power levels.

**$NO_x$ (Oxides of Nitrogen)**: These are the products of nitrogen and oxygen that result from high combustion temperature. $NO_x$ reacts with hydrocarbons in the air to form low level ozone in the presence of sunlight. The $NO_x$ emission level can be lowered by reducing combustion temperatures; one way is to retard injection timing and another is exhaust gas recirculation, both of which could result in higher fuel consumption and lower total power from the engine.

**PM (Particulate Matter)**: This is residue of combustion consisting of soot, unburned fuel, the oxides of sulphur and lubricating oil. Increasing the combustion temperatures and duration can lower PM. Technologies that control $NO_x$, such as retarding injection timing, usually result in higher PM emissions. Conversely, technologies that control PM often result in increased $NO_x$ emissions.

**$SO_x$ (Oxides of Sulphur)**: These are the result of burning diesel fuels that contain sulphur compounds. These emissions can be reduced by using diesel fuel with lower sulphur content.

**RAC LEM Protocol**: refers to the collection of financial and statistical data from RAC members and the RAC database where this data is systematically stored for various RAC applications. Data from the RAC's database that is used in this report includes revenue tonne kilometres, gross tonne kilometres, Intermodal tonnes, passenger traffic statistics, fuel consumption and locomotive inventory. Much of this data is also reported by the Class 1's in their "Annual Report" and "Financial and Related Data" submissions to Transport Canada.

**Revenue Tonne-Kilometers (RTK)**: refer to the product of the tonnes of goods carried and the distance traveled; the tonnes of goods carried refer to the total weight of the goods in the cars of the train handled over the distance moved and excludes the tonne-kilometers involved in the movement of railway materials.

# Abbreviations Used in this Report

| | |
|---|---|
| AAR | Association of American Railroads |
| CCME | Canada Committee of the Ministers of the Environment |
| CN | Canadian National Railways |
| COFC | Container on Flat Car |
| CP | Canadian Pacific Railway |
| $CO_2$ | Carbon Dioxide |
| CO | Carbon Monoxide |
| CAC | Criteria Air Contaminants |
| DB | Dynamic Brake |
| EF | Emissions Factor |
| EC | Environment Canada |
| GE | General Electric Transportation |
| GM/EMD | General Motors - Electromotive Division |
| g | Gram |
| g/GTK | Grams per gross tonne-kilometers |
| g/L | Grams per litre |
| g/RTK | Grams per net tonne-kilometers |
| GTK | Gross tonne-Kilometers |
| HP | Horsepower |
| hr | Hour |
| HC | Hydrocarbons |
| kt | Kilotonnes |
| kg/1000 RTK | Kilograms per 1000 revenue tonne-kilometers |
| L | Litre |
| L/hr | Litres/hour |
| LEM | Locomotive Emissions Monitoring |
| MOU | Memorandum of Understanding |
| MLW | Montreal Locomotive Works |
| N1, N2 ... | Notch 1, Notch 2.... |
| $NO_x$ | Oxides of Nitrogen |
| $SO_x$ | Oxides of Sulphur |
| PM | Particulate Matter |
| ppm | parts per million |
| lb | Pounds |
| RAC | Railway Association of Canada |
| RTK | Revenue Tonne-Kilometers |
| SwRI | Southwest Research Institute |
| TOFC | Trailer on Flat Car |
| TOMA | Tropospheric Ozone Management Areas |
| U.S. EPA | United States Environmental Protection Agency |
| VIA | Via Rail Canada |

# Table of Contents



**List of Tables**



**List of Figures**



**Appendicies**

# 1 Introduction

Photo courtesy of CN

Attached as Appendix A are the terms of the Memorandum of Understanding (MOU) between Environment Canada (EC) and the Railway Association of Canada (RAC) with respect to control of emissions produced by locomotives. Data are collected by the RAC for this Locomotive Emissions Monitoring (LEM) report through a questionnaire sent annually to each railway according to a RAC LEM Protocol. The MOU requires the RAC to submit an annual LEM report to EC. The LEM report is to include calendar year data on all rail traffic, diesel fuel consumption and locomotive exhaust emissions including the oxides of nitrogen ($NO_x$), carbon dioxide, hydrocarbons (HC), carbon monoxide (CO), particulate matter (PM) and the oxides of sulphur ($SO_x$). Of particular interest are emissions of oxides of nitrogen ($NO_x$) vis-à-vis the voluntary cap of 115 kt per year targeted in the MOU.

Separate sections of the report highlight traffic, locomotive emissions, and carbon dioxide ($CO_2$). Also included is a section on initiatives to reduce fuel consumption, and consequently, $CO_2$ emissions, a greenhouse gas. There is also a section reporting on traffic, fuel consumption and emissions in three designated Tropospheric Ozone Management Areas (TOMA): the Lower Fraser Valley in British Columbia, the Windsor–Quebec City Corridor, and the Saint John area in New Brunswick.

The MOU expires in 2005 and the RAC is negotiating a new MOU with both Environment Canada and Transport Canada regarding locomotive emissions.

Starting with the 2001 issue, 1990 was selected as the base year for historical data. Statistics dating from 1975 can be found in earlier (LEM) reports[(1)]. The significance of this change reflects the relevance of the Kyoto protocol which also specifies 1990 as the base year for emissions comparisons.

Metric units are used in this report. Gross ton-miles and net ton-miles referred to in earlier reports have been replaced by gross tonne-kilometers (GTK) and revenue tonne-kilometers (RTK).

(1) 1995 LEM – EPS 2/TS/10 – November 1997;
1996 and 1997 LEM – EPS 2/TS/11 – May 1999;
1998 LEM – EPS 2/TS/13 – October 2000;
1999 and 2000 LEM – EPS 2/TS/15 – April 2002

# 2 Traffic and Fuel Consumption Data

## 2.1 Traffic

As shown in Table 1, there has been overall growth in freight traffic since 1990, although since 2000 there has been a slight decline in traffic by 0.5 percent. GTK increased from 454.94 billion in 1990 to 582.06 billion in 2002, a 27.9 percent increase in freight traffic. Similarly, RTK increased from 250.13 billion in 1990 to 320.69 billion in 2002, a 28.2 percent increase. These data are shown in Figure 1.

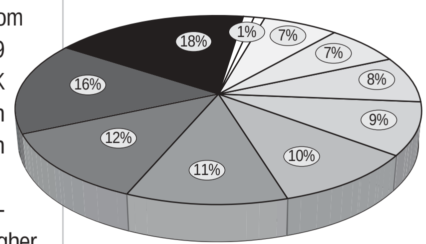
Annual growth in traffic since 1990 has been approximately 2.2 percent per year. This is significantly higher than the annual 1.2 percent increase in GTK and 1.5 percent increase in RTK predicted in 1995 when the MOU was signed. Traffic growth is expected to follow North American economic activity.

Canadian rail freight commodity carloads for 2002 are shown in Figure 2. Of note, is the 18 percent of carloads for intermodal traffic.

*Figure 2*

**Freight Carloads by Commodity Group – 2002**

*Originatesd carloads by commodity grouping*




18% Intermodal
16% Minerals
12% Fuels & Chemicals
11% Forest Products
10% Agriculture
9% Coal
8% Metals
7% Paper Products
7% Machinery & Auto
1% Food Products
1% Manufactured & Miscellaneous

Figure 1

**Freight Traffic**

*Tonne kilometres (billion)*

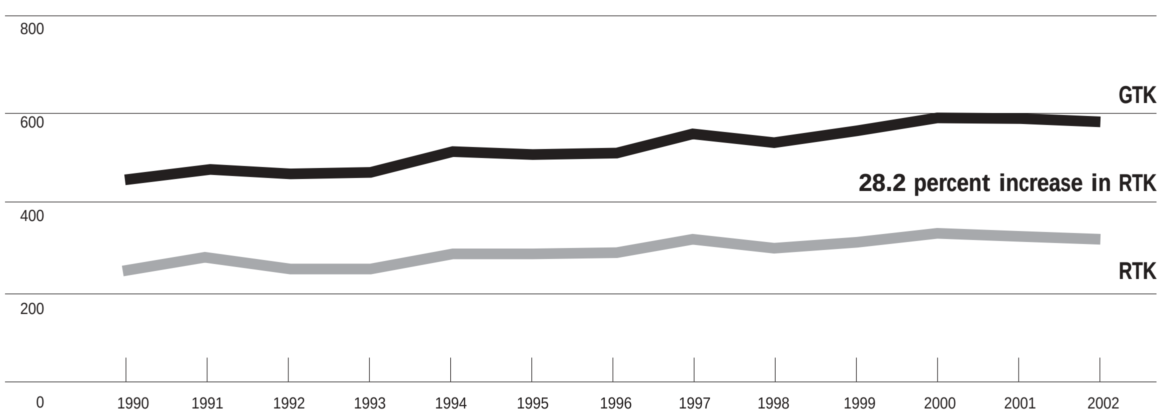


Table 1

**Traffic and Fuel Consumption**

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Freight Traffic** | | | | | | | | | | | | | |
| Gross tonne-kilometers *Billion GTK* | 454.9 | 476.2 | 462.2 | 466.8 | 521.8 | 505.7 | 505.9 | 544.1 | 529.7 | 554.8 | 586.6 | 583.2 | 582.1 |
| Revenue tonne-kilometers *Billion RTK* | 250.1 | 262.4 | 252.5 | 257.8 | 288.9 | 282.4 | 283.9 | 304.2 | 297.0 | 302.0 | 322.4 | 321.7 | 320.7 |
| *Ratio of RTK/GTK* | 0.550 | 0.550 | 0.546 | 0.552 | 0.554 | 0.559 | 0.561 | 0.559 | 0.561 | 0.544 | 0.550 | 0.552 | 0.551 |
| **Fuel Consumption Data** | | | | | | | | | | | | | |
| Freight Service *million litres* | 1,823 | 1,878 | 1,824 | 1,813 | 1,934 | 1,937 | 1,872 | 2,031 | 1,881 | 1,800 | 1,836 | 1,823 | 1,870 |
| Yard Switching Service *million litres* | 120 | 120 | 121 | 124 | 137 | 140 | 136 | 113 | 118 | 87 | 87 | 89 | 74 |
| Work Train Service *million litres* | 16 | 13 | 15 | 12 | 12 | 10 | 7 | 6 | 7 | 5 | 4 | 5 | 6 |
| Total Freight Operations *million litres* | 1,958 | 2,012 | 1,960 | 1,948 | 2,083 | 2,087 | 2,014 | 2,150 | 2,007 | 1,892 | 1,927 | 1,918 | 1,950 |
| Passenger Fuel *million litres* | 103 | 72 | 64 | 69 | 60 | 56 | 59 | 61 | 59 | 58 | 61 | 99 | 101 |
| Total Fuel – All Operations *million litres* | 2,061 | 2,084 | 2,024 | 2,017 | 2,143 | 2,143 | 2,073 | 2,211 | 2,066 | 1,950 | 1,988 | 2,017 | 2,051 |
| Litres per 1,000 GTK *Total Freight* | 4.3039 | 4.2193 | 4.2404 | 4.1744 | 3.9919 | 4.1272 | 3.9810 | 3.9513 | 3.7884 | 3.4101 | 3.2853 | 3.2888 | 3.3499 |
| Litres per 1,000 RTK *Total Freight* | 7.8281 | 7.6667 | 7.7635 | 7.5559 | 7.2111 | 7.3892 | 7.0945 | 7.0618 | 6.7584 | 6.2657 | 5.9774 | 5.9613 | 6.0804 |

## 2.2 Intermodal Service

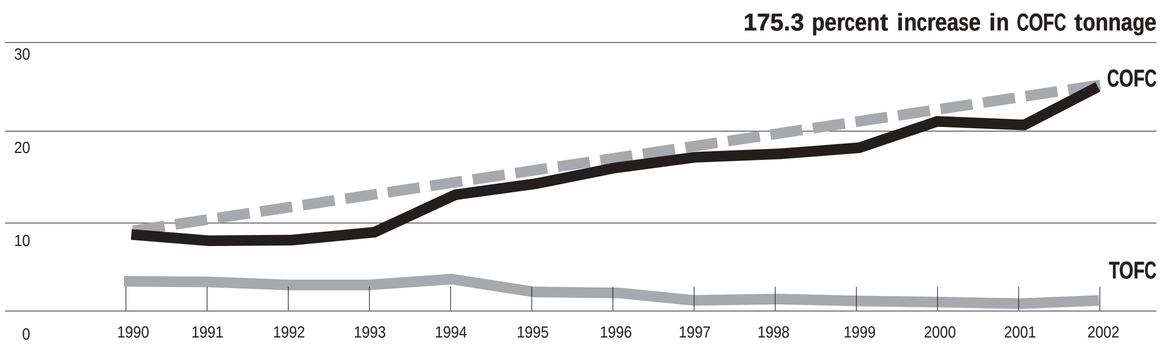
Intermodal activity continues to grow rapidly. Growth in domestic intermodal service is an indication that Canadian railways have been effective in partnering with shippers and the trucking industry to affect a modal shift in the transportation of goods. Each domestic carload replaces approximately 2.8 trucks[(2)] from Canadian highways. As shown in Figure 2, intermodal carloads represent 18 percent of total rail carloads by commodity.

Canadian Intermodal carloads increased from 637,443 in 2001 to 690,933 in 2002, an increase of 8.4 percent. Intermodal tonnage increased from 22.59 million tonnes in 2001 to 26.14 million tonnes in 2002, an increase of 15.7 percent from 2001. The growth in overall intermodal tonnage has been 104.3 percent since 1990.

Container on flat car (COFC) traffic increased 15.7 percent – from 21.59 million tonnes in 2001 to 24.97 million tonnes in 2002. Since 1990 the increase in COFC traffic was 175.3 percent. Trailer on flat car (TOFC) traffic increased slightly from 1.00 million tonnes in 2001 to 1.17 million tonnes in 2002. Intermodal tonnage growth since 1990 is shown in Figure 3.

(2) AAR/RAC

Figure 3
**Intermodal Traffic**
*Tonnes (millions)*



## 2.3 Rail Passengers

### 2.3.1 Intercity Rail

The number of intercity rail passengers in 2002 was 4.22 million, up from 4.11 million in 2001, an increase of 2.7 percent. The growth in intercity rail passengers since 1990 is 5.0 percent and is shown in Figure 4. Fuel consumption is 1.3 percent lower in 2002 compared to 2001.

Intercity train efficiency can be expressed as the average passenger kilometers per train kilometer. As shown in Figure 5 train efficiency has been increasing.

Figure 4
**Intercity Rail Passengers**
*millions*

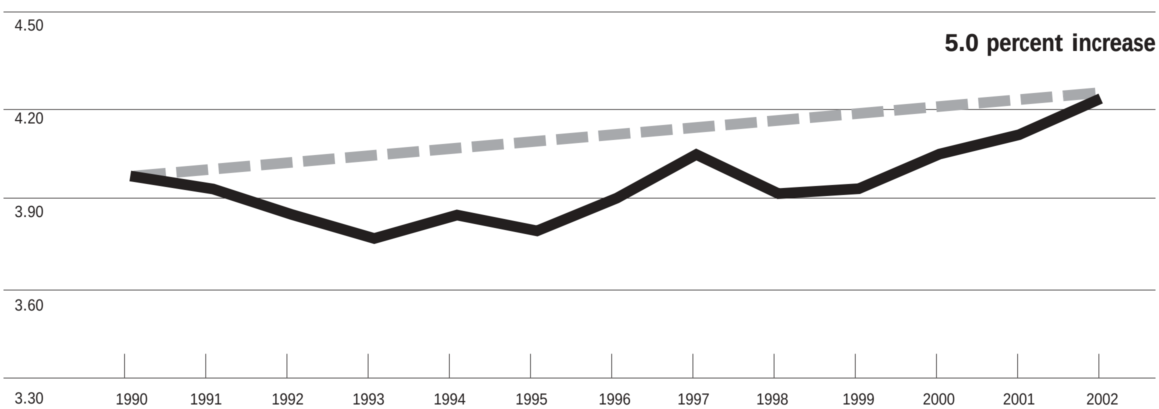
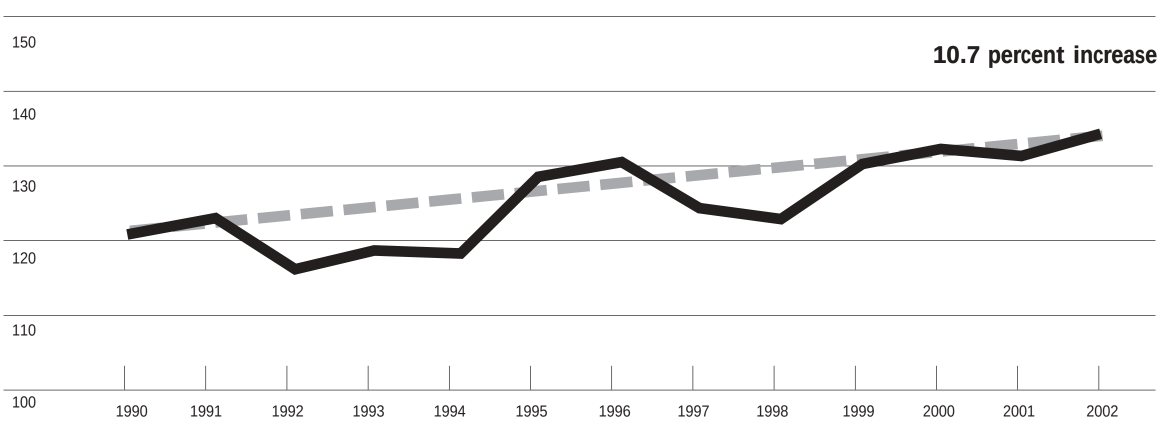



Figure 5
**Intercity Rail Passengers Efficiency**
*passenger Km per train Km*



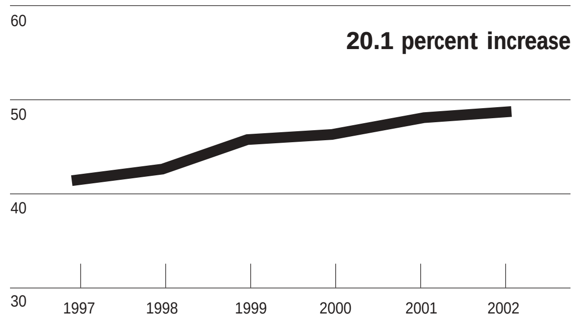
## 2.3 Rail Passengers

### 2.3.2 Commuter Rail

The number of commuter rail passengers in 2002 was 49.25 million. This is up 2.7 percent from 47.97 million in 2001, and, as shown in Figure 6, is up 20.1 percent from 41.00 million in 1997, when the RAC first started to collect commuter rail statistics. The average annual growth in commuter rail passengers is 3.8 percent. Commuter rail fuel consumption is up by 12.2 percent from 2001.

Overall intercity and commuter rail fuel consumption increased by 2.9 percent from 2001.

Figure 6
**Commuter Rail Passengers**
*passengers (millions)*




Commuter rail operators reporting are AMT (Montreal), Capital (Ottawa), GO Transit (Toronto) and West Coast Express (Vancouver).

## 2.4 Freight Fuel Consumption

As shown in Table 1 and Figure 7, freight locomotive fuel consumption decreased from 1,958 million litres (L) in 1990 to 1,950 million L in 2002, a 0.4 percent decrease. Total rail fuel consumption decreased from 2,061 million L in 1990 to 2,051 million L in 2002, an overall 0.5 percent decrease.

Canadian freight railways aim to further reduce fuel consumption per 1,000 RTK by continuing a fleet replacement policy of purchasing modern locomotives while retiring older less fuel efficient locomotives. As well, operating practices that reduce fuel consumption will continue to be evaluated and implemented. Fuel consumption reduction initiatives are detailed in Section 4.0.

In 2002, Canadian freight railways hauled 28.2 percent more RTK tonnage with 0.5 percent less fuel than 1990. This fact clearly shows the results of fuel conservation practices put in place by the railways.

The efficiency with which freight traffic was handled has improved overall since 1990, with the improvement between 1997 and 2000 being at a higher rate than average. This value decreased from 7.83 L per 1,000 RTK in 1990 to 6.07 L per 1,000 RTK in 2002, a 22.3 percent reduction and is shown in Figure 8. This shows clearly the success of the Canadian freight railways to accommodate higher traffic growth while reducing fuel consumption.

Figure 7
**Total Freight Fuel Consumption**
*fuel consumption ($Lx10^6$)*

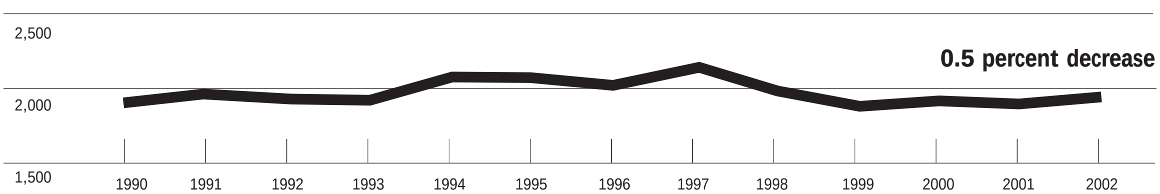
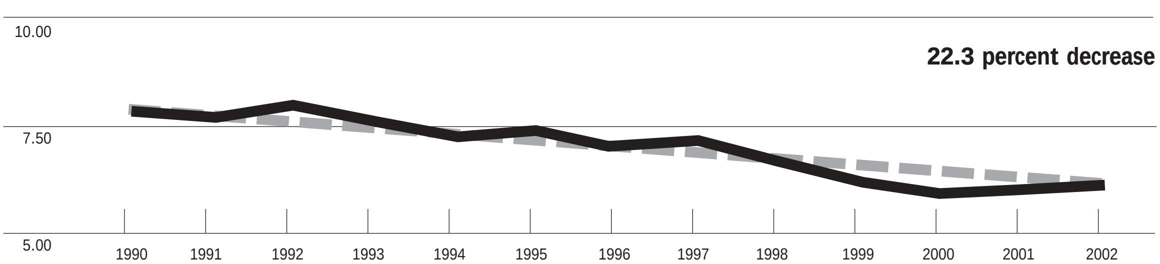



Figure 8
**Freight Fuel Consumption per 1,000 RTK**
*litres per 1,000 RTK*



# 3 Locomotive Emissions

### 3.1 Introduction

The emissions from locomotive operations have been calculated using Emissions Factors (EF) giving quantities of selected exhaust gases and particulate matter per litre of fuel consumed. Emissions factors are based on emissions data for the different engines in the various throttle notch settings applied to the duty cycle for locomotive operation applicable to Canadian service. These factors were derived from test measurements, in the early 1990s, by the Association of American Railroads (AAR) and the locomotive manufacturers [3]. Since then there has been further testing by the U.S. Environmental Protection Agency (EPA) at Southwest Research Institute on the newest high-horsepower locomotives plus changes in operational duty cycle of locomotives. The Emissions Factor (EF) for $NO_x$, agreed upon by EC and the RAC in 2001, was again used for the 2002 LEM emissions calculations [4].

Emissions are calculated for oxides of nitrogen ($NO_x$), carbon monoxide (CO), hydrocarbons (HC), oxides of sulphur ($SO_x$), particulate matter (PM), and carbon dioxide ($CO_2$) for the several types of service and for the total for all railway operations.

### 3.2 Canadian Locomotive Fleet

The fleet of locomotives operating in 2002 in Canada is shown in Appendix B.

Canadian railways have been renewing their fleets since the early 1990s with new fuel-efficient, higher horsepower locomotives. New locomotives, purchased since 2000, meet U.S. EPA Tier 0 and Tier 1 emissions limits, which came into effect in 2000 and 2002 respectfully. There is a direct correlation between U.S. EPA compliant locomotives and lower $NO_x$. For example, Canadian $NO_x$ emissions in 2002 are 4.5 percent lower than they would otherwise be if non-EPA compliant locomotives had been purchased since 2000. Table 2 shows the introduction rate of these new locomotives and those meeting either Tier 0 or Tier 1.

Canadian railways continue upgrading their locomotives to EPA Tier 0 level when overhauled. The U.S. EPA has estimated that it could take 20 years to replace the entire U.S. fleet with EPA compliant locomotives. At that time, as shown in Table 3, Tier 2 locomotive $NO_x$ emissions will be 59.2% lower than pre-2000 locomotives.

Table 2

**New Locomotives Introduced into the Canadian Fleet**

| Model | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|
| Total New higher horsepower locomotives* | 225 | 350 | 565 | 568 | 657 | 680 | 707 | 722 |
| Number of Locomotives that are U.S. EPA Tier 0 or 1 | 0 | 0 | 0 | 0 | 0 | 80 | 179 | 198 |

** EMD SD-75, SD-90 and GE Dash 9, P42DC*

Table 3

**$NO_x$ Emissions Reduction for Line-Haul Locomotives**

| | Year | $NO_x$ (g/bhp hr) | Percent Reduction |
|---|---|---|---|
| Non-compliant Locomotives | Pre- 2000 | 13.5 | |
| Tier 0 | 2000 | 9.5 | 29.6 |
| Tier 1 | 2002 | 7.4 | 45.2 |
| Tier 2 | 2005 | 5.5 | 59.2 |

(3) See Tables 10 and 12 in EPS 2/TS/8, Recommended Reporting Requirements for the Locomotive Emissions Monitoring (LEM) Program – September 1994

(4) Review of Memorandum of Understanding Between Environment Canada and the Railway Association of Canada Regarding Railway Locomotive Emissions – June 2001.


## 3.3 Emissions

### 3.3.1 Oxides of Nitrogen ($NO_x$)

$NO_x$ emissions are related to the emissions profile of individual locomotive types. Canadian railways are committed to purchasing new locomotives that meet U.S. EPA emissions limits. $NO_x$ emissions, therefore, should decrease as the railways continue to introduce new locomotives, meeting Tier 1 and Tier 2, and overhaul older main-line locomotives to Tier 0.

As shown in Table 4, total rail $NO_x$ emissions were 120.2 kt in 2002 up slightly from 2001. Figure 9 shows the historical record since 1990 vis-a-vis the voluntary cap of 115 kt targeted in the MOU. The average annual $NO_x$ emissions since 1990 are 114.5 kt. Freight operations account for 95 percent of railway generated $NO_x$ emissions in Canada.

Kilotonnes of $NO_x$ per 1000 RTK has decreased 17.1 percent since 1990 decreasing from 0.43 in 1990 to 0.36 in 2002 despite an increase in RTK of 28.2 percent. The value of total $NO_x$ emissions per work unit is shown in Figure 10.

The purchase of new fuel-efficient locomotives and other fuel consumption reduction initiatives, discussed in section 4, will result in a continuing decrease in $NO_x$ per unit of work.

Figure 9
**NOx Emissions**
*NOx Emissions (kilotonnes)*

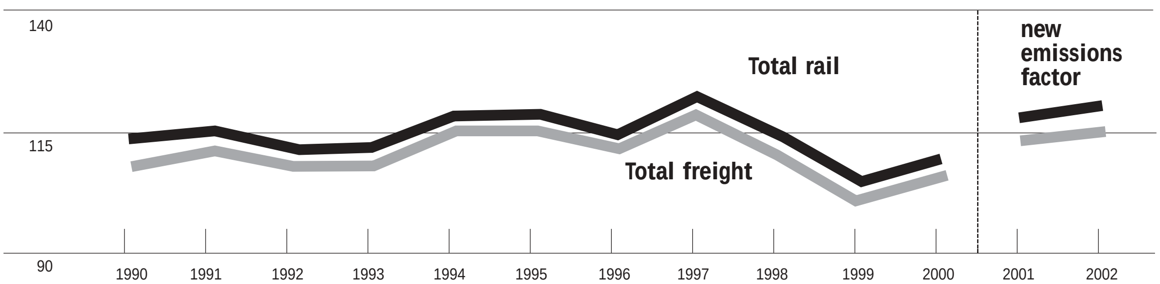



Figure 10
**Freight $NO_x$ Emissions per 1,000 RTK**
*NOx Emissions (kg/1,000 RTK)*

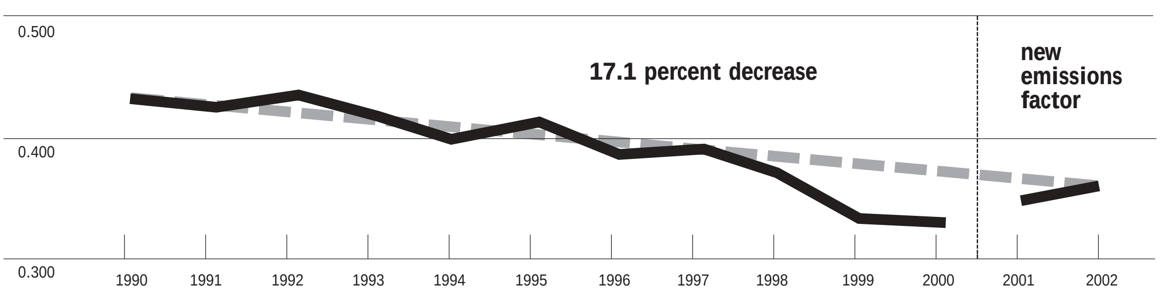


Table 4a

## Locomotive Emissions, 1990 - 1995

| Annual Emissions | | Emissions Factors | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Freight & Passenger g/L | | Yard & Work g/L | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
| | | | | | kilotonnes | | | | | |
| **Freight – Mainline & Branchline** | | **1990-2000** | **2001-2002** | | | | | | | |
| | $NO_x$ | 54.69 | 58.81 | | 99.68 | 102.73 | 99.77 | 99.16 | 105.77 | 105.93 |
| | CO | 10.51 | | | 19.15 | 19.73 | 19.17 | 19.05 | 20.32 | 20.35 |
| | HC | 2.73 | | | 4.98 | 5.13 | 4.98 | 4.95 | 5.28 | 5.29 |
| Adjusted to 0.15% Sulphur Fuel | $SO_x$ | 2.54 | | | 4.62 | 4.76 | 4.63 | 4.60 | 4.91 | 4.91 |
| | PM | 1.30 | | | 2.37 | 2.44 | 2.37 | 2.36 | 2.51 | 2.52 |
| Based on 86.5% Carbon Fuel | $CO_2$ | 2709 | | | 4,938 | 5,089 | 4,942 | 4,912 | 5,239 | 5,248 |
| **Yard Switching & Work Train** | | | | | | | | | | |
| | $NO_x$ | | | 61.01 | 8.27 | 8.14 | 8.28 | 8.26 | 9.07 | 9.14 |
| | CO | | | 10.42 | 1.41 | 1.39 | 1.41 | 1.41 | 1.55 | 1.56 |
| | HC | | | 3.61 | 0.49 | 0.48 | 0.49 | 0.49 | 0.54 | 0.54 |
| Adjusted to 0.15% Sulphur Fuel | $SO_x$ | | | 2.53 | 0.34 | 0.34 | 0.34 | 0.34 | 0.38 | 0.38 |
| | PM | | | 1.48 | 0.20 | 0.20 | 0.20 | 0.20 | 0.22 | 0.22 |
| Based on 86.5% Carbon Fuel | $CO_2$ | | | 2,709 | 367 | 362 | 368 | 367 | 403 | 406 |
| **Passenger** | | | | | | | | | | |
| | $NO_x$ | 54.69 | | | 5.63 | 3.94 | 3.50 | 3.77 | 3.28 | 3.06 |
| | CO | 10.51 | | | 1.08 | 0.76 | 0.67 | 0.72 | 0.63 | 0.59 |
| | HC | 2.73 | | | 0.28 | 0.20 | 0.17 | 0.19 | 0.16 | 0.15 |
| Adjusted to 0.15% Sulphur Fuel | $SO_x$ | 2.54 | | | 0.26 | 0.18 | 0.16 | 0.18 | 0.15 | 0.14 |
| | PM | 1.30 | | | 0.13 | 0.09 | 0.08 | 0.09 | 0.08 | 0.07 |
| Based on 86.5% Carbon Fuel | $CO_2$ | 2,709 | | | 279 | 195 | 173 | 187 | 163 | 152 |
| **Total – Rail Operations** | | | | | | | | | | |
| | $NO_x$ | 54.69 | | 61.01 | 113.59 | 114.81 | 111.55 | 111.19 | 118.12 | 118.13 |
| | CO | 10.51 | | 10.42 | 21.64 | 21.88 | 21.25 | 21.19 | 22.50 | 22.50 |
| | HC | 2.73 | | 3.61 | 5.75 | 5.81 | 5.65 | 5.63 | 5.98 | 5.98 |
| Adjusted to 0.15% Sulphur Fuel | $SO_x$ | 2.54 | | 2.53 | 5.23 | 5.29 | 5.13 | 5.12 | 5.43 | 5.43 |
| | PM | 1.30 | | 1.48 | 2.70 | 2.73 | 2.65 | 2.65 | 2.81 | 2.81 |
| Based on 86.5% Carbon Fuel | $CO_2$ | 2,709 | | 2,709 | 5,584 | 5,645 | 5,484 | 5,466 | 5,805 | 5,805 |
| **Emissions from Freight Operations** | | | | | | | | | | |
| | $NO_x$ | 54.69 | 58.81 | 61.01 | 107.95 | 110.87 | 108.05 | 107.42 | 114.84 | 115.07 |
| | CO | 10.51 | | 10.42 | 20.56 | 21.13 | 20.58 | 20.46 | 21.87 | 21.91 |
| | HC | 2.73 | | 3.61 | 5.47 | 5.61 | 5.47 | 5.44 | 5.82 | 5.83 |
| Adjusted to 0.15% Sulphur Fuel | $SO_x$ | 2.5 | | 2.53 | 4.97 | 5.10 | 4.97 | 4.94 | 5.28 | 5.29 |
| | PM | 1.3 | | 1.48 | 2.57 | 2.64 | 2.57 | 2.56 | 2.73 | 2.74 |
| Based on 86.5% Carbon Fuel | $CO_2$ | 2709 | | 2709 | 5,305 | 5,450 | 5,310 | 5,279 | 5,642 | 5,653 |
| **Emissions from Freight Traffic Unit** | | | | | kilograms / 1000 RTK | | | | | |
| | $NO_x$ | | | | 0.432 | 0.423 | 0.428 | 0.417 | 0.398 | 0.407 |
| | CO | | | | 0.082 | 0.081 | 0.082 | 0.079 | 0.076 | 0.078 |
| | HC | | | | 0.022 | 0.021 | 0.022 | 0.021 | 0.020 | 0.021 |
| | $SO_x$ | | | | 0.020 | 0.019 | 0.020 | 0.019 | 0.018 | 0.019 |
| | PM | | | | 0.010 | 0.010 | 0.010 | 0.010 | 0.009 | 0.010 |
| | $CO_2$ | | | | 21.213 | 20.771 | 21.030 | 20.477 | 19.530 | 20.019 |

Table 4b

**Locomotive Emissions, 1996 - 2002**

| Annual Emissions | | Emissions Factors: Freight & Passenger g/L | Freight & Passenger g/L | Yard & Work g/L | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | kilotonnes | | | | | | |
| **Freight – Mainline & Branchline** | | **1990-2000** | **2001-2002** | | | | | | | | |
| | $NO_x$ | 54.69 | 58.81 | | 102.37 | 111.05 | 102.90 | 94.43 | 100.43 | 107.21 | 109.86 |
| | CO | 10.51 | | | 19.67 | 21.33 | 19.77 | 18.91 | 19.29 | 19.15 | 19.63 |
| | HC | 2.73 | | | 5.11 | 5.55 | 5.14 | 4.92 | 5.02 | 4.98 | 5.10 |
| Adjusted to 0.15% Sulphur Fuel | $SO_x$ | 2.54 | | | 4.75 | 5.15 | 4.77 | 4.57 | 4.66 | 4.62 | 4.74 |
| | PM | 1.30 | | | 2.43 | 5.64 | 2.45 | 2.34 | 2.39 | 2.37 | 2.43 |
| Based on 86.5% Carbon Fuel | $CO_2$ | 2,709 | | | 5,071 | 5,501 | 5,097 | 4,875 | 4,975 | 4,938 | 5,060 |
| **Yard Switching & Work Train** | | | | | | | | | | | |
| | $NO_x$ | | | 61.01 | 8.71 | 7.28 | 7.65 | 5.60 | 5.53 | 5.74 | 4.88 |
| | CO | | | 10.42 | 1.49 | 1.24 | 1.31 | 0.96 | 0.94 | 0.98 | 0.83 |
| | HC | | | 3.61 | 0.52 | 0.43 | 0.45 | 0.33 | 0.33 | 0.34 | 0.29 |
| Adjusted to 0.15% Sulphur Fuel | $SO_x$ | | | 2.53 | 0.36 | 0.30 | 0.32 | 0.23 | 0.23 | 0.24 | 0.20 |
| | PM | | | 1.48 | 0.21 | 0.18 | 0.18 | 0.14 | 0.13 | 0.14 | 0.12 |
| Based on 86.5% Carbon Fuel | $CO_2$ | | | 2,709 | 387 | 323 | 340 | 249 | 246 | 255 | 217 |
| **Passenger** | | | | | | | | | | | |
| | $NO_x$ | 54.69 | | | 3.23 | 3.34 | 3.23 | 3.17 | 3.34 | 5.41 | 5.47 |
| | CO | 10.51 | | | 0.62 | 0.64 | 0.62 | 0.61 | 0.64 | 1.04 | 1.05 |
| | HC | 2.73 | | | 0.16 | 0.17 | 0.16 | 0.16 | 0.17 | 0.27 | 0.27 |
| Adjusted to 0.15% Sulphur Fuel | $SO_x$ | 2.54 | | | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.25 | 0.25 |
| | PM | 1.30 | | | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.13 | 0.13 |
| Based on 86.5% Carbon Fuel | $CO_2$ | 2,709 | | | 160 | 165 | 160 | 157 | 165 | 268 | 271 |
| **Total – Rail Operations** | | | | | | | | | | | |
| | $NO_x$ | 54.69 | | 61.01 | 114.30 | 121.67 | 113.78 | 103.21 | 109.30 | 118.36 | 120.21 |
| | CO | 10.51 | | 10.42 | 21.78 | 23.21 | 21.70 | 20.48 | 20.88 | 21.17 | 21.51 |
| | HC | 2.73 | | 3.61 | 5.79 | 6.15 | 5.75 | 5.41 | 5.51 | 5.59 | 5.66 |
| Adjusted to 0.15% Sulphur Fuel | $SO_x$ | 2.54 | | 2.53 | 5.26 | 5.61 | 5.24 | 4.95 | 5.04 | 5.11 | 5.19 |
| | PM | 1.30 | | 1.48 | 2.72 | 5.90 | 2.71 | 2.55 | 2.60 | 2.64 | 2.68 |
| Based on 86.5% Carbon Fuel | $CO_2$ | 2,709 | | 2,709 | 5,618 | 5,990 | 5,597 | 5,282 | 5,386 | 5,462 | 5,548 |
| **Emissions from Freight Operations** | | | | | | | | | | | |
| | $NO_x$ | 54.69 | 58.81 | 61.01 | 111.08 | 118.33 | 110.55 | 100.03 | 105.96 | 112.95 | 114.74 |
| | CO | 10.51 | | 10.42 | 21.16 | 22.57 | 21.08 | 19.87 | 20.23 | 20.13 | 20.46 |
| | HC | 2.73 | | 3.61 | 5.63 | 5.98 | 5.59 | 5.25 | 5.35 | 5.32 | 5.39 |
| Adjusted to 0.15% Sulphur Fuel | $SO_x$ | 2.5 | | 2.53 | 5.11 | 5.45 | 5.09 | 4.80 | 4.89 | 4.86 | 4.94 |
| | PM | 1.3 | | 1.48 | 2.64 | 5.82 | 2.63 | 2.48 | 2.52 | 2.51 | 2.55 |
| Based on 86.5% Carbon Fuel | $CO_2$ | 2,709 | | 2,709 | 5,458 | 5,825 | 5,437 | 5,125 | 5,221 | 5,194 | 5,227 |
| **Emissions per Freight Traffic Unit** | | | | | kilograms / 1000 RTK | | | | | | |
| | $NO_x$ | | | | 0.391 | 0.389 | 0.372 | 0.331 | 0.329 | 0.351 | 0.358 |
| | CO | | | | 0.075 | 0.074 | 0.071 | 0.066 | 0.063 | 0.063 | 0.064 |
| | HC | | | | 0.020 | 0.020 | 0.019 | 0.017 | 0.017 | 0.017 | 0.017 |
| | $SO_x$ | | | | 0.018 | 0.018 | 0.017 | 0.016 | 0.015 | 0.015 | 0.015 |
| | PM | | | | 0.009 | 0.019 | 0.009 | 0.008 | 0.008 | 0.008 | 0.008 |
| | $CO_2$ | | | | 19.224 | 19.147 | 18.306 | 16.969 | 16.193 | 16.144 | 16.299 |

## 3.3 Emissions

### 3.3.2 Carbon Dioxide ($CO_2$)

The Canadian transportation sector contributes approximately one quarter of all Canadian $CO_2$ emissions. Rail contributes 4 percent of the total transportation $CO_2$ emissions[(5)]. As shown in Figure 11, the Canadian railway sector has demonstrated that it has made significant progress in lowering its $CO_2$ emissions. $CO_2$ emissions by the railway sector in 2002 are 0.6 percent lower than in 1990. This fact is the result of improvements in fuel efficiency in railway operations. (See section 2.4 and Figure 7)

As shown in Figure 12, kilotonnes of $CO_2$ per 1,000 RTK have decreased 23.2 percent from 1990 going from 21.21 in 1990 to 16.30 in 2002. Of particular interest is the fact that the reduction in overall freight $CO_2$ emissions has decreased rapidly since 1997 when the railways invested in new locomotives. It is expected that this trend of lower emissions of $CO_2$ per 1,000 RTK will continue as Canadian railways continue to replace their fleet with new locomotives and continue to implement fuel consumption reduction strategies. This is discussed further in Section 4.

Figure 11
**Carbon Dioxide Emissions**
*$CO_2$ emissions (kilotonnes)*

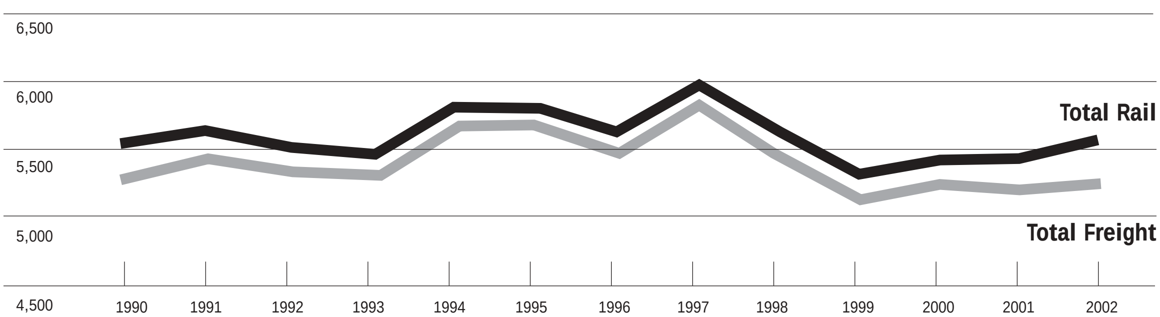
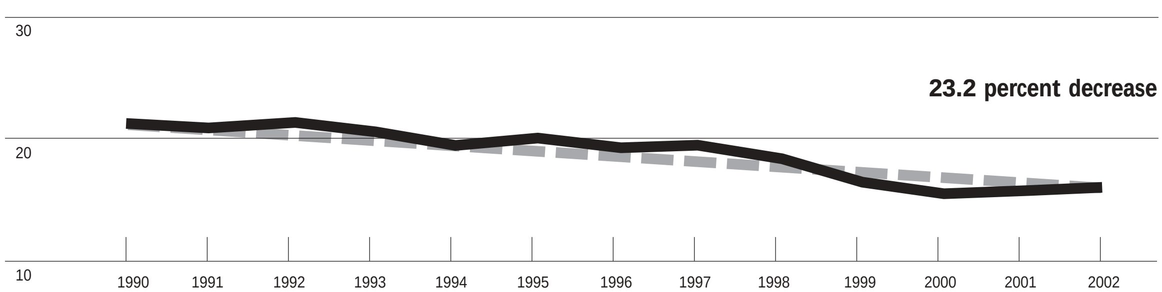



Figure 12
**Freight $CO_2$ Emissions per 1,000 RTK**
*$CO_2$ emissions (kg/1,000 RTK)*




(5) Natural Resources Canada *"Energy Efficiency Trends in Canada, 1990 – 2000"*, June 2002

## 3.4 Locomotive Duty Cycle

The duty cycle of Canadian locomotives was recently evaluated by Canada's Class 1 railways and by a commuter railway by evaluating the time spent at each notch level for a statistically significant sample of locomotives. The duty cycles, shown in Table 5, are for road freight, passenger and switching service. Also shown is the duty cycle used to calculate emissions data in 1990. The influence of duty cycles on $NO_x$ emissions have been found to be minimal [(6)] even though duty cycles have changed since 1990, particularly in the amount of time spent in dynamic braking. The variation in $NO_x$ emissions factors for example is +/- 0.7 percent for older locomotives and is +/- 1.2 percent for newer higher horsepower locomotives. Since this study was undertaken, the amount of idle time has been reduced through the use of automatic stop/start devices and through a strict shutdown policy. As a result, the idle time shown in Table 5 now includes shut down time from these devices and policies.

Table 5

**Duty Cycle by Locomotive Service (Percent of Time)**

| Service | Idle | N1 | N2 | N3 | N4 | N5 | N6 | N7 | N8 | DB |
|---|---|---|---|---|---|---|---|---|---|---|
| 2001 Freight | 58.1 | 3.9 | 5.0 | 4.4 | 3.7 | 3.3 | 3.0 | 1.5 | 12.0 | 5.1 |
| 2001 Passenger | 69.6 | 0.0 | 4.8 | 2.1 | 1.4 | 1.2 | 0.8 | 0.2 | 19.5 | 0.0 |
| 2001 Switching | 83.0 | 4.1 | 4.0 | 3.6 | 2.0 | 1.0 | 0.5 | 0.3 | 1.5 | 0.0 |
| 1990 Freight | 60.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 12.0 | 0.0 |
| 1990 Branch/Yard | 81.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 5.0 | 0.0 |


CPR

(6) Transport Canada Report, TP 13945E Influence of Duty Cycles and Fleet Profile on Emissions from Locomotives in Canada

# 4 Emissions Reductions Initiatives

Locomotive exhaust emissions can be reduced via not only engine technology but also a variety of train handling and infrastructure improvements. The principal initiatives being pursued by Canadian railways are listed in this section.

## 4.1 Fleet Renewal

Canadian freight and passenger railways are progressively renewing their fleets by purchasing EPA compliant locomotives. As well, they are upgrading, their pre-2000 locomotives to Tier 0 upon overhaul. These costly measures will ensure emissions, particularly $NO_X$, will continue to be reduced per unit of work.

Locomotives meeting U.S. EPA Tier 2 will be available by 2005. Tier 2 locomotives will have $NO_X$ emissions 25.7 percent lower than 2001 locomotives and 59.2 percent lower than pre-2000 locomotives. The RAC is an active participant in developing Tier 3 objectives for locomotives with the U.S. EPA and AAR. It is expected that Tier 3 locomotives will focus on lower particulate emissions.

## 4.2 Co-Production

Co-production initiatives are being implemented. An example is an agreement between Canada's two Class 1 railways to share track in the Fraser canyon. This agreement allows the railways to haul heavily loaded trains over lighter grade (less steep) track on one railway and light loads (empty cars) on heavier grade track on the other. The result of this agreement has lowered fuel consumption, hence emissions, on both railways.

## 4.3 Government Programs

The railways have taken advantage of Transport Canada's Freight Sustainability Demonstration Program, and have received funding for fuel reduction schemes. Some examples are top of rail lubrication, being tested on BC Rail, electronic fuel injection and automatic stop/start systems that are being evaluated on several short line railways.

## 4.4 Train Handling

The proportion of main line locomotives fitted with dynamic brake equipment continues to increase. This allows the increased use of the dynamic brake for control of train speed rather than the use of the air brake system. As the latter does not allow the locomotive engineer to reduce the severity of a brake application already in force, it is frequently necessary to apply power at the same time as the brakes to maintain speed over variable track grades. This causes the fuel consumption to be increased significantly. When the dynamic brake is used to control speed the severity of the application can be varied at will, and the fuel consumption is reduced.

As well, the railways have on-going training programs that focus on awareness and on the importance of fuel conservation practices, including locomotive shutdown in yards.

## 4.5 Rail Lubrication

Efficient rail gauge face lubrication has been shown in many tests to reduce fuel consumption. The railways have on-going programs to ensure that the system of track mounted rail lubricators is maintained in good operating condition. Railways which have applied on-board locomotive wheel flange lubricators also have programs to keep these in working order.

Top of rail lubrication is being evaluated on BC Rail and early results have shown fuel consumption reductions.

GO Transit Photo by Timothy Hudson

## 4.6 Freight Car Productivity Improvement

The maximum allowable axle load has been increased on many lines in Canada. This enables the railways to use certain cars with a gross weight on rail of up to 129,800 kg instead of 119,400 kg. The gross to tare ratio of such freight cars is increased so that the quantity of gross tonne-kilometers accumulated to move a given amount of freight is reduced, contributing to the improvement in the ratio of RTK to GTK. The railways have also invested in aluminum cars to replace the heavier steel cars.

## 4.7 Low Idle Applications

The railways are extending the application of the "Low Idle" feature to more mainline locomotives. This feature allows the diesel engine to idle at a reduced speed with a consequently reduced load from fans. The reduction in fuel consumption can be as much as 10 L/hr, and on the accepted duty cycles can be as much as 3 percent of the annual fuel consumption. The use of the low idle feature is limited in some cases by the ability of the auxiliary power system to generate sufficient power for battery charging. However a continued reduction in overall fuel consumption is expected from this feature.

## 4.8 Automatic Start / Stop Systems

Railways are installing devices on both mainline and switching locomotives which will automatically shut down and restart the diesel engine when the locomotive is not in use. The device is regulated by several locomotive system parameters such as water temperature and battery condition. It will restart the engine to idle for a time to prevent freezing and to charge the batteries. The railways now have a policy of shutting down unused engines when ambient temperatures permit; automatic start/stop systems will allow this practice to be extended all year.

# 5 Diesel Fuel Properties

The railways use diesel fuel that complies with the existing engine builders requirements of an average sulphur content of no greater than 5,000 parts per million (ppm). In general, Canadian railways use fuel with a much lower Canadian average sulphur content of approximately 1500 ppm [(7)].


(7) Transport Canada Report, TP 13783E, Diesel Fuel Quality and Locomotive Emissions in Canada, April 2001

# 6 Fuel Consumption and Emissions in Tropospheric Ozone Management Areas

## 6.1 Data Derivation

Three Tropospheric Ozone Management Areas (TOMA) have been designated as being of particular interest for emissions. These areas, and the sections of the several railways which operate within them, are shown in Appendix C.

The fuel consumption in these TOMAs is derived from knowledge of the total traffic in the areas, expressed in gross tonne-kilometers, as a proportion of the total rail traffic in Canada. The emissions are then calculated using the established factors for the various gases.

The fuel consumed in the TOMAs is also shown as a percentage of the total fuel consumption in all rail operations. The results for the three TOMAs are shown in Table 6.

The balance of the total fuel consumption that is 79.4 percent in 2002 was used outside of the three TOMAs. The resulting emissions were therefore spread widely over areas with a relatively low population density.

## 6.2 Seasonal Data

The emissions in the TOMAs during 2002 have been divided according to two seasonal periods:

- Winter (7 months) January to April and October to December inclusively.
- Summer (5 months) May to September, inclusively, as specified in the initiating Memorandum of Understanding.

The division of traffic by winter/summer periods was received from the major railways for their entire systems. The division of traffic in the TOMAs in the seasonal periods was then taken as equal to that on the whole system for each railway. As the split was very close to the proportion of days in the periods, the latter ratio was used for the smaller railways for which no seasonal traffic data were received.

The fuel consumption in each TOMA was therefore divided in the proportion derived for the traffic on each railway, excepting in the case of GO Transit in TOMA No.2 where the actual seasonal fuel consumption data were available. The emissions in the seasonal periods were then calculated as before, the results being shown in Table 7.

Table 6

**TOMA Percentage of Total Fuel Consumption**

| TOMA | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|
| Lower Fraser Valley, B.C. | 4.27 | 4.42 | 4.17 | 4.26 | 4.24 | 4.02 | 3.83 | 3.36 |
| Windsor-Quebec City Corridor | 14.7 | 15.3 | 14.83 | 16.29 | 17.13 | 17.35 | 15.62 | 17.05 |
| Saint John, N.B. | 0.11 | 0.13 | 0.09 | 0.10 | 0.11 | 0.12 | 0.11 | 0.17 |

VIA Rail *Photo: Matthew G. Wheeler*

Table 7

**Tropospheric Ozone Management Areas – Traffic, Fuel Consumption and Emissions Data, 2002**

| **TOMA** | | **No. 1 Lower Fraser Valley, B.C.** | | | **No.2 Windsor-Quebec City** | | | **No. 3 Saint-John, N.B. Area** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Seasonal Split | | | Seasonal Split | | | Seasonal Split | |
| | | GTK | Winter | Summer | GTK | Winter | Summer | GTK | Winter | Summer |
| CN | million GTK | 5,901 | 58.0% | 42.0% | 57,384 | 58.0% | 42.0% | 832 | 58.53% | 41.47% |
| CPR | million GTK | 13,432 | 58.0% | 42.0% | 29,243 | 58.0% | 42.0% | | | |
| B.C. Rail* | million GTK | 390 | 58.0% | 42.0% | | | | | | |
| Burlington Northern Santa Fe Railroad | million GTK | 415 | 58.0% | 42.0% | | | | | | |
| Southern Railway of B.C. | million GTK | 175 | 58.0% | 42.0% | | | | | | |
| GO Transit | million GTK | | | | 8 | 58.0% | 42.0% | | | |
| Essex Terminal Railway | million GTK | | | | 26 | 58.0% | 42.0% | | | |
| Goderich-Exter Railway | million GTK | | | | 336 | 58.1% | 42.0% | | | |
| CSX | million GTK | | | | 153 | 58.1% | 42.0% | | | |
| So. Ontario Railink | million GTK | | | | 96 | 58.1% | 42.0% | | | |
| Norfolk Southern | million GTK | | | | 314 | 58.1% | 42.0% | | | |
| Ottawa Valley – Railink | million GTK | | | | 480 | 58.1% | 42.0% | | | |
| Quebec Gatineau | million GTK | | | | 335 | 58.1% | 42.0% | | | |
| Quebec Southern | million GTK | | | | 69 | 58.1% | 42.0% | | | |
| St. Lawrence & Atlantic | million GTK | | | | 247 | 58.1% | 42.0% | | | |
| N.B. Southern Railway | million GTK | | | | | | | 222 | 58.08% | 41.92% |
| Total Freight | million GTK | 20,313 | | | 88,693 | | | 1054 | | |
| VIA | million GTK | 74 | 58.08% | 41.92% | 2,659 | 58.08% | 42.0% | | | |
| **Fuel Consumption** | | | | | | | | | | |
| Fuel Rate – Freight Service | Litres per 1,000 GTK | 3.3 | | | 3.3 | | | 3.3 | | |
| Fuel Rate – Passenger Service | Litres per 1,000 GTK | 10.9 | | | 10.9 | | | 10.9 | | |
| Freight Fuel Consumption in TOMA | Million Litres | 68.0 | 39.4 | 28.6 | 297 | 172.2 | 124.7 | 3.5 | 2.1 | 1.5 |
| VIA Fuel Consumption in TOMA | Million Litres | 0.8 | 0.5 | 0.3 | 29 | 16.8 | 12.1 | | | |
| GO Transit | Million Litres | | | | 23 | 13.6 | 9.8 | | | |
| Total Fuel Consumption in TOMA | Million Litres | 68.8 | 39.9 | 28.9 | 349 | 202.50 | 146.6 | 3.5 | 2.1 | 1.5 |
| Canadian Total Fuel Consumption | Million Litres | 2,048.0 | | | 2,048.0 | | | 2,048.0 | | |
| TOMA Fuel Consumption & Canadian Total | | 3.36% | | | 17.05% | | | 0.17% | | |

| **Emissions** | Emissions Factors Standard g/L | Yard g/L | Combined** g/L | | No. 1 GTK | Winter | Summer | No.2 GTK | Winter | Summer | No. 3 GTK | Winter | Summer |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oxides of Nitrogen ($NO_x$) | 58.81 | 61.01 | 59.2 | kilotonnes | 4.07 | 2.36 | 1.71 | 20.67 | 11.99 | 8.68 | 0.21 | 0.12 | 0.09 |
| Carbon Monoxide (CO) | 10.51 | 10.42 | 10.5 | kilotonnes | 0.72 | 0.42 | 0.30 | 3.67 | 2.13 | 1.54 | 0.04 | 0.02 | 0.02 |
| Hydrocarbons (HC) | 2.73 | 3.61 | 2.9 | kilotonnes | 0.20 | 0.12 | 0.08 | 1.01 | 0.59 | 0.43 | 0.01 | 0.01 | 0.00 |
| Sulphur Oxides ($SO_x$) | 2.54 | 2.53 | 2.54 | kilotonnes | 0.17 | 0.10 | 0.07 | 0.89 | 0.51 | 0.37 | 0.01 | 0.01 | 0.00 |
| Particulate Matter (PM) | 1.30 | 1.48 | 1.31 | kilotonnes | 0.09 | 0.05 | 0.04 | 0.46 | 0.27 | 0.19 | 0.00 | 0.00 | 0.00 |
| Carbon Dioxide ($CO_2$) | 2,709 | 2,709 | 2,709 | kilotonnes | 186.34 | 108.08 | 78.26 | 945.80 | 548.57 | 397.24 | 9.56 | 5.58 | 3.97 |

* B.C. Rail GTK for TOMA No. 1 derived as % length of line in TOMA No. 1 of total line length.

** Combined emission factors derived from standard & yard factors with fuel consumption data from Table 1.

# 7 Summary and Conclusions


The rates of emission of $NO_x$ and $CO_2$ in kg/1,000 RTK have decreased by 17.1 percent and 23.2 percent, respectively, since 1990. The rate of decrease was greatest in 1998, 1999 and 2000 showing the effects of the continual improvement in the fuel efficiency of rail transportation.

In 2002, the emissions of $NO_x$ were above the voluntary cap of 115 kt. A new Emission Factor for $NO_x$ and the growth in traffic since 1990 greater than forecast at the onset of the MOU contributed to higher $NO_x$ emissions in 2002. The beneficial effect of the introduction of new locomotives meeting U.S. EPA Tier 0 and Tier 1, into the fleet is expected to reduce progressively $NO_x$ emissions per unit of work, expressed as kg/1,000 RTK, in the future.

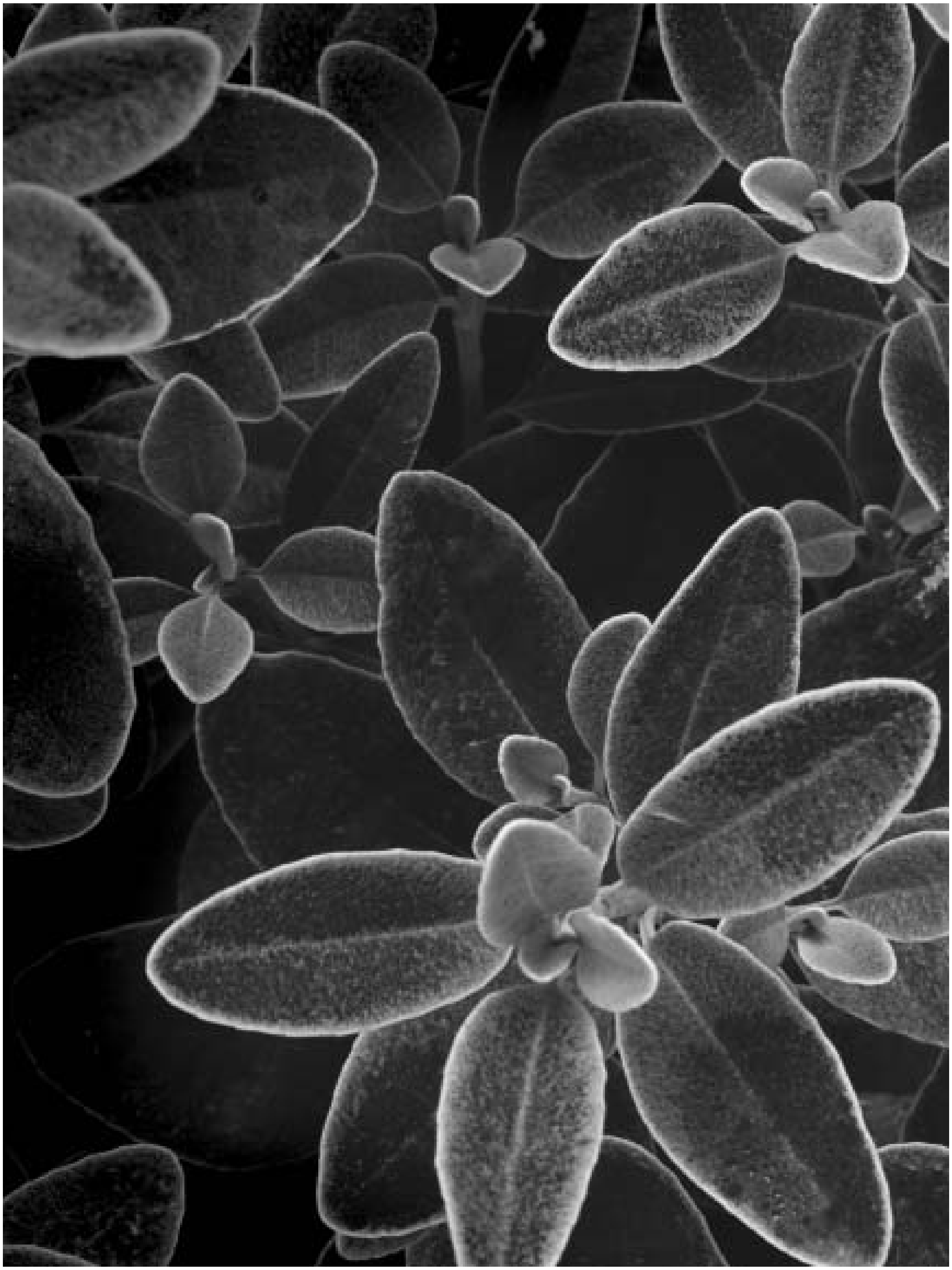
One area of traffic growth has been in the movement of containers. The growth in domestic intermodal traffic is the result of the success of Canadian railways in developing strategic partnerships with shippers and trucking companies for the transportation of goods. Tonnage of intermodal traffic on Canadian railways increased by 15.2 percent in 2002, and is 104.3 percent higher than in 1990. Container tonnage has increased by 175.3 percent since 1990.

Traffic levels closely match North American economic activity and will continue to be monitored closely. Higher economic growth, or continued intermodal growth, would increase rail traffic. This modal shift would reduce overall transportation sector fuel consumption but would increase rail fuel consumption slightly. If higher rail traffic growth develops and persists over the longer term, consideration would have to be given to the revision of the measure by which emissions are reported. This concept was recognized in the EC Report "Recommended Reporting Requirements for the Locomotive Emissions Monitoring (LEM) Program" [8].

The Canadian railway industry continues its long term trend of improving the efficiency of its operations, measured by fuel consumption and emissions, per unit of traffic hauled.

(8) Environment Canada, Environmental Protection Series, Report EPS 2/TS/8, September 1994.

# Appendices



# Appendix A

**MEMORANDUM OF UNDERSTANDING**
**between**
**ENVIRONMENT CANADA and THE RAILWAY ASSOCIATION OF CANADA**

## Part 1 – Introduction

The purpose of this document is to set out the principles of the basic agreements reached among The Railway Association of Canada (RAC), The Canadian Council of Ministers of the Environment (CCME) and Environment Canada (EC) with respect to the control of emissions of oxides of nitrogen ($NO_x$) produced by locomotives during all rail operations in Canada.

The Memorandum of Understanding (MOU) has been developed from the recommendations contained in the joint Environment Canada / Railway Association of Canada (EC/RAC) report entitled "Recommended Reporting Requirements for the Locomotive Emissions Monitoring (LEM) Program".

## Part 2 - Background

The Railway Association of Canada, being an association of environmentally concerned corporations doing business in Canada, proposed to the Canadian Council of Ministers of the Environment (CCME), a voluntary cap on the total emissions of oxides of nitrogen from locomotive engines in Canada of 115 kilotonnes per year. The RAC proposal for a voluntary cap on $NO_x$ emissions has been included in the CCME $NO_x$/VOC Management Plan and is officially validated by this MOU.

## Part 3 – The Program

Between January 1, 1990 and December 31, 2005 the RAC will endeavour to collect all data necessary to calculate the total amount of emissions of oxides of nitrogen ($NO_x$) produced during all rail operations in Canada and, if necessary, take whatever action is necessary to avoid exceeding the agreed maximum $NO_x$ emissions of 115 kilotonnes per year.

The RAC will make every effort to report once per year to Environment Canada in the manner described below. The data collected should represent the activity of all RAC members and the RAC will endeavour to encourage Associate members of the RAC and non-members to participate in the data reporting.

The RAC also agrees to monitor developments in railway operations technology and encourage member railways to implement new cost-effective technologies that will reduce the $NO_x$ emissions from their new equipment.

## Part 4 – Reports

As outlined in the joint EC/RAC report entitled "Recommended Reporting Requirements for the Locomotive Emissions Monitoring (LEM) Program", the RAC will make every effort to submit to Environment Canada annual reports containing the following information;

1) A list of the Gross Ton Miles (GTM), Net Ton Miles (RTM) and total fuel consumption data for railway operations plus estimates of the emissions of oxides of nitrogen ($NO_x$), hydrocarbons (HC), oxides of sulphur ($SO_x$), particulate matter (PM), carbon monoxide (CO) and carbon dioxide ($CO_2$) using the RAC emissions factors as corrected in Table 9 of the Report referenced above. All fuel consumption and emissions data will be listed separated with respect to passenger, freight and yard switching services. These data will be submitted for the reporting year and will include revised projections for years 1995, 2000 and 2005;
2) In addition to the national aggregate figures, fuel consumption and emissions should be provided for each Tropospheric Ozone Management Area (TOMA) as geographically defined in the $NO_x$/VOCs Management Plan (CCME, 1990);
3) The emissions data for the TOMAs should be further separated into two additional categories: the Winter Months and the Critical Ground Level Ozone Forming Months of May, June, July, August and September;
4) Updated information should be provided about the composition of the locomotive fleet by year of manufacture, horsepower, engine model, duty type and railway company;
5) A brief written update should be provided on the progress of the railway industry in introducing new, more $NO_x$-efficient operating procedures and/or technology on rail operations;
6) Companies should submit a report on any emissions control systems, hardware or techniques installed or implemented during an engine rebuild program that would effect $NO_x$ emissions;
7) A report should be provided on new emissions performance data and new emissions factors for locomotives operated by railways obtained from the AAR, the manufacturers or other agencies;

8) Information should be provided about changes in the properties of diesel fuels used when the properties significantly depart from those specified in the Canadian General Standards Board Specifications CAN/CGSB-3-18-92, entitled Diesel Fuel for Locomotive Type Medium Speed Diesel Engines. Data should be reported from any tests on the sensitivity of emissions from various locomotive engines to fuel quality or to alternative fuels; and

9) A brief report should be provided on the progress and success of any other emissions reduction initiatives or changes in operational procedure, as well as any major changes in the type of duty cycles or service that would significantly affect emissions and their relative percentage of the overall railway operation.

The RAC will make every effort to submit an annual report containing all of the information indicated above by June 30th of the year following the report year. The first report covered by the MOU will be for the year 1990 and last report under this MOU will be for the year 2005.

**Part 5 – General**

The baseline of 115 kilotonnes per year for locomotive $NO_x$ emissions is based upon the best technical information that was available by the end of 1989 and on projections for traffic increases. It is understood that, if new emissions factors significantly departing from those used to determine the baseline are developed as a result of advanced research on engine emissions or if the rail traffic growth rate is significantly impacted by a shift of traffic from or to another mode of transport, a new environmental review will be initiated.

Although both of the parties hereto have indicated by their signature, acceptance of the principles set out herein, this MOU is not intended to create a legally binding agreement and shall not be construed as creating enforceable contractual obligations among the parties hereto.

DATED at .................................... this .......... day of .................... 1995

MINISTER OF THE ENVIRONMENT

______________________________

Sheila Copps

THE RAILWAY ASSOCIATION OF CANADA

______________________________

R. H. Ballantyne

# Appendix B-1

**Canadian Locomotive Fleet – Mainline and Branchline, 2002**

| Builder | MODEL | ENGINE | HP | YEAR | TOTAL | CN | CP | VIA | BC Rail | GO Transit | Total Other |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GM/EMD | SD-90 "H" | 16V-265H | 6000 | 99 | 4 | | 4 | | | | 0 |
| | SD-90 | 16V-710G3C | 4300 | 98 | 61 | | 61 | | | | 0 |
| | SD-75 | 16V-710G3C | 4300 | 96-01 | 179 | 173 | | | | | 6 |
| | SD-70 | 16V-710G3B | 4000 | 95 | 26 | 26 | | | | | 0 |
| | SD-60 | 16V-710G3 | 3800 | 85-89 | 63 | 63 | | | | | 0 |
| | F59PH | 12V-710G3 | 3000 | 88-95 | 62 | | | | | 45 | 17 |
| | SD-50 | 16V-645F3B | 3600 | 85-94 | 60 | 60 | | | | | 0 |
| | GP-40 | 20V-645 | 2000 | | 1 | | | | | | 1 |
| | SD-45-2 | 16V-645 | 3600 | | 4 | | | | | | 4 |
| | SD-40 | 16V-645E3 | 3000 | 66-90 | 642 | 186 | 416 | | | | 40 |
| | SD-40 | 16V-645E3B | 3000 | 85-87 | 15 | | | | 15 | | 0 |
| | F40PH2 | 16V-695E3C | 3000 | 87-89 | 46 | | | 46 | | | 0 |
| | F40PH2 | 16V-645E3C | 3000 | 70-79 | 5 | | | | | | 5 |
| | SD-40 | 16V-645D3A | 2250 | 64-66 | 6 | | | | | | 6 |
| | GP-40 | 16V-645 | 3000 | 70-79 | 28 | | 4 | | | | 24 |
| | SD-38 | 16V-645 | 2000 | 71-74 | 4 | | | | | | 4 |
| | GP-38 | 16V-645 | 2000 | 69-76 | 127 | 68 | | | | | 59 |
| | GP-35 | 16V-645 | 3000 | | 3 | | | | | | 3 |
| | GP-35 | 16V-645 | 2000 | 72-76 | 3 | | | | | | 3 |
| | FP-9A | 16V-645C | 1800 | 83-85 | 1 | | | 1 | | | 0 |
| | MP-15 | 12V-645 | 1500 | 76 | 3 | | | | | | 3 |
| | GP-15-1 | | 1500 | 77 | 2 | | | | | | 2 |
| | GP-9 | 16V-645 | 1800 | 84-87 | 11 | | | | | | 11 |
| | SW-1200 | 16V-645 | 1200 | 62 | 1 | | | | | | 1 |
| | SW-1000 | 8V-645E | 900 | 67-69 | 2 | | | | | | 2 |
| | GP-9 | 16V-567C | 1750 | 55-68 | 6 | | | | | | 6 |
| | F92B | 16V-567C | 1750 | 58 | 1 | | | | | | 1 |
| | SW-9 | 8V-567C | 900 | 56-64 | 10 | | | | | | 10 |
| SUB-TOTAL | | | | 1376 | 576 | 485 | 47 | 15 | 45 | 208 | |
| MLW | | | 3600 | 70-72 | 7 | | | | | | 7 |
| | | 16V-251E | 2400 | 63-66 | 2 | | | | | | 2 |
| | CE-424 | | 2000 | 62 | 1 | | | | | | 1 |
| | | 12V-251 | 2000 | 71 | 7 | | | | | | 7 |
| | | 16V-251E | 1800 | 85-89 | 12 | | | | | | 12 |
| | RS-18 | | 1800 | 54-58 | 6 | | | | | | 6 |
| | RS-23 | | 1000 | 57-58 | 5 | | | | | | 5 |
| | MR-9 EMU | | 800 kw | 95 | 29 | | | | | | 29 |
| | Talent DM | BR643 | 1000 | 01 | 3 | | | | | | 3 |
| SUB-TOTAL | | | | 72 | 0 | 0 | 0 | 0 | 0 | 72 | |
| GE | Dash 9-44CM | 16V-7FDL | 4400 | 94-98 | 198 | 173 | | | 14 | | 11 |
| | Dash 9-44CW | 16V-7FDL | 4400 | 94-98 | 259 | | 240 | | | | 19 |
| | P42DC | 16V-7FDL | 4250 | 01 | 21 | | | 21 | | | 0 |
| | Dash 8-40CM | 16V-7FDL | 4000 | 90-94 | 84 | 55 | | | 26 | | 3 |
| | B39-8 | 16V-FDL16 | 3900 | 87-88 | 12 | | | | 12 | | 0 |
| | B39-7 | 16V-FDL16 | 3600 | 80 | 8 | | | | 8 | | 0 |
| | B39-7ME | 16V-FDL16 | 3600 | 80 | 4 | | | | 4 | | 0 |
| | B30-7 | | 3000 | 75-80 | 5 | | | | | | 5 |
| | C30-7 | | 3000 | 75-80 | 9 | | | | | | 9 |
| | DL535 | Alco 251D | 1200 | 69 | 8 | | | | | | 8 |
| | LL162/162 | Alco 251B | 990 | 54-66 | 10 | | | | | | 10 |
| SUB-TOTAL | | | | 618 | 228 | 240 | 21 | 64 | 0 | 65 | |
| Budd | | | | | 3 | | 3 | | | | 0 |
| Steam | | | | | 5 | | 1 | | | | 4 |
| **Total – Mainline & Branchline** | | | | | **2074** | **804** | **729** | **68** | **79** | **45** | **349** |

# Appendix B-2

**Canadian Locomotive Fleet – Yard & Switching & Grand Total, 2002**

| Builder | MODEL | ENGINE | HP | YEAR | TOTAL | CN | CP | VIA | BC Rail | GO Transit | Total Other |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GM/EMD | | 16V-645 | 3000 | 75-90 | 26 | | 22 | | | | 4 |
| | | 16V-645E | 2000 | 71-01 | 170 | 24 | 129 | | | | 17 |
| | GP-9 | 16V-645 | 1800 | 54-81 | 155 | 151 | | | | | 4 |
| | GP-20 | 16V-645 | 1800 | 66 | 1 | | | | | | 1 |
| | SD-18 | 16V-645 | 1800 | | 1 | | | | | | 1 |
| | GP-9 | 16V-645 | 1750 | 51-81 | 195 | | 194 | | | | 1 |
| | GP-9 | 16V-645 | 1700 | 60 | 19 | | | | | | 19 |
| | | 16V-645 | 1500 | 81-84 | 1 | | | | | | 1 |
| | GP-15 | | 1500 | | 3 | | | | | | 3 |
| | | 12V-645 | 1200 | 81-85 | 52 | 50 | | | | | 2 |
| | | 16V-567 | 1750 | 51-63 | 2 | | | | | | 2 |
| | GP-9 | 16V-567 | 1700 | | 2 | | | | | | 2 |
| | GP-7 | 16V-567 | 1500 | 51-78 | 2 | | | | | | 2 |
| | SW-1500 | 16V-567 | 1500 | 51-78 | 23 | | 16 | | | | 7 |
| | SW-1200 | 12V567 | 1200 | 55-60 | 45 | 6 | 33 | | | | 6 |
| | GP-9 | 12V567 | 1200 | 55-60 | 1 | | | | | | 1 |
| | SW-9 | | 1200 | 62 | 1 | | 1 | | | | |
| | SW-10 | | 1200 | | 8 | | 8 | | | | |
| | | 8V-567 | 900 | 84-85 | 1 | | 1 | | | | |
| | SW1000 | 8-695E | 1000 | 66 | 2 | | | 2 | | | |
| SUB-TOTAL | | | | 710 | 231 | 404 | 2 | 0 | 0 | 73 | |
| MLW | | RS18 | 1800 | 54-58 | 4 | | | | | | 4 |
| | | 12V-251B | 1800 | 56-65 | 15 | | | | | | 15 |
| | | RS23 | 1000 | 59-60 | 3 | | | | | | 3 |
| | | RS13 | 1000 | 59-60 | 2 | | | | | | 2 |
| SUB-TOTAL | | | | 24 | 0 | 0 | 0 | 0 | 0 | 24 | |
| Other | CAT | 12V-3512 | 2000 | | 26 | | | | 26 | | 0 |
| | GE | 7FDL | 2250 | 90-91 | 3 | | | | | | 3 |
| | Alco F9A | | 1750 | | 6 | 6 | | | | | 0 |
| | Alco F9B | | 1750 | | 2 | 2 | | | | | 0 |
| | Alco FP7A | | 1750 | | 2 | 1 | 1 | | | | 0 |
| | | | 1000 | | 3 | | | | | | 3 |
| | Slug | | | | 12 | | | | 10 | | 2 |
| SUB-TOTAL | | | | 54 | 9 | 1 | 0 | 36 | 0 | 8 | |
| **Total Yard & Switching** | | | | | **788** | **240** | **405** | **2** | **36** | **0** | **105** |
| **Grand Total – Mainline, Branchline, Yard and Switching** | | | | | **2862** | **1044** | **1134** | **70** | **115** | **45** | **454** |

# Appendix C

**Railway Lines Included in Troposhperic Ozone Management Areas**

TOMA No.1

**Lower Fraser Valley, British Columbia**

**CPR**

| | |
|---|---|
| *Operations Service Area:* | Vancouver |
| *Subdivision:* | Cascade |
| | Mission |
| | Page |

**CN**

| | |
|---|---|
| *Division:* | **Pacific** |
| *Subdivision:* | Rawlison |
| | Yale |

| | |
|---|---|
| **B.C. Rail** | 3.07% of total |
| **Burlington Northern Railroad** | All |
| **Southern Railway of BC Ltd** | All |

TOMA No. 2

**Windsor - Quebec City Corridor, Ontario and Quebec**

**CPR**

| | |
|---|---|
| *Division:* | SLH Quebec |
| | SLH Ontario |
| | Northern Ontario |
| *Subdivision:* | All |
| | All |
| | Chalk River |
| *Remarks:* | Smiths Falls-Arnprior |

**CN**

| | | |
|---|---|---|
| *District:* | **Champlain** | |
| *Subdivisions:* | Becancour | Rouses Point |
| | Bridge | Sorel |
| | Deux-Montagnes | St. Hyacinthe |
| | Drummondville | St. Laurent |
| | Joliette | Valleyfield |
| | Montreal | |

| | | | |
|---|---|---|---|
| *District:* | **Great Lakes** | | |
| *Subdivisions:* | Alexandria | Grimsby | Strathroy |
| | Caso | Halton | Talbot |
| | Chatham | Kingston | Uxbridge |
| | Dundas | Oakville | Weston |
| | Guelph | Paynes | York |

| | |
|---|---|
| **Essex Terminal Railway** | **All** |
| **Goderich - Exeter Railway** | **All** |
| **CSX** | **All** |
| **Norfolk Southern** | **All** |
| **Ottawa Valley – Railink** | **Part** |
| **Quebec – Gatineau** | **All** |
| **Quebec – Southern** | **All** |
| **So. Ont. – Railink** | **All** |
| **St. Lawrence & Atlantic** | **All** |

TOMA No. 3

**Saint John Area, New Brunswick**

**CN**

| | |
|---|---|
| *District:* | Champlain |
| *Subdivision:* | Denison |
| | Sussex |

# Participating Railways

*(as of the end of 2002)*

Agence métropolitaine de transport

Alberta Prairie Railway Excursions

Alberta RailNet

Arnaud Railway Company

Athabasca Northern Railway Ltd.

Barrie-Collingwood Railway

BC Rail

Burlington Northern (Manitoba) Ltd.

Burlington Northern Santa Fe Railway Company

Canadian Pacific Railway

Cape Breton & Central Nova Scotia Railway

Capital Railway

Cartier Railway Company

Central Manitoba Railway Inc.

Central Western Railway

Charlevoix Railway Company Inc.

Chemin de fer de la Matapédia et du Golfe inc.

CN

CSX Transportation Inc.

E & N Railway Company (1998) Ltd.

Essex Terminal Railway Company

GO Transit

Goderich-Exeter Railway Company Limited

Great Canadian Railtour Company Ltd.

Huron Central Railway Inc.

Kelowna Pacific Railway Ltd.

Lakeland & Waterways Railway

Mackenzie Northern Railway

New Brunswick East Coast Railway Inc.

New Brunswick Southern Railway Company Limited

Norfolk Southern Corporation

Ontario Northland Transportation Commission

Ontario Southland Railway Inc.

Ottawa Central Railway Inc.

Ottawa Valley Railway

Québec Gatineau Railway Inc.

Québec North Shore and Labrador Railway Company Inc.

Roberval and Saguenay Railway Company

South Simcoe Railway

Southern Manitoba Railway

Southern Ontario Railway

Southern Railway of British Columbia Ltd.

St. Lawrence & Atlantic Railroad (Québec) Inc.

Sydney Coal Railway

Trillium Railway Company Limited

VIA Rail Canada Inc.

Wabush Lake Railway Company, Limited

West Coast Express Ltd.

White Pass & Yukon Route

Windsor & Hantsport Railway